CARDIMED

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DEMOs value chains, monitoring and validation

Deliverable 2.2

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Executive summary

This deliverable is the compilation of 18 monitoring plans corresponding to the NbS planned in the 9 DEMO sites of the CARDIMED project. The document can be considered a single unit but has been designed as a collection of independent monitoring plans specifically tailored to each case.

The structure of the plan is the same for each case. It begins with a list of the indicators to be measured, ranged by environmental sector (energy, water, plant and faunal biodiversity, soil, food, ...). For every indicator, the document provides a description of the meaning and importance of the indicator, its units of measure, a detailed sampling plan (depending on the characteristics of each DEMO case, the sampling plan can be substituted by a data collection plan), a sampling calendar, information about the field and laboratory equipment required, proposals on the need to recruit experts, calculation formulas, expected evolution of the indicator over time, relationship with other indicators (if any), and literature references.

For each case, the list of indicators has been designed to include Key Performance Indicators (KPI) that inform about the efficiency of the solution in achieving its main proposed objective, and a variable number of additional indicators that make it possible to assess the contribution of the solution to the improvement of various environmental services to produce co-benefits. It should be remembered that the growing popularity of the NbS is partly explained by these entailing additional benefits for the socio-environmental system.

The selection of the indicators was preceded by an in-depth review of the monitoring plans included in previous EU funded projects on NbS, and of European and other national and international frameworks for assessment of NbS impact. As most of these projects and frameworks focus on urban environments, the resulting list of indicators resulted incomplete to address the wide variety of cases covered by the CARDIMED project (urban climate shelters, water recycling systems, forest pest management, agricultural transformation, soil desalination, riparian forest restoration, flood risk reduction, etc.). Most deficiencies were found in indicators referent to faunal diversity and soil and, to supply them a group of experts has been contributing their personal expertise.

The non-inclusion in European projects of a budget earmarked to cover the NbS monitoring plans, frequent difficulties for NbS leaders to access expert knowledge beyond the project consortium, and the absence of official responsibility for the implementation of the monitoring plans after the project end mean that most monitoring plans become a paper tiger. To minimize this risk, the final selection of indicators is the result of an interactive process between the expert team and the leaders of each DEMO case in search of balancing reliability and feasibility. Accordingly, only a few of the many indicators initially compiled have been included in the definitive lists.

At the time of delivering this document, only one of the NbS has been fully implemented, while the others are yet to be developed or, in some cases, still are in their planning phase. Therefore, the level of definition of the monitoring plans is variable and will be improved for less advanced projects in cooperation with the coordinators of the NbS.

The value chains aspect that originally was part of this deliverable, has been relocated to the deliverable 2.3, led by UVIC team.

Introduction

Monitoring is fundamental to assess the impact of NbSs over time, to learn from successes and mistakes, to test assumptions and hypotheses, to build the evidence-base for future NbSs, to develop an adaptive management of the affected urban or rural landscapes, and to build stakeholder trust.
Monitoring plans are always written as a condition when NbSs are proposed, but they are rarely implemented efficiently due to weaknesses in the plans themselves and to external barriers.
Barriers include:

a) lack of engagement of local stakeholders on choosing indicators, either because they have not been consulted or because they lack the knowledge or technical support to measure them.
b) although it seems difficult to believe after so many years of experience in monitoring different environmental sectors (i.e. restoration plans, environmental impact assessments, urban plans, etc.), there is an astonishing lack of indicators relative to specific environmental compartments (i.e. soil), or the available indicators are not correctly adapted to NbS spatial scales and characteristics (i.e. urban zones, rural areas, protected spaces, river and coastal environments, etc).
c) another frequent flaw is the lack of specifications provided in the monitoring plans about measurement methods. These methods are seldom generalizable and must be tailored to each study case for replicability of measurement over time and credibility of the results.
d) a very important barrier stems from the non-inclusion of monitoring costs in the budget of the project to be carried out.
e) another crucial difficulty for efficient execution of monitoring plans is related to long-term monitoring. Effects of interventions on many natural and social compartments of the ecosystem are not evident immediately following NbS implementation or show contrasting sign or intensity over time (e.g. forest plantations cause soil C losses in the short-term although they can contribute to C sequestration years later). Therefore, the implementation time of the monitoring plan is often longer than the duration of the project and, if there is no legal responsibility for the continuity of monitoring, it will not be carried out.

This monitoring plan has been written with the intention of being executed, and thus a serious effort has been made to overcome the aforementioned barriers.

Methodology

CARDIMED is made of 9 DEMO sites that, in most cases, include several independent NbS and, in one case (DEMO7), is made of two NbSs interlinked in such a way that a monitoring plan at the landscape level was considered necessary in addition to monitoring each individual NBS. In all, **18 separate monitoring plans**, plus one simulation of effects of the combined effect of two NbSs on the evolution of landscape connectivity have been prepared.

The typology of these 18 NbSs is very variated due both to the type of environment and to the problem that each NbS addresses: 9 NbSs are being implemented in urban sites and are oriented to control floods, to collect rainwater for watering municipal gardens, to recover grey water to feed vertical gardens, to depave public areas and to reduce temperature in schoolyards; 4 NbSs are being applied in agricultural environments already existing or that will be created, and include fertigation projects using treated water, desalination of groundwater by injection of treated urban water to recover grazeland productivity, and recovery of pastures by elimination of invasive shrubs; 2 NbSs are being designed to retain rainwater in dry Mediterranean ravines; in forest areas, two very different NbSs are being implemented, the first of which consisting of recovering riparian forests highly degraded because of plant invasions, and the second addressing the elimination of a mistletoe pest. Given the heterogeneity of the situations, a monitoring plan has been specifically created for each CARDIMED case and, in this sense, this document can be read as the compendium of 18 independent monitoring plans.

The methodology followed was as follows:

1. The first step was to review in deep the documentation submitted by the coordinators of each study case and to create coherent narratives for each case.
2. Once the narratives were clear, we scheduled at least one (most often two or three) on-line meeting with the coordinators of each DEMO case to clarify all details concerning which environmental compartments might be affected by the planned actions. This phase was very labour-intensive given the lack of detail regarding NbSs planning in the early stages of the project
3. After identifying the environmental sectors that should be considered for each case, we summoned a work team composed by sectoral experts on energy, water, forestry, agriculture, soil, plant and animal diversity, and societal dynamics. The expert team made an exhaustive literature review including technical and policy documents (European projects on NbSs, other national and international projects including monitoring plans, EC documents on monitoring and NbS monitoring, etc) and peer reviewed literature on environmental indicators relative to our environmental compartments. Available documentation about indicators of the following EU projects was reviewed: Nature4cities, Connecting Nature, DivAirCity, proGIreg, JUST-Nature, URBAN GREEN-UP, UN-HABITAT, CityKeys, UNALAB, and REGREEN. Some European networks also provided important information (EdiCitNet, -a network for urban food-, and The Green City Accord – an EC initiative to make cities greener, cleaner and healthier)
4. From this review, we extracted a list of frequently used indicators. After cleaning the list for repetitions, redundant indicators and indicators that were not suitable at the scale of our NBSs, the final list included 570 indicators. Only 35 indicators were adequate to assess impacts on biodiversity and only 50 indicators were adequate to monitor effects of soil health and food production.
5. Each sectoral expert was invited to choose several indicators that might be potentially included in the monitoring plan of each DEMO case, and to inform about field sampling calendar, intensity and spatial design and about needs for expert equipment, lab analyses, expert knowledge and other necessary means that can generate unforeseen expenses.

6. A second round of discussions between experts and NbS leaders was conducted (more than one round when appropriate). During these discussions, the indicators to be included in the monitoring plan for each DEMO site were decided by mutual agreement. The election was done trying to guarantee the technical and economic viability of the monitoring plan. For each environmental compartment, several indicators of increasing sensitiveness, and technical complexity and economic cost were proposed. We chose the indicators that offered the highest sensitiveness at affordable cost. We had to reject some sensitive indicators that required high expertise when it was not available to the DEMO coordinators.
7. Finally, we drafted a detailed monitoring plan for each case. We included the necessary instructions (sampling plan and map, necessary equipment, calculation formulas, expected behaviour) for NbS coordinators to be able to execute the monitoring autonomously or in collaboration with their partnering research centres.

It must be noted that the landscape indicator mentioned above for DEMO 7 (forest restoration in a riparian corridor) is not deployed in the corresponding monitoring plan. The reason is that the indicator is being prepared now by CREAF experts in cooperation with the DEMO coordinators. Current connectivity, based on the theoretical mobility pattern of a target species, has been mapped and calculated, and connectivity after forest recovery will be calculated once the location of the intervention areas (under negotiation between DEMO coordinators, landowners and territorial administration) is clarified. Impact of the intervention on landscape connectivity will be assessed by comparison between both maps. No further monitoring is required.

Important Remarks

- ✓ The title of the deliverable is kept as in the DoA "DEMOs value chains, monitoring and validation", while the contents are adjusted. In particularly, the section of the *DEMOs value chains* (contribution of the *T2.3 Definition of the value chain and stakeholder groups for the demonstrations*) is moved to the deliverable D2.3 DEMO Action Plans. Work of the T2.3 consists of mapping of the whole chain the whole value chain of the stakeholders including recommendations for actions for stakeholder and community engagement strategy. In its final form, the outcomes of T2.3 suit much the structure of the D2.3 rather than D2.2.

- ✓ For each DEMO case, the monitoring plan has been prepared based on the description of the actions provided by the DEMO leaders before August 2024. Additional adaptations can be necessary as NbS projects progress.

- ✓ The monitoring plans included in this report do not consider social indicators. ANNEX J includes three proposed indicators that must be discussed with the coordinators of the NbSs and adapted to the specificities of each case before inclusion in the monitoring plan. As thus, these indicators will be assessed over the course of the project through the activities in WP3 and WP7 (Task 7.1) and will be assessed through interviews with DEMO teams (including DEMO leaders) and policy stakeholders that will be realised and assessed by the Utrecht University research team.

DEMO1: Aegean Islands

DEMO1.1: Lesvos

A circular system was implemented by the National Technical University of Athens in 2021, at Antissa, Lesvos (Greece), in the framework of the European project HYDROUSA to improve water recovery from domestic wastewater treatment. The plant produces reclaimed water, biogas and sludge. The UASB effluent is treated by a constructed wetland system for further purification and is then used in a nearby ecological agroforestry field for fertigation. The sludge is composted onsite, however due to environmental regulations it is not suitable to be used in ecological food production and it is exported elsewhere.

To test the use of reclaimed water in the agroforestry field, two experiments have been implemented. In the main field, several plots are irrigated with tap water (control), and an equivalent number of plots are fertigated with the reclaimed water. This field is planted with aromatic plants (lavender and oregano) and woody species (olive trees, apple trees, and fig trees). Aromatics are exploited for essential oil production. In the second field a maize-barley rotation system was implemented and is co-cultivated with aromatic plants (lavender), shrubs (Aronia, Myrtus) and trees (apple, fig, almond, quince, laurel). This field also has control plots irrigated with tap water and comparable plots irrigated with reclaimed water.

DEMO1.1: Lesvos	Sector	Code
Soil Physical and Chemical Fertility	Soil	Lesvos_Soil01
Soil Organic Carbon Content	Soil	Lesvos_Soil02
Soil Bulk Density (ρ)	Soil	Lesvos_Soil03
Nematode Maturity Index (MI)	Soil	Lesvos_Soil04
Water Holding Capacity	Soil	Lesvos_Soil05
Soil Respiration	Soil	Lesvos_Soil06
Food Production (FP)	Soil	Lesvos_Soil07
Effective Wastewater Treatment (WWTEFF)	Water	Lesvos_Water01
Reclaimed Water in non-potable Uses (RWnpU)	Water	Lesvos_Water02
Reclaimed Water Production (RWP)	Water	Lesvos_Water03
Water-Related Materials' Recovery (WR)	Water	Lesvos_Water04
Water Provision by The Ecosystem (Wavailable)	Water	Lesvos_Water05
Water Availability (WA)	Water	Lesvos_Water06
Water Footprint (WFP)	Water	Lesvos_Water07
Water Footprint (ISO)	Water	Lesvos_Water08
Agricultural Water Withdrawal (AWW)	Water	Lesvos_Water09
Water Storage Capacity (WSC)	Water	Lesvos_Water10
Compliant Reclaimed Water (CtotalRW)	Water	Lesvos_Water11
Effluent Pollutant Removal (EPR)	Water	Lesvos_Water12
Rate of Evapotranspiration (ETrate)	Water	Lesvos_Water13
Biogas Generation Due to Wastewater Treatment	Energy	Lesvos_Energy01
Energy Consumption for Wastewater Treatment	Energy	Lesvos_Energy02
Electricity Use in Agriculture	Energy	Lesvos_Energy03
Energy Footprint Per Kg of Food	Energy	Lesvos_Energy04
Operational Energy Consumption	Energy	Lesvos_Energy05

DEMO1.2: Mykonos

Two NbS systems were implemented to harvest rainwater for irrigation and domestic uses in the Ano Mera village in Mykonos Island (Greece). In the first system, a sub-surface rainwater collector was constructed to collect rainwater and store it in underground storage tanks, which is then used to irrigate a nearby field planted with aromatic plants (lavender). The harvested plants are given to local agrotourism, or used to produce essential oil. This NbS system helps to mitigate flood risks, while providing economic value with the production of aromatic herbs and essential oil.

The second system is composed of three subsystems, a smart residential water management, a slow sand filter, and a bioswale. A rainwater harvesting system incorporates a bioswale that captures stormwater runoff from rooftops and residential yards. This water is stored in detention vaults and tanks, primarily for non-potable domestic uses, while some is used to irrigate a 0.2 hectare lavender field. Smart irrigation systems, monitored online, ensure water efficiency for the irrigation of lavender fields. Additionally, the system replenishes the aquifer during wet seasons and provides a water source for non potable uses during dry periods. Smart sensors for online monitoring, ensure optimal resource use.

DEMO1.2: Mykonos	Sector	Code
Soil Physical and Chemical Fertility	Soil	Mykonos_Soil01
Water Holding Capacity (WHC)	Soil	Mykonos_Soil02
Reclaimed Water in Non-Potable Uses (Rwnpu)	Water	Mykonos_Water01
Water Availability (WA)	Water	Mykonos_Water02
Water Storage Capacity (WSC)	Water	Mykonos_Water03
Water Quality Compliance (WQC)	Water	Mykonos_Water04
Rainfall Interception of NBS (RI)	Water	Mykonos_Water05
Insect Sampling	Biodiversity	Mykonos_Bio01
Electricity Uses in Agriculture	Energy	Mykonos_Energy01
Energy Footprint Per Kg of Food	Energy	Mykonos_Energy02

DEMO1.3: Sifnos

A network of 120 stone-built weirs in the Kamares catchment area, Sifnos Island (Greece) will be constructed with the aim of flood mitigation and aquifer recharge. Two water streams will be selected for the construction of small-scale stone dams which will lower the risk of floods by collecting the water in small dams and letting the water infiltrate into the ground rather than flow downstream. This increased infiltration rate will recharge the aquifers. In addition to the dams, small water storage ponds will further aid water retention for agricultural irrigation, while low rock barriers enhance water management and soil erosion control.

DEMO1.3: Sifnos	Sector	Code	Page
Water Availability (WA)	Water	Sifnos_Water01	
Water Storage Capacity (WSC)	Water	Sifnos_Water02	
Rainfall Interception of NBS (RI)	Water	Sifnos_Water03	
Increased Groundwater Recharge (GWR)	Water	Sifnos_Water04	
Avoided Floods (AF)	Water	Sifnos_Water05	
Marsh Frog Abundance	Biodiversity	Sifnos_Bio01	
Area of Mediterranean Temporary Ponds Created	Biodiversity	Sifnos_Bio02	

DEMO2: Halcor

A smart water management system is implemented using natural-based solutions in Oinofyta (Greece). The solutions are developed and implemented at the Halcor premises, a metal industrial complex in Central Greece. The design aims to achieve a reduction in water demand, by combining the reuse of harvested rainwater/stormwater and treated industrial wastewater.

DEMO2: Halcor	Sector	Code
Effective Wastewater Treatment (WWTeff)	Water	Halcor_Water01
Effective Stormwater Treatment (SWTeff)	Water	Halcor_Water02
Reclaimed Water in Non-Potable Uses (RWnpU)	Water	Halcor_Water03
Reclaimed Water Production (RWP)	Water	Halcor_Water04
Water Availability (WA)	Water	Halcor_Water05
Water Footprint (ISO)	Water	Halcor_Water06
Water Footprint (WFP)	Water	Halcor_Water07
Water Storage Capacity (WSC)	Water	Halcor_Water08
Effluent Pollutant Removal (EPR)	Water	Halcor_Water09
Rainfall Interception of NBS (RI)	Water	Halcor_Water10
Rate of Evapotranspiration (ETrate)	Water	Halcor_Water11
Water Quality Compliance (WQC)	Water	Halcor_Water12
Avoided Floods (AF)	Water	Halcor_Water13
Captured Runoff (Vrunoff)	Water	Halcor_Water14
Flood-Excess Volume (FEV)	Water	Halcor_Water15
Linear Water Losses (LWL)	Water	Halcor_Water16
Energy Consumption for Wastewater Treatment	Energy	Halcor_Energy01
Operational energy consumption	Energy	Halcor_Energy02

DEMO3: Sardinia

The wastewater plant of San Marco, Sardinia Island (Italy) is treating water to be reused in agriculture. The treated effluents will be stored in tanks to be used when needed, following two different pathways. First, agricultural runoff will be treated through a riparian buffer before it is discharged into the river or nearby surface waters. Water quality will be monitored. Second, to another agricultural zone in which agricultural runoff will be treated in a free water surface constructed wetland. Once the agricultural runoff water has been treated by the constructed wetland, a part of the effluent will be used to grow fish in fish tanks. A solar energy plant will provide the energy for wastewater treatment and irrigation systems. In the two agricultural zones, a five-year rotation has been designed in which a winter cereal (wheat), a summer cereal (corn or rice), and a perennial crop (alfalfa) will alternate. The crop rotation will be managed according to the principles of integrated agricultural systems. Moreover, livestock effluents will be used for soil fertilization. This NbS system is aimed to reduce the water stress and the water consumption of the crops while improving its physiology and increase water productivity.

DEMO3: Sardinia	Sector	Code
Soil Physical and Chemical Fertility	Soil	Sardinia_Soil01
Hydrological Regulation	Soil	Sardinia_Soil02
Soil Organic Carbon Content	Soil	Sardinia_Soil03
Water Holding Capacity	Soil	Sardinia_Soil04
Soil Biodiversity	Soil	Sardinia_Soil05
Agricultural Water Withdrawal (AWW)	Water	Sardinia_Water01
Compliant Reclaimed Water (CtotalRW)	Water	Sardinia_Water02
Effluent Pollutant Removal (EPR)	Water	Sardinia_Water03
Reclaimed Water in Non-Potable Uses (RWnpU)	Water	Sardinia_Water04
Reclaimed Water Production (RWP)	Water	Sardinia_Water05
Water Availability (WA)	Water	Sardinia_Water06
Water Footprint (ISO)	Water	Sardinia_Water07
Water-Related Materials' Recovery (WR)	Water	Sardinia_Water08
KPI2 - Energy Recovered/Saved	Energy	Sardinia_Energy01
KPI3 - Reduction of The Energy Footprint Per Unit of Water	Energy	Sardinia_Energy02
KPI4 - Energy / CO2 Footprint of Irrigation Systems	Energy	Sardinia_Energy03
KPI5 - Water-Energy-Food-Carbon Footprint of The Integrated System	Energy	Sardinia_Energy04
KPI6 - Energy Saving from Rainwater Removed from Combined Sewer and Not Treated in Centralized Wastewater Treatment Plant	Energy	Sardinia_Energy05
KPI7 – Renewable Energy Sources (RES) Units Integrated and Capacity	Energy	Sardinia_Energy06
KPI8 - Gross Renewable Consumption Relative to Total Gross Final Consumption	Energy	Sardinia_Energy07
KPI9 - Increase in Renewable Energy Use in the Area	Energy	Sardinia_Energy08
Sustainable Energy Practices	Energy	Sardinia_Energy09
Energy Consumption for Wastewater Treatment	Energy	Sardinia_Energy10
Energy Footprint Per Kg of Food	Energy	Sardinia_Energy11

DEMO4: Sicily

DEMO4.1: Catania

To reduce the risk of urban flood peaks, a nature-based solution is being developed in Andrea Doria, Catania (Italy). The main objective is to capture the water runoff from Alessandro Doria Avenue and Via del Bosco, during the storms thus decreasing flood risks in the city. This is achieved with the implementation of staggered filters made of soil and other materials, that can remove pollutants and help to improve water infiltration. This NbS will be complemented by adding a rain garden with local plants, reducing urban flood peaks. The system will also store the purified water and make it usable for irrigation purposes.

DEMO4.1: Catania		
Avoided Floods (AF)	Water	Catania_Water01
Captured Runoff (Vrunoff)	Water	Catania_Water02
Effective Stormwater Treatment (SWTeff)	Water	Catania_Water03
Effluent Pollutant Removal (EPR)	Water	Catania_Water04
Flood-Excess Volume (FEV)	Water	Catania_Water05
Rainfall Interception of NBS (RI)	Water	Catania_Water06
Water Availability (WA)	Water	Catania_Water07
Water Quality Compliance (WQC): Biological, Physical and Chemical Parameters	Water	Catania_Water08
Flying Insect Sampling	Biodiversity	Catania_Bio01
Electricity consumption during construction stage (in terms of working hours)	Energy	Catania_Energy01
Electricity consumption during urgent irrigation purposes	Energy	Catania_Energy02

DEMO4.2: Ferla

The construction of a green living wall system, a NbS that showed a production of averagely 150-200 l/day of greywater, has been carried out in a schoolyard in Ferla, Sicily (Italia). The system is used to manage the greywater from the hand washing stations of the school, and to reuse it to cultivate and grow vegetation on the wall. After excess water from the living wall is then reused again as treated greywater for toilet flushing. Temperature sensors are installed to provide continuous monitoring on how the green wall helps lower the temperature inside the school building.

DEMO4.2: Ferla	Sector	Code
Compliant Reclaimed Water (CtotalRW)	Water	Ferla_Water01
Effective Wastewater Treatment (WWTeff)	Water	Ferla_Water02
Effluent Pollutant Removal (EPR)	Water	Ferla_Water03
Rate of Evapotranspiration (ETrate)	Water	Ferla_Water04
Reclaimed Water in Non-Potable Uses (RWnpU)	Water	Ferla_Water05
Water Availability (WA)	Water	Ferla_Water06
Water Quality Compliance (WQC)	Water	Ferla_Water07
Flying Insect Sampling	Biodiversity	Ferla_Bio01
New Fauna Habitat Area	Biodiversity	Ferla_Bio02
Air Temperature At 2 Meters (Daytime and Night-Time)	Human Well-being	Ferla_Well01
Daily Temperature Range (Difference Between the Daily Maximum and Daily Minimum Temperature)	Human Well-being	Ferla_Well02
Heatwave Risks (Number of Combined Tropical Nights (>20°c) And Hot Days (>35°c))	Human Well-being	Ferla_Well03
Days With Temperature >90th Percentile (TX90p)	Human Well-being	Ferla_Well04
Mean Or Peak Daytime Local Temperatures (°C)	Human Well-being	Ferla_Well05
Monthly Mean Value of Daily Maximum Temperature (TXx)	Human Well-being	Ferla_Well06
Monthly Mean Value of Daily Minimum Temperature (TNn)	Human Well-being	Ferla_Well07
KPI1 - Energy Consumption Of NBS, Compared with Equivalent Conventional Infrastructure (% Decrease)	Energy	Ferla_Energy01
KPI10 - Decrease in Urban Heat Island (UHI) Effect (In Terms of Surface Temperatures)	Energy	Ferla_Energy02
Energy Consumption for Wastewater Treatment	Energy	Ferla_Energy03
Building Temperature Behavior	Energy	Ferla_Energy04
Energy Performance of Building (Energy Bills of the School)	Energy	Ferla_Energy05

DEMO5: Marseille

DEMO5.1: Saint Jérôme (peri-urban)

The main activity of the NBS consists of the unsealing 0,55 ha of paved soils around the Saint- Jerôme campus. This approach aims to achieve two primary objectives: (a) enhancing campus quality of life by mitigating heatwave intensity and improving air quality, and (b) reducing the pollutant load reaching the marine environment as a result of rain and stormwater runoff. After the unsealing, the areas will be renaturalized with local trees and shrubs to increase shading areas and biodiversity benefits.

DEMO5.1: St. Jerome		
Soil Physical and Chemical Fertility	Soil	Jerome_Soil01
Soil Sealing	Soil	Jerome_Soil02
Water Holding Capacity	Soil	Jerome_Soil03
Soil Organic Carbon Content	Soil	Jerome_Soil04
Soil Bulk Density (ρ)	Soil	Jerome_Soil05
Water Availability (WA)	Water	Jerome_Water01
Water Storage Capacity (WSC)	Water	Jerome_Water02
Rainfall Interception of NBS (RI)	Water	Jerome_Water03
Infiltration Rate (IR)	Water	Jerome_Water04
Air Temperature at 2 Meters (Daytime and Night-Time)	Human Well-being	Jerome_Well01
Daily Temperature Range (Difference Between the Daily Maximum and Daily Minimum Temperature	Human Well-being	Jerome_Well02
Days With Temperature >90th Percentile (TX90p)	Human Well-being	Jerome_Well03
Heatwave Risks (Number of Combined Tropical Nights (>20°C) and Hotdays (>35°C))	Human Well-being	Jerome_Well04
Mean Or Peak Daytime Local Temperatures (°C)	Human Well-being	Jerome_Well05
Monthly Mean Value of Daily Maximum Temperature (TXx)	Human Well-being	Jerome_Well06
Monthly Mean Value of Daily Minimum Temperature (TNn)	Human Well-being	Jerome_Well07
Relative Humidity (%)	Human Well-being	Jerome_Well08
PM10	Human Well-being	Jerome_Well09
PM2.5	Human Well-being	Jerome_Well10
Recreational Opportunities Provided by Green Infrastructure	Human Well-being	Jerome_Well11
Self-Reported Well-Being/ Good Moods	Human Well-being	Jerome_Well12
Normalised Difference Vegetation Index (NDVI)	Human Well-being	Jerome_Well13
Number of trees	Human Well-being	Jerome_Well14
Air temperature reduction in case study areas	Energy	Jerome_Energy01
Electricity use for irrigation purposes	Energy	Jerome_Energy02
Plant Mortality Rate	Biodiversity	Jerome_Bio01
Canopy Cover Growth Rate	Biodiversity	Jerome_Bio02
Edible Fruits Produced by Planted Plants	Biodiversity	Jerome_Bio03
Species Richness (Trees, Shrubs and Herbaceous Plants), Jaccard Index (Inter-Annual Similarity)	Biodiversity	Jerome_Bio04
Number of Planted Trees and Shrubs	Biodiversity	Jerome_Bio05
Mosquito Bites	Biodiversity	Jerome_Bio06

DEMO5.2: Saint Charles (urban, city centre)

In subDEMO 5.2, the implementation will begin with surface unsealing and terracing of an area of approximately 4000 m^2, followed by the installation of porous asphalt and concrete to enhance water infiltration. In the second phase, a green corridor will be planted to increase the area's green cover and contribute to urban cooling. Mulching will be used around the trees to help retain soil moisture, suppress weeds, and regulate soil temperature. This will achieve two goals, to improve the quality of life by alleviating heatwave intensity and improving air quality, and to reduce the pollution that ends up in the sea caused by rain and stormwater runoff. After the unsealing, the areas will be renaturalized with local trees and shrubs to increase shading areas and biodiversity benefits.

DEMO5.2: St. Charles	Sector	Code
Soil Physical and Chemical Fertility	Soil	Charles_Soil01
Soil Organic Carbon Content	Soil	Charles_Soil02
Soil Bulk Density (ρ)	Soil	Charles_Soil03
Water Holding Capacity	Soil	Charles_Soil04
Soil Sealing	Soil	Charles_Soil05
Water Availability (WA)	Water	Charles_Water01
Water Storage Capacity (WSC)	Water	Charles_Water02
Rainfall Interception of NBS (RI)	Water	Charles_Water03
Infiltration Rate (IR)	Water	Charles_Water04
Air temperature at 2 meters (daytime and night-time)	Human Well-being	Charles_Well01
Daily Temperature Range (Difference Between the Daily Maximum and Daily Minimum Temperature)	Human Well-being	Charles_Well02
Days With Temperature >90th Percentile (TX90p)	Human Well-being	Charles_Well03
Heatwave Risks (Number of Combined Tropical Nights (>20°c) and Hotdays (>35°c))	Human Well-being	Charles_Well04
Mean Or Peak Daytime Local Temperatures	Human Well-being	Charles_Well05
Monthly Mean Value of Daily Maximum Temperature (Txx)	Human Well-being	Charles_Well06
Monthly Mean Value of Daily Minimum Temperature (Tnn)	Human Well-being	Charles_Well07
Relative humidity	Human Well-being	Charles_Well08
PM10	Human Well-being	Charles_Well09
PM2.5	Human Well-being	Charles_Well10
Recreational opportunities provided by green infrastructure	Human Well-being	Charles_Well11
Self-reported well-being/ Good Moods	Human Well-being	Charles_Well12
Normalised Difference Vegetation Index (NDVI)	Human Well-being	Charles_Well13
Number of Tree	Human Well-being	Charles_Well14
Air temperature reduction in case study areas	Energy	Charles_Energy01
Energy use for irrigation purposes	Energy	Charles_Energy02
Plant Mortality Rate	Biodiversity	Charles_Bio01
Canopy Cover Growth Rate	Biodiversity	Charles_Bio02
Edible Fruits Produced by Planted Plants	Biodiversity	Charles_Bio03
Species Richness (Trees, Shrubs and Herbaceous Plants), Jaccard Index (Inter-Annual Similarity)	Biodiversity	Charles_Bio04
Number of Planted Trees and Shrubs	Biodiversity	Charles_Bio05
Mosquito Bites	Biodiversity	Charles_Bio06

DEMO6: Aragon

DEMO6.1: Teruel

In the forests near Teruel, Aragon (Spain) the infection of pine trees by mistletoe, a parasitic plant, has caused an increased pine mortality which also increased the forests vulnerability to wildfires. To control the expansion of mistletoe, a different approach to forest management is being developed. Mainly, this is done through three different actions. First, encouragement of local bird species which can consume and reduce mistletoe plants. Second, the elimination and thinning of most affected trees, to prevent mistletoe reproduction. And third, research in the valorization of mistletoe and the wood removed from infected trees.

DEMO6.1: Teruel	Sector	Code
Percentage of Affected Trees by Degree of Infestation at Tree Level	Biodiversity	Teruel_Bio01
Number Of Parasitized Trees	Biodiversity	Teruel_Bio02
Number of Trees Removed	Biodiversity	Teruel_Bio03
Aboveground Carbon Stored (Trees)	Biodiversity	Teruel_Bio04
Aboveground Carbon Removed (Trees)	Biodiversity	Teruel_Bio05
Tree Regeneration	Biodiversity	Teruel_Bio06
Tree Mortality Rate	Biodiversity	Teruel_Bio07
Energy footprint per kg of food	Energy	Teruel_Energy01
Operational energy consumption	Energy	Teruel_Energy02

DEMO6.2: Zaragoza

In Zaragoza, Aragon (Spain), two schools were selected for the renaturalization of their schoolyards. The schoolyards from the CEIP Maria Moliner and CEIP Vadorrey, were redesigned to increase their green spaces, which will provide an accessible way for urban children to interact with nature and to reduce temperature during heat-wave episodes. At CEIP Maria Moliner, the project includes bioretention cells (rain garden) and surface unsealing, which serve as buffers for effective water management. Meanwhile, CEIP Vadorrey will implement a vegetated pergola to support the growth of shading vines and plants, enhancing aesthetic appeal while providing natural cooling. Both schools will also incorporate techniques for fauna refuge and nesting, such as insect hotels, bird and bat houses, and amphibian ponds to further enrich biodiversity.

DEMO6.2: Zaragoza		
Soil Physical and Chemical Fertility	Soil	Zaragoza_Soil01
Soil Bulk Density (P)	Soil	Zaragoza_Soil03
Soil Sealing	Soil	Zaragoza_Soil05
Water Holding Capacity	Soil	Zaragoza_Soil06
Infiltration Rate (IR)	Water	Zaragoza_Water01
Rainfall Interception of NBS (RI)	Water	Zaragoza_Water02
Water Availability (WA)	Water	Zaragoza_Water03
Number of Planted Trees and Shrubs	Biodiversity	Zaragoza_Bio01
Tree Density	Biodiversity	Zaragoza_Bio02
Air Temperature At 2 Meters (Daytime and Night-Time)	Human Well-being	Zaragoza_Well01
Daily Temperature Range (Difference Between the Daily Maximum and Daily Minimum Temperature)	Human Well-being	Zaragoza_Well02
Days With Temperature >90th Percentile (TX90p)	Human Well-being	Zaragoza_Well03
Heatwave risks (number of combined tropical nights (>20ºC) and hotdays (>35ºC))	Human Well-being	Zaragoza_Well04
Mean or peak daytime local temperatures (ºC)	Human Well-being	Zaragoza_Well05
Monthly mean value of daily maximum temperature (TXx)	Human Well-being	Zaragoza_Well06
Monthly mean value of daily minimum temperature (TNn)	Human Well-being	Zaragoza_Well07
Relative humidity (%)	Human Well-being	Zaragoza_Well08
Number of trees	Human Well-being	Zaragoza_Well10
Recreational opportunities provided by green infrastructure	Human Well-being	Zaragoza_Well11
Self-reported well-being/ Good Moods	Human Well-being	Zaragoza_Well12
Energy savings for cooling	Energy	Zaragoza_Energy01
Air temperature reduction in building	Energy	Zaragoza_Energy02
Operational energy consumption	Energy	Zaragoza_Energy03

DEMO7: Central Alentejo

Alentejo is the hottest and driest region in mainland Portugal, which demands a restoration of landscape areas where climate change is more concerning, specially linked to water availability. This landscape restoration of riverside vegetation, caried out by the Évora University and the Comunidade Intermunicipal do Alentejo Central, consists of the rehabilitation of the riparian territory through the increase in connectivity, increase of local plant biodiversity through seeding, and the control of invasive species. The montados, the main agroforestry system in Portugal, consist of low-density trees combined with agriculture or livestock grazing. The landscape restoration is also be achieved by improving the restoration of degraded *montados* that have been invaded by brushy vegetation due to underexploitation.

DEMO7: Central Alentejo	Sector	Code
Soil Physical and Chemical Fertility	Soil	Alentejo_Soil01
Soil Organic Carbon Content	Soil	Alentejo_Soil02
Bulk Density (ρ)	Soil	Alentejo_Soil03
The Maturity Index of Bongers (Mi)	Soil	Alentejo_Soil04
Water Holding Capacity	Soil	Alentejo_Soil05
Aboveground Carbon Stored (Trees)	Biodiversity	Alentejo_Bio01
Tree Regeneration	Biodiversity	Alentejo_Bio02
Overall Conservation Status of Habitats Under the EU Habitats Directive	Biodiversity	Alentejo_Bio03
Number Of Habitats Under the EU Habitats Directive	Biodiversity	Alentejo_Bio04
Number Of Planted Trees	Biodiversity	Alentejo_Bio05
Number Of Planted Shrubs	Biodiversity	Alentejo_Bio06
Tax of Planted Trees Surviving Per Year	Biodiversity	Alentejo_Bio07
Tax of Planted Shrubs Surviving Per Year	Biodiversity	Alentejo_Bio08
Area Covered by Invasive Species	Biodiversity	Alentejo_Bio09
Linear Metres of Linear Landscape Elements Affected by Invasive Species	Biodiversity	Alentejo_Bio10
Area Of Habitats Restored	Biodiversity	Alentejo_Bio11
Area Of Habitats Under the EU Habitats Directive	Biodiversity	Alentejo_Bio12
Electricity use in agriculture	Energy	Alentejo_Energy01

DEMO8: Gediz Delta

Soil contamination by saline intrusion from the sea is a paramount issue in the Gediz Delta in Izmir (Turquey). DEMO 8 presents a comprehensive plan for coastal wetland restoration, integrating various NBS to address environmental and social challenges. The initiative begins with the deployment of riparian buffer areas, primarily aimed at diversifying habitats and enhancing native vegetation. The riparian buffers provide additional protection to water quality as a secondary pollution removal mechanismt. Next, diversion channels branching from the main open diversion channel are constructed to facilitate the inflow of freshwater into the existing wetlands. This measure aims to reduce salinity levels and promote a healthier habitat for indigenous flora and fauna. Additionally, green corridors will be developed within these diversion channels to enhance ecological connectivity. Invasive alien species control will be prioritised, targeting species that consume excessive water and degrade habitats along with techniques for fauna refuge and nesting (artificial nests for bird species on the roofs of shelters, bird perches), restoring native vegetation and reintroduction of native fauna, such as buffaloes, to enhance biodiversity and ecosystem resilience within the delta region. Sustainable communal grazing practices will be introduced to regulate animal husbandry, alleviating ecological pressures on the delta ecosystem.

DEMO8: Gediz Delta	Sector	Code
Soil Physical and Chemical Fertility	Soil	Gediz_Soil01
Soil Organic Carbon Content	Soil	Gediz_Soil02
Soil Bulk Density (ρ)	Soil	Gediz_Soil03
The Maturity Index of Bongers (Mi)	Soil	Gediz_Soil04
Soil Pollution by Arsenic (As)	Soil	Gediz_Soil05
Arsenic (As) Concentration in Pastures	Soil	Gediz_Soil06
Water Holding Capacity	Soil	Gediz_Soil07
Effective Wastewater Treatment (WWTeff)	Water	Gediz_Water01
Reclaimed Water Production (RWP)	Water	Gediz_Water02
Water Provision by the Ecosystem (Wavailable)	Water	Gediz_Water03
Water Availability (WA)	Water	Gediz_Water04
Effluent Pollutant Removal (EPR)	Water	Gediz_Water05
Aquifer Surface Ratio with Excessive Nitrate (ASREN)	Water	Gediz_Water06
Aquifer Surface Ratio with Excessive Arsenic (ASREA)	Water	Gediz_Water07
Increased Groundwater Recharge (GWR)	Water	Gediz_Water08
Infiltration Rate (IR)	Water	Gediz_Water09
Average Groundwater Electrical Conductivity (GWEC)	Water	Gediz_Water10
Area Of Habitats Restored	Biodiversity	Gediz_Bio01
Number Of Focal Habitat Specialist Species	Biodiversity	Gediz_Bio02
Focus Or Key Habitat(S) Area	Biodiversity	Gediz_Bio03
Tree Biomass Removed	Biodiversity	Gediz_Bio04
Biogas Generation Due to Wastewater Treatment	Energy	Gediz_Energy01
Energy Consumption of Biogas Production System	Energy	Gediz_Energy02
PV Electricity Generation and Total Land Used	Energy	Gediz_Energy03

DEMO9: Nicosia

To address the heat island effect, the lack of freshwater resources, and support the disadvantaged communities through food production and community engagement, three coordinated actions of different scales in different public parks of Nikosia (Cyprus) will be implemented. The actions consist in the creation of a rainwater harvesting system (filter drain) in the Polykratous Park, a halophyte-based water treatment (photobioreactor) in Kaimakli Park, and a vertical hydroponic wall system (green facade) located in the Gardens of the Future. These actions will help to improve the microclimate, to expand the green and natural spaces around the city, and to enhance quality of life of its residents.

DEMO 9.1: Nikosia - Kaimakli Park	**Sector**	**Code**
Soil Physical and Chemical Fertility	Soil	Nikosia-1_Soil01
Soil Bulk Density (ρ)	Soil	Nikosia-1_Soil02
Effective Groundwater Treatment (GWTeff)	Water	Nikosia-1_Water01
Reclaimed Water in Non-Potable Uses (RWnpU)	Water	Nikosia-1_Water02
Water-Related Materials' Recovery (WR)	Water	Nikosia-1_Water03
Water Storage Capacity (WSC)	Water	Nikosia-1_Water04
Effluent Pollutant Removal (EPR)	Water	Nikosia-1_Water05
Water Quality Compliance (WQC)	Water	Nikosia-1_Water06
Aquifer Surface Ratio with Excessive Nitrate (ASREN)	Water	Nikosia-1_Water07
Physico-Chemical Status of Groundwater/Surface Water (Wstatus)	Water	Nikosia-1_Water08
Bird Species Richness	Biodiversity	Nikosia-1_Bio01
New Fauna Habitat Area	Biodiversity	Nikosia-1_Bio02
Energy Consumption for Groundwater Treatment	Energy	Nikosia-1_Energy01
DEMO9.2: Nikosia - Polykratous Park		
Soil Physical and Chemical Fertility	Soil	Nikosia-2_Soil01
Soil Bulk Density (ρ)	Soil	Nikosia-2_Soil02
Reclaimed Water in Non-Potable Uses (RWnpU)	Water	Nikosia-2_Water01
Water Storage Capacity (WSC)	Water	Nikosia-2_Water02
Water Quality Compliance (WQC)	Water	Nikosia-2_Water03
Rainfall Interception of NBS (RI)	Water	Nikosia-2_Water04
Bird Species Richness	Biodiversity	Nikosia-2_Bio01
New Fauna Habitat Area	Biodiversity	Nikosia-2_Bio02
Energy Indicators	Biodiversity	Nikosia-2_Bio03
Air Temperature Measurement (Weather Station)	Energy	Nikosia-2_Energy01
Air Humidity Measurement (Weather Station)	Energy	Nikosia-2_Energy02
Energy consumption of Water Storage and Irrigation in green areas	Energy	Nikosia-2_Energy03
DEMO9.3: Nikosia - Gardens of the Future		
Water Footprint (WFP)	Water	Nikosia-3_Water01
Tap Water Consumption (TWC)	Water	Nikosia-3_Water02
Number of Individuals Producing Edible Fruits	Biodiversity	Nikosia-3_Bio01
Fruit Production Per Species	Biodiversity	Nikosia-3_Bio02
Flying Insect Sampling	Biodiversity	Nikosia-3_Bio03
Electricity Use in Agriculture	Energy	Nikosia-3_Energy01
Food production (yield in terms of weight for energy footprint)	Energy	Nikosia-3_Energy02
Renewable Energy Sources (RES) units integrated and capacity	Energy	Nikosia-3_Energy03
Gross Renewable consumption relative to total gross final consumption	Energy	Nikosia-3_Energy04
Increase In Renewable Energy Use in The Area	Energy	Nikosia-3_Energy05

ANNEXES

ANNEX A: DEMO1

ANNEX B: DEMO2

ANNEX C: DEMO3

ANNEX D: DEMO4

ANNEX E: DEMO5

ANNEX F: DEMO6

ANNEX G: DEMO7

ANNEX H: DEMO8

ANNEX I: DEMO9

ANNEX J: Social Indicators

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CLIMATE ADAPTATION AND RESILIENCE
DEMONSTRATED IN THE MEDITERRANEAN REGION

Deliverable 2.2

ANNEX A: DEMO1

DEMO1: Aegean Islands

DEMO1.1: Lesvos	Sector	Code
Soil Physical and Chemical Fertility	Soil	Lesvos_Soil01
Soil Organic Carbon Content	Soil	Lesvos_Soil02
Soil Bulk Density (ρ)	Soil	Lesvos_Soil03
Nematode Maturity Index (MI)	Soil	Lesvos_Soil04
Water Holding Capacity	Soil	Lesvos_Soil05
Soil Respiration	Soil	Lesvos_Soil06
Food Production (FP)	Soil	Lesvos_Soil07
Effective Wastewater Treatment (WWTEFF)	Water	Lesvos_Water01
Reclaimed Water in non-potable Uses (RWnpU)	Water	Lesvos_Water02
Reclaimed Water Production (RWP)	Water	Lesvos_Water03
Water-Related Materials' Recovery (WR)	Water	Lesvos_Water04
Water Provision by The Ecosystem (Wavailable)	Water	Lesvos_Water05
Water Availability (WA)	Water	Lesvos_Water06
Water Footprint (WFP)	Water	Lesvos_Water07
Water Footprint (ISO)	Water	Lesvos_Water08
Agricultural Water Withdrawal (AWW)	Water	Lesvos_Water09
Water Storage Capacity (WSC)	Water	Lesvos_Water10
Compliant Reclaimed Water (CtotalRW)	Water	Lesvos_Water11
Effluent Pollutant Removal (EPR)	Water	Lesvos_Water12
Rate of Evapotranspiration (ETrate)	Water	Lesvos_Water13
Biogas Generation Due to Wastewater Treatment	Energy	Lesvos_Energy01
Energy Consumption for Wastewater Treatment	Energy	Lesvos_Energy02
Electricity Use in Agriculture	Energy	Lesvos_Energy03
Energy Footprint Per Kg of Food	Energy	Lesvos_Energy04
Operational Energy Consumption	Energy	Lesvos_Energy05
DEMO1.2: Mykonos		
Soil Physical and Chemical Fertility	Soil	Mykonos_Soil01
Water Holding Capacity (WHC)	Soil	Mykonos_Soil02
Reclaimed Water in Non-Potable Uses (Rwnpu)	Water	Mykonos_Water01
Water Availability (WA)	Water	Mykonos_Water02
Water Storage Capacity (WSC)	Water	Mykonos_Water03
Water Quality Compliance (WQC)	Water	Mykonos_Water04
Rainfall Interception of NBS (RI)	Water	Mykonos_Water05
Insect Sampling	Biodiversity	Mykonos_Bio01
Electricity Uses in Agriculture	Energy	Mykonos_Energy01
Energy Footprint Per Kg of Food	Energy	Mykonos_Energy02
DEMO1.3: Sifnos		
Water Availability (WA)	Water	Sifnos_Water01
Water Storage Capacity (WSC)	Water	Sifnos_Water02
Rainfall Interception of NBS (RI)	Water	Sifnos_Water03
Increased Groundwater Recharge (GWR)	Water	Sifnos_Water04
Avoided Floods (AF)	Water	Sifnos_Water05
Marsh Frog Abundance	Biodiversity	Sifnos_Bio01
Area of Mediterranean Temporary Ponds Created	Biodiversity	Sifnos_Bio02

DEMO1.1: Lesvos

A circular system was implemented by the National Technical University of Athens in 2021, at Antissa, Lesvos (Greece), in the framework of the European project HYDROUSA to improve water recovery from domestic wastewater treatment. The plant produces reclaimed water, biogas and sludge. The UASB effluent is treated by a constructed wetland system for further purification and is then used in a nearby ecological agroforestry field for fertigation. The sludge is composted onsite, however due to environmental regulations it is not suitable to be used in ecological food production and it is exported elsewhere.

To test the use of reclaimed water in the agroforestry field, two experiments have been implemented. In the main field, several plots are irrigated with tap water (control), and an equivalent number of plots are fertigated with the reclaimed water. This field is planted with aromatic plants (lavender and oregano) and woody species (olive trees, apple trees, and fig trees). Aromatics are exploited for essential oil production. In the second field a maize-barley rotation system was implemented and is co-cultivated with aromatic plants (lavender), shrubs (Aronia, Myrtus) and trees (apple, fig, almond, quince, laurel). This field also has control plots irrigated with tap water and comparable plots irrigated with reclaimed water.

1.1.1 Soil Indicators

1.1.1.1 Soil Physical and Chemical Fertility

- **Code**: Lesvos_Soil01
- **Environmental Sector**: Soil / Soil Health
- **Units:** Multi-component indicator. Diverse units for specific components

Meaning and importance of the indicator

Soil productive capacity (a key soil ecosystem service) is the result of complex interactions between biological, chemical and physical properties. Achieving and maintaining appropriate levels of physical and chemical soil fertility is of paramount importance for sustainable cropland management and, at large scale, for food security. Nutrients naturally arrive to soil from geological materials, from water, from atmospheric deposition and from decomposition of plant and animal residues. Nutrient availability to crops is significantly affected by soil acidity (pH), and nutrient presence in the soil solution is highly dependent on soil texture and soil cation exchange capacity; water provision to plants is notably improved by soil organic matter. Soil electrical conductivity warns about soil salinity, a serious risk for crops under Mediterranean conditions. Soil analysis is the basic tool to evaluate soil fertility and to guide farmers towards sustainable management.

Expected evolution of the indicator

There are recommended ranges and critical values for most of the soil components to be analysed. For a given crop (maize, barley and aromatic plants in this case), these values are available from local and regional farmer associations. Most generally, together with the results of soil analyses, agricultural laboratories provide an evaluation of the level of each analysed parameter (deficient – correct – excessive or similar). The value of each parameter should evolve towards these reference values.

Data obtention

Required data:

- To be analysed only the first time: soil texture (% sand; % clay; % silt); textural class.
- To be analysed at each soil sampling campaign: pH; Electrical conductivity (CEC); Total organic carbon (%, dry soil basis); Carbonates; Total nitrogen (Kjeldahl); Available phosphorus (Olsen); Cation exchange capacity; Interchangeable bases (Ca, Mg, Na and K); Micronutrients (Fe, Zn, Mn)

Sampling plan:

Field sampling followed by lab analyses. Samples will always be taken at the same period of the year, preferably a few days after sowing barley in the "second field" (November), and in the same day for the two experimental fields.

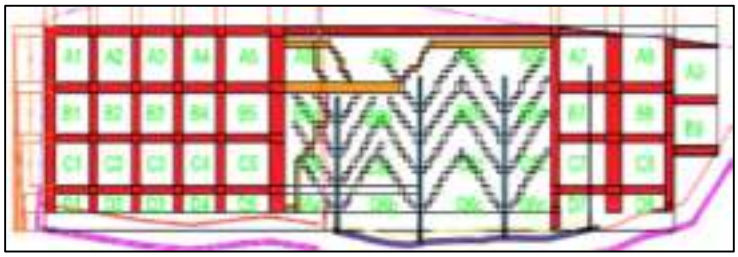

Figure 1

In the main field, plots A5, B5, C5, A8, B8, C8 and D8 will be sampled with 15 cm depth soil borers (see "equipment"). At each plot, two soil samples will be taken from two points randomly chosen under the spearmint plantation. The four samples of A5-B5, C5-D5, A8-B8 and C8-D8 will be mixed together into a unique plastic zip bag duly labelled with the date and the name of the plot (4 composite samples in total).
In the second field, all 8 plots will be sampled with same soil sampler used in the main field. At each plot, two soil samples will be taken from two points randomly chosen under the maize plants. The four samples of 1-2, 3-4, 5-6 and 7-8 will be mixed and put together into a unique zip bag duly labelled with the date and the name of the plot (4 composite samples in total).

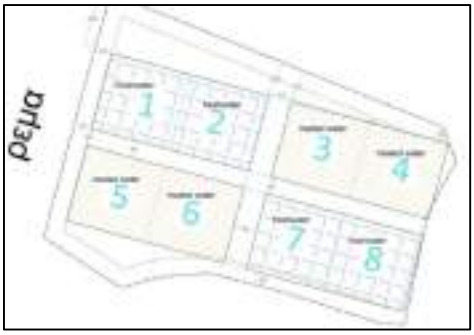

Figure 2

The resulting 8 composite samples will be sent to an expert lab for analysis as soon as possible. The soil lab must have been previously consulted for instructions about the preparation of the samples before shipping.
The samples must be analysed for total organic carbon after removal of carbonates. SOC will be provided by the lab in the form of % OC.

Sampling calendar

The two fields will be sampled in the proposed dates every two years for 10 years (5 times). C content varies over the year with season and the development state of the crop. Therefore, it is very important to sample the plots in the same dates every year.

Equipment

Samples will be extracted from soil with soil borers of known and constant (the same for all samples at each sampling campaign) depth and diameter. The borer should be 15 cm long and the recommended diameter is 5 cm. Some indicative providers of these soil samplers are: https://www.ams-samplers.com/soil-augers/; https://www.vanwalt.com/equipment/telescoping-augers/. Any other equivalent sampler of these dimensions is acceptable (but try to respect the 15 cm depth). Some small field materials, such as zip bags are needed.

External subcontracting

Yes. A trustable lab delivering soil fertility analyses must be hired.

References

- Al-Hamaiedeh, H., Bino, M. (2010). Effect of treated grey water reuse in irrigation on soil and plants. *Desalination*, 256(1-3), 115-119.
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- O'connor, G. A., Elliott, H. A., Bastian, R. K. (2008). Degraded water reuse: An overview. *Journal of Environmental Quality*, 37(S5), S-157.
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- For soil fertility in crops: https://www.agromatica.es/referencia-de-un-analisis-de-suelo/; https://www.fbn.com/community/blog/how-to-read-a-soil-analysis-report; https://pubs.nmsu.edu/_circulars/CR676/; For soil fertility in gardens: https://extension.umaine.edu/gardening/manual/soils/interpreting-soil-tests/

1.1.1.2 Soil Organic Carbon Content

- **Code**: Lesvos_Soil02
- **Environmental Sector**: Soil / Soil Health
- **Units:** %C

Meaning and importance of the indicator

Soil organic carbon (SOC) constitutes about 58% of soil organic matter that is a chief indicator of soil health. SOC enters the soil through the decomposition of plant and animal residues, root exudates and living and dead soil biota (including microorganisms). Plant carbon comes from the C that plants remove from the atmosphere (photosynthesis), and animals obtain C from plant ingestion; therefore, the final origin of SOC is atmospheric CO_2. The stable fraction of SOC (the soil fraction that stays in soil for longtime periods and resists microbial attack) is considered "sequestered carbon" and contributes to climate change mitigation.

Expected evolution of the indicator

Increasing positive difference between %C in the soil of fertigated and control plots.

Data obtention

Required data: Organic carbon analysis in an expert lab.

Sampling plan:

Soil organic carbon analysis is already included in the analyses of soil physical and chemical fertility (Lesvos_Soil01). No additional sampling required.

Sampling calendar

This indicator will be produced every two years for a total of 10 years, coinciding with the evaluation of soil physical and chemical fertility (Lesvos_Soil01).

Equipment

See Lesvos_Soil01.

External subcontracting

The analysis is included the general analyses of soil physical and chemical fertility (Lesvos_Soil01)

References

- Blanco-Canqui, H., Shapiro, C. A., Wortmann, C. S., Drijber, R. A. et al. (2013). Soil organic carbon: The value to soil properties. *Journal of Soil and Water Conservation*, 68(5), 129A-134A.
- Bot, A., Benites, J. (2005). The importance of soil organic matter: Key to drought-resistant soil and sustained food production (No. 80). Food & Agriculture Org.

1.1.1.3 Soil Bulk Density (ρ)

- **Code:** Lesvos_Soil03
- **Environmental Sector:** Soil / Soil Health
- **Units:** g cm^{-3}

Meaning and importance of the indicator

Soil bulk density indicates the degree of soil compaction. Bulk density is inversely related to soil porosity which allows air and water to move through the soil and facilitates plant root penetration through the soil.

Expected evolution of the indicator

Bulk density is affected by soil texture (sand, silt, and clay proportion) and organic matter content. Fine-textured soils (such as silt and clay loams) with good structure have lower bulk density compared to sandy soils. According to data from the EU Joint Research Centre, mean European values for soil bulk density are 1.26 g cm^{-3} for arable lands, 1.23 g cm^{-3} for permanent crops, and 1.14 cm^{-3} for heterogeneous agricultural areas. Bulk density should increase as soil organic carbon increases in the fertigated plots.

Data obtention

Required data Field sampling followed by a very simple analysis.

Sampling plan: Soil will always be sampled at the same moment of the year, preferably a few days before the start of the maize harvest in the "second field", and in the same day for the two experimental fields.

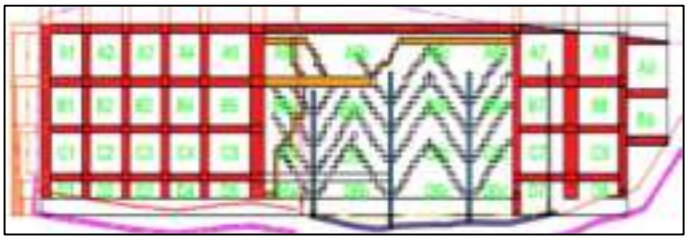

Figure 3

In the main field, at each sampling campaign, one sample will be taken from plots A5, B5, C5, A8, B8 and C8 with a metallic ring described in the "equipment" section.

In the second field, at each sampling campaign, one sample will be taken from each of the 8 plots with the same type of ring used for the main field.

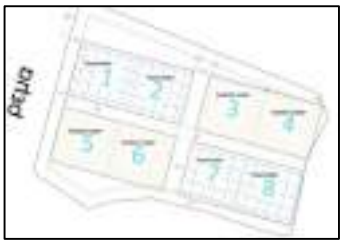

Figure 4

A detailed explanation of the sampling method is provided in the USDA Soil Quality Test Kit Guide (1999), pg. 9 (see references). In short, for each sample, drive the metal cylinder all the way into the ground until its upper edge is level with the surface of the ground (using a mallet and a block of wood). Remove the ring taking great care not to lose soil. To do so, dig around the ring and, with a trowel underneath it, carefully lift it out. Remove excess soil from the sample with a flat-bladed knife. The top and bottom of the soil sample should be flat and even with the edges of the ring. Using the flat-bladed knife, push out the entire soil sample into a plastic zip bag. Label the

bag correctly. Take the samples to the lab (or any other place where there is a scale – with two decimal places of accuracy- and a drying oven). Transfer each sample individually from the plastic bag to a foil or paper tray duly labelled. Let the soil samples to dry at 100 ºC until constant weight (usually 4 days is enough). Weight the dry soil (in g) and register it in your soil data worksheet. If a drying oven is not available, you can use a microwave (see the method in the USDA Soil Quality Test Kit Guide (in references)

Sampling calendar

Bulk density will be measured together with soil fertility (Lesvos_Soil01), every two years for ten years.

Equipment

Bulk density is the ratio between soil dry weight and soil volume. Therefore, soil samples will be taken with a stainless-steel cylinder of perfectly know volume. The recommended dimensions for this case are 10 cm deep and 8 cm in diameter. Additional field materials: a mallet, a block of wood, a trowel, a knife and zip-bags.

External subcontracting

If a reliable scale and a microwave are available, bulk density can be obtained very simply without the need of an expert lab.

Calculation formula

$$\rho = M / V$$

ρ is expressed as g cm^{-3}; M is the dry weight of the sample (in g), and V the volume of the soil cylinder (in cm^3). For each plot, calculate the average of the two density values.

References

- Soil Quality Indicators. Bulk Density. USDA Natural Resources Conservation Service https://www.nrcs.usda.gov/sites/default/files/2022-10/nrcs142p2_051591.pdf
- Soil Quality Test Kit Guide. USDA Natural Resources Conservation Service. 1999. https://efotg.sc.egov.usda.gov/references/public/WI/Soil_Quality_Test_Kit_Guide.pdf
- Walter, K., Don, A., Tiemeyer, B., Freibauer, A. (2016). Determining soil bulk density for carbon stock calculations: a systematic method comparison. *Soil Science Society of America Journal*, 80(3), 579-591.

1.1.1.4 Nematode Maturity Index (MI)

- **Code**: Lesvos_Soil04
- **Environmental Sector**: Soil / Soil Health
- **Units:** Number

Meaning and importance of the indicator

Nematodes are one of the most abundant and diverse groups of soil organisms. They account for four-fifths of all animals on land and play key roles in regulating soil microbial populations, with direct effects on the metabolism of organic matter, nutrient release and terrestrial carbon cycle. Nematodes are good indicators of biological soil activity. Nematode families can be classified into functional groups depending on trophic preferences (bacterivores, fungivores, plant feeders, predators and omnivores) and ecological strategy (within a continuum from colonizer -c- to persistent -p- behaviour). "Colonizer" nematodes show rapid increases of population under favourable conditions, short life cycle, and high capacity for colonization, and are tolerant to environmental disturbances. "Persistent" nematodes have low reproductive rates and long-life cycles, and low capacity for colonization, and are more sensitive to environment disturbances. Taxa within the same c-p class show similar responses to changes in soil environmental condition.

Expected evolution of the indicator

The Maturity Index is expected to increase in the fertigated plots by comparison with the control plots as soil resilience increases, which is related to increasing availability of mature organic matter and soil food web resilience. Possible soil pollution associated to incorrect quality of irrigation water will lead to decreasing values of the index in the fertigated plots.

Data obtention

Required data: Frequency of the families of soil nematodes included in the calculation of the Maturity Index for each soil sample.

Sampling plan:

Soil will always be sampled at the same moment of the year, corresponding with the sampling calendar for soil fertility assessment (Lesvos_Soil01), preferably a few days before the start of the maize harvest in the "second field", and in the same day for the two experimental fields. In the main field, at each sampling campaign, one sample will be taken from plots A5, B5, C5, A8, B8 and C8. In the second field, at each sampling campaign, one sample will be taken from each of the 8 plots. Soil cores will include the top 15 cm of the soil (after removing the vegetal residues from the ground surface) and will be taken with soil borers 15 cm long and 5 cm in diameter (see the "equipment" section). To avoid damage to soil nematodes by compaction during soil extrusion from the borer, we recommend the use of split soil core samplers. Each sample will be transferred to a zip bag duly labelled with the date and the name of the plot and will be carefully (avoid stacking the samples) conserved at 4 ºC until extraction. The samples will be sent to an expert lab for nematode extraction by the Baermann-funnel method that provides a reasonable compromise between simplicity and extraction efficiency. For extraction, 100 g of wet soil (weight it) will be used per sample. The nematodes can be collected in water and will be immediately fixed with hot formalin (10% dilution) for conservation until further classification to the taxonomic level proposed by Bongers and Bongers (1998).

20 g of soil from each sample will be put to dry at 100 ºC until constant weight (usually 4 days is enough). Weight the dry soil (in g) and register it in your soil data worksheet. Nematode data will be referred to 100 g of dry soil. Previous studies of the community of soil nematodes have already been performed in this study site at the request of the DEMO case managers. Nematodes extractions were done following Cobb's sieving and decanting method (see Van Bezooijen, 2006). For the sake of comparability of results with previous data, this method can be used instead of the Baermann funnel method.

Sampling calendar

This indicator will be produced every two years for a total of 10 years, coinciding with the evaluation of soil physical and chemical fertility (Lesvos_Soil01).

Equipment

See Lesvos_Soil01.

External subcontracting

Yes. An expert laboratory for nematode analysis must be hired.

Calculation formula

$$MI = \sum_{i=1}^{n} v(i) * f(i)$$

Where MI is the Maturity Index, *v (i)* is the cp value of taxon *i* (after Bongers 1998) in sample n, and *f (i)* is the frequency of taxon *i* in sample n

References

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1.1.1.5 Water Holding Capacity

- **Code**: Lesvos_Soil05
- **Environmental Sector**: Soil / Soil Health
- **Units:** %

Meaning and importance of the indicator

The water holding capacity (WHC) is an important agronomic characteristic. The WHC of a soil is the maximum amount of water a soil can hold under standard conditions. Water holding capacity is affected by soil texture (sand, silt, and clay proportion) and soil structure (pore size, porosity, pores connectivity distribution and characteristics are essential determinants). A soil with a limited WHC reaches sooner the saturation than a soil with a higher WHC, especially between sandy soils as they tend to have low water storage capacity.

Expected evolution of the indicator

Soil structure can be improved by adding organic matter content to stimulate the soil porosity, which increases the water holding capacity. Also, a better water holding capacity of the soil can be accomplished by increasing the soil organic carbon. However, deforestation and farming activities may decrease soil water holding capacity.

Data obtention

Required data: Field sampling followed by lab analyses (See Lesvos_Soil01).

Sampling plan:

Collect the sample using a soil core, air dry it, break the aggregates and pass through a 2.0 mm sieve. Place the core containing soil in a water tray for saturation overnight and then place the sample in an oven at 105º C for 24-48 h. Finally, weight the core sample. For further instructions go to the Practical manual on measurement of soil physical properties, on page 34.

Sampling calendar

This indicator will be produced every two years for a total of 10 years, coinciding with the evaluation of soil physical and chemical fertility (See Lesvos_Soil01).

Equipment

Additional field materials: A soil cylinder /core, a tray, filter papers, a spatula, a sieve, water try, a balance and a drying oven (See Lesvos_Soil01).

External subcontracting

If a reliable scale and an oven are available, WHC can be obtained very simply without the need of an expert lab. If not, a trustable lab delivering soil fertility analyses must be hired (See Lesvos_Soil01).

Calculation formula

$$WHC\ \% = (Vw/Vt) * 100$$

where Vw is volume of water and Vt, is total volume of saturated soil.

References

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1.1.1.6 Soil Respiration

- **Code**: Lesvos_Soil5
- **Environmental Sector**: Soil / Soil Health
- **Units:** µg $C\text{-}CO_2 * g^{-1}$ dry soil day^{-1}

Meaning and importance of the indicator

Soil respiration, also referred as soil basal respiration, is a measure of the metabolic activity of the soil microbial community. It reflects both soil microbial size and the pool of carbon that is readily available for microbial decomposition. Also, soil respiration rate allows for the estimation of nutrient cycling and the ability of the soil to sustain plant growth and biological activity. In a fact, soil respiration, can give information about the turnover of nutrients of the soil organic matter to forms available for plant uptake. Soil respiration is influenced by moisture, temperature, and land management, making it a useful indicator for assessing the impacts of these factors on soil quality.

Expected evolution of the indicator

Increasing positive difference between soil respiration in the soil of fertigated and control plots due to the priming effect on microbial activity.

Data obtention

Required data:

Soil respiration measurement in an expert lab.

Sampling plan:

Field sampling followed by lab analyses.

Sampling calendar

This indicator will be produced every two years for a total of 10 years, coinciding with the evaluation of soil physical and chemical fertility (Lesvos_Soil01).

Equipment

See Lesvos_Soil01.

External subcontracting

Yes. A trustable lab delivering soil respiration measurement must be hired.

References

Food and Agriculture Organization of the United Nations. (2024). Standard operating procedure for soil respiration rate. https://openknowledge.fao.org/server/api/core/bitstreams/e9f3525e-d101-4fee-9330-ba166eafa90d/content

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1.1.1.7 Food Production (FP)

- **Code**: Lesvos_Soil07
- **Environmental Sector**: Soil / Soil Fertility
- **Units:** T $ha^{-1}y^{-1}$

Meaning and importance of the indicator

Reusing wastewater for crop irrigation is an important subject worldwide, particularly in world zones where climate change is exacerbating water scarcity, limiting crop production and compromising food security. Irrigating crops with reused municipal water properly treated to guarantee human safety may have multiple environmental benefits, including groundwater recharge, freshwater saving and increasing crop yield due to fertilization by nutrients remaining in reclaimed water.

Expected evolution of the indicator

Positive difference between fertigated and control plots irrigated with tap water should increase over time.

Data obtention

Sampling plan: Maize and barley grains will be weighted in the second field of the demonstrator site at the time of harvesting, and maize, barley and total combined production will be registered at the end of the agricultural year. Weighting will be done for plots 3, 4, 5, 6 (treatment, fertigated plots), and 1, 2, 7 and 8 (control plots irrigated with tap water). Since all 8 plots are usually harvested at the end of the growing season, total production per plot will be registered. The harvested area must be also registered at each plot.

Sampling calendar

Grain yield (maize, barley and maize + barley) will be registered at the end of the agricultural season every year for ten years.

Equipment

Agricultural equipment for harvesting and weighting. The managers of the DEMO site have been measuring plant production since the implementation of the experience. They can keep using the same equipment.

External subcontracting

Not needed if internal technical resources are available.

Calculation formula

For each plot, total annual maize grain production and barley grain and total annual barley grain production will be expressed in t $ha^{-1}y^{-1}$.

References

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1.1.2 Water Indicators

1.1.2.1 Water Monitoring Plan

Sampling points

A Sustainable Circular System Promoting Wastewater Valorization through NBS.

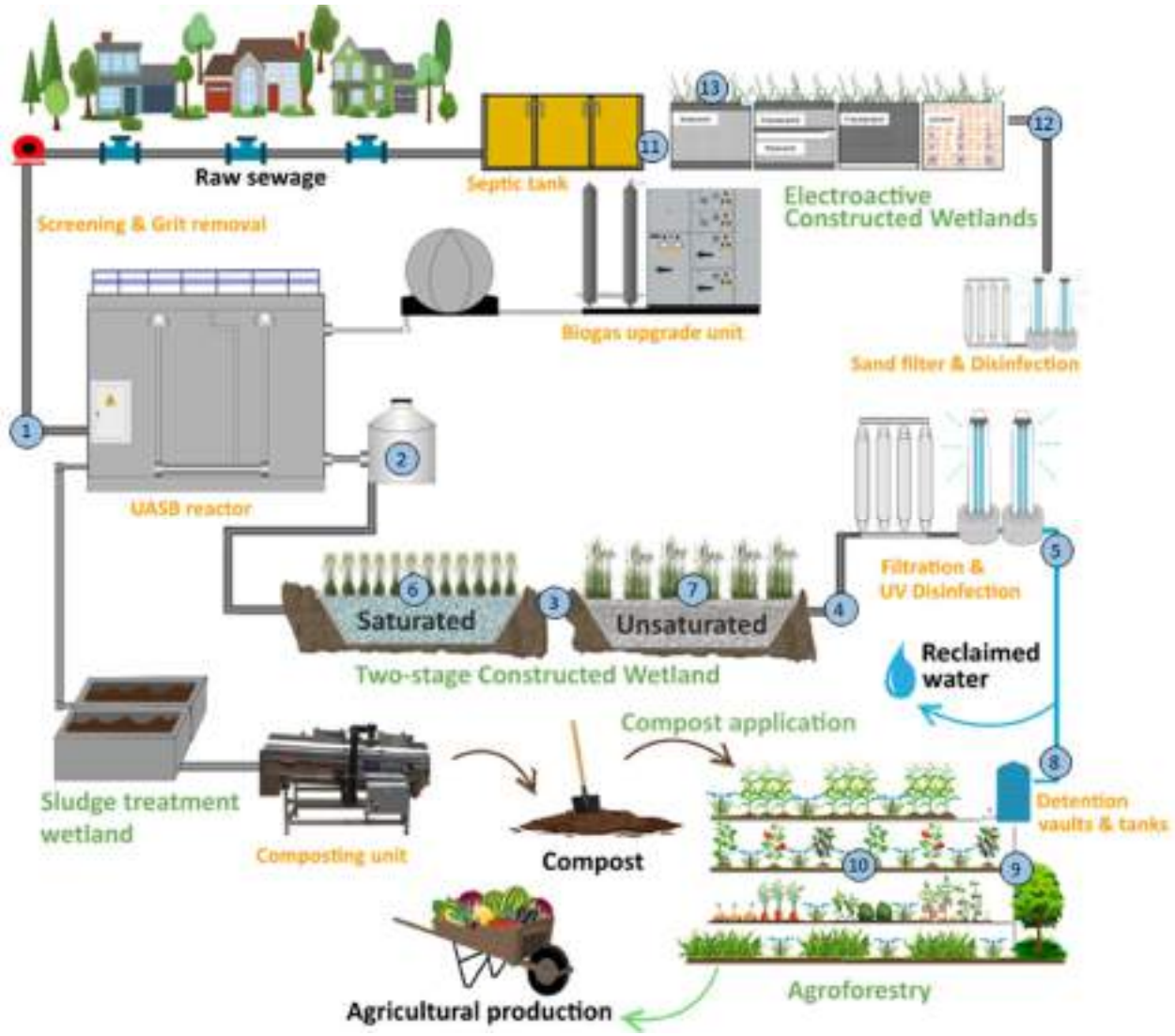

Figure 5

Sampling point	Location	Purpose
SP-01	Inlet of treatment system (before pretreatment and UASB reactor)	Monitor wastewater to be treated (efficiency of the whole treatment)
SP-02	Inlet of vertical flow constructed wetlands	Monitor UASB/constructed wetland efficiency
SP-03	Outlet of the saturated vertical flow	Monitor constructed wetland efficiency

	constructed wetland	
SP-04	Outlet of the unsaturated vertical flow constructed wetland	Monitor constructed wetland efficiency
SP-05	Outlet of the main line treatment system (after filtration and UV disinfection)	Monitor reclaimed water quality and availability (efficiency of the whole treatment, nutrient content and volume)
SP-06	Middle of the surface of the saturated vertical flow constructed wetland	Monitor evapotranspiration
SP-07	Middle of the surface of the unsaturated vertical flow constructed wetland	Monitor evapotranspiration
SP-08	Reclaimed water pipe to the irrigation tank (after stream disposal and before the tank)	Monitor reclaimed water availability for irrigation (volume)
SP-09	Main connection to agroforestry irrigation (i.e. outlet of the irrigation tank)	Monitor total volume of water used for irrigation (reclaimed and tap water)
SP-10	Agroforestry field soil	Monitor evapotranspiration
SP-11	Inlet of electroactive constructed wetlands	Monitor constructed wetland efficiency
SP-12	Outlet of electroactive constructed wetlands	Monitor constructed wetland efficiency
SP-13	Middle of the surface of the electroactive wetland (if it's saturated)	Monitor evapotranspiration

Parameters to be analyzed

Parameter	Applicable Sampling Point	Related indicators	Type
Volume of treated wastewater (WW)	SP-01, SP-08	WWTeff; RWP; WA	water flow measurements [volume/time]
Volume of reclaimed water produced	SP-08	RWP; WA; WFP (WFN and ISO)	water flow measurements [volume/time]
Volume of reclaimed water used for irrigation	SP-09	RWnpU, WSC	water flow measurements [volume/time]
Total volume of water used for agroforestry irrigation (reclaimed water and tap water)	SP-09	RWnpU	water flow measurements [volume/time]

Water withdrawal for irrigation (tap water, surface water, groundwater, etc.)	SP-09	AWW; WFP (WFN and ISO)	water flow measurements [volume/time]
Water quality parameters: -Nitrogen content (TN, NO_3 or NH_3) depending on the fertilizer it would replace and its N content. -Total phosphorus (TP) content	SP-01, SP-02, SP-03, SP-04, SP11, SP-12	WR; WFP (WFN and ISO)	water quality parameters
Water quality parameters: Conductivity, COD, BOD_5, TSS, TN, TP, TOC, Temperature, turbidity, E. coli	SP-01, SP-02, SP-03, SP-04, SP11, SP-12	CtotalRW; EPR; WFP (WFN and ISO)	water quality parameters
Amount of water that is lost by evapotranspiration over a period	SP-06, SP-07, SP-10, SP-13	ETrate; WFP (WFN and ISO)	water depth variation [mm]

Sampling method

Water flow measurements:

Direct measurement of volume provided during a time period or water flow with flow meters and/or water level sensors.

a) Automatic method (main treatment line)

Automatic flow meters can be installed at the recommended sampling points (SP). For the automatization process, it is recommended to register the measurements with a datalogger/digital control system in the DEMO. It is recommended to measure the flow at the recommended sampling points (SP).

Data should be stored in a datalogger/digital control system and then be able to be exported in a spreadsheet to calculate the associated indicators. When this is not possible, manual readings of the flow meters can be done instead.

b) Manual method (electroactive pilot CWs line)

This could be applied as the last option if there is no possibility to apply the automatic method.

- Periodic manual measurements
- If no devices are available to measure, correct and reliable estimates must be made to assess the indicator.
- Measure the volume at the point of reuse or approximate the value based on the amount of water demand met by agroforestry for reuse.

Water quality parameters:

Automatic measurement methods (a) or manual sampling campaigns (water sampling + laboratory analysis) (b) can be employed, with specific requirements for different types of pollutants.

a) Automatic method

Advanced sensors of water quality can be installed in the recommended sampling points (SP) to continuously monitor and measure various water quality parameters, such as temperature, pH, turbidity, dissolved oxygen, NO_3, etc. These sensors collect data in real-time, providing continuous and accurate information about water quality. The data is often transmitted wirelessly to a central database, or sensors can be also connected to a datalogger. The data is often transmitted wirelessly to a central database, or sensors can be also connected to a datalogger.

b) Manual method

As the DEMO is already implemented, mature and operating, sampling campaigns will be carried out periodically to control the operation and performance of the treatment system. Samples will be collected at the recommended

sampling points (SP). Two types of water quality analysis have been defined: **basic** and **complete**. Basic analysis will include all water quality parameters that are required to be monitored by legislation for reclaimed water reuse for irrigation: turbidity, COD/BOD_5, E. coli, TSS (other if required by legislation). Complete analysis includes other water quality parameters for general monitoring and indicators' assessment: conductivity, TN, TP, TOC, temperature, NO_3 and/or NH_3. Samples can be obtained manually or using automatic sampling equipment. An automatic sampler is a device that can be refrigerated or non-refrigerated and include automatic sampling pumps and upward stage samplers. The process involves collecting water samples intended for laboratory analysis of water quality parameters. However, there are limitations associated with automatic sampling, such as intermediate sampling containers, sampling from a fixed point, and sample storage and preservation, which must be considered and documented. Personnel using these methods should have training and prior experience in the use and calibration of automatic sampling equipment. The laboratory analysis is done following current ISO laboratory protocols for each different parameter.

Water depth variation:

The variation in the water content of the wetlands and the soil can be done manually or through automatic methods.

a) Automatic method

For the constructed wetlands: Water level sensors, weather stations, remote sensing through hydrological models.
For the agroforestry soil: weather stations, sensors, remote sensing through hydrological models.

b) Manual method

For the constructed wetlands: direct water level measurements in a period of time. Measure water depth of the wetland at the initial time and after a period of time (e.g. minutes, hours, 1 day, etc.)
For the agroforestry soil: field direct measurements using lysimeters or scintillometers.

Sampling calendar

Water flow measurements and water depth variation:

Data should be collected frequently for a relevant time period (e.g., daily, weekly, monthly) to allow for accumulation over the entire reporting period (yearly). This high frequency is also relevant to study seasonal variations.

Water quality parameters:

During the operation, the recommended frequency of water quality analysis is 1 basic analysis per week (as reclaimed water is being used in agroforestry) and 1 complete analysis per month.

Equipment

a) Water flow measurements:

Water flow meters are essential tools for monitoring and assessing the efficiency of these systems, as they provide real-time data on water movement and usage through the treatment processes and the different pipes, helping to determine the volume of water at those particular locations. Some providers of these water flow meters are:

- Endress+Hauser
- Systec Controls
- Aobo instrument

Any equivalent water flow meter is acceptable, these are given as examples.

b) Water quality parameters:

The automatic sampling method requires simple or multiparametric sensors for water quality and data loggers or digital control systems for data recording. It also requires personnel for data collection and treatment. The manual sampling campaign requires laboratory and field personnel for manual sampling and analysis and also reagents and laboratory material depending on the current ISO laboratory protocols for each parameter. Some indicative providers for water quality parameters are but not limited to:

- ANISE sensor (NH_4 and NO_3) - Hach

- Conductivity meter - METTLER TOLEDO
- pH meter - METTLER TOLEDO
- Multi-parameter water quality analyser (temperature, pH, conductivity, DO, turbidity, BOD, COD, ammonia nitrogen, NO_3, colour, chloride, depth, etc.) - BOQU instruments

Any equivalent water level sensor is acceptable, this is given as an example.

c) Water depth variation:

Some providers are:

- Lysimeter - Royal Eijkelkamp ; MundoRiego
- Sensor - LI-COR
- Scintillometer - SCINTEC
- Water level sensor - ATMI

External subcontracting

Yes. A trustable laboratory delivering water quality analyses must be hired if not available internally.

1.1.2.2 Effective Wastewater Treatment (WWTEFF)

- **Code**: Lesvos_Water01
- **Environmental Sector:** Water / Safeguarded Water Ecosystems
- **Units:** %

Meaning and importance of the indicator

The indicator measures the percentage of wastewater that is treated in compliance with legal and regulatory standards out of the total volume of wastewater treated. Includes the wastewater treatment coverage and volumetric efficiency. The concept is based on having an overview of the share of customers that is connected to the public wastewater system or is having a local legal treatment system in place. Based on population data, the share of total generated wastewater that is being treated can then be estimated. This indicator is used to have an overview of how much wastewater is generated in an area and it's important because untreated wastewater or not complying treated wastewater will have a negative impact on ecosystems in all kinds of water bodies.

Expected evolution of the indicator

The range is from 0 to 100%, the optimal value for the WWTeff indicator is ideally 100%, indicating that all treated wastewater meets or exceeds legal standards. However, achieving and maintaining values above 90-95% is considered very good and indicative of a highly effective wastewater treatment system.

Possible relationship with other indicators

Water quality compliance: biological, physical and chemical parameters, Reclaimed Water in non-potable Uses.

Data obtention

Sampling plan:

- Volume of treated wastewater complying with legal requirements (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO. Only data that complies with legal requirements will be selected.
- Volume of wastewater generated and treated in the DEMO (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.

Calculation formula

$$WWTeff = \frac{V_{Treatment}}{WW} \cdot 100$$

Where:

- WWTeff: Effective wastewater treatment (%),
- $V_{Treatment}$: Volume of treated wastewater complying with legal requirements (m^3/year),
- WW: Volume of treated wastewater (m^3/year).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- European Commission, Directorate-General for Research and Innovation (2021). Evaluating the impact of nature-based solutions: A handbook for practitioners. Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577
- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

1.1.2.3 Reclaimed Water in non-potable Uses (RWnpU)

- **Code**: Lesvos_Water02
- **Environmental Sector:** Water / Water Resource Recovery and Use
- **Units**: %

Meaning and importance of the indicator

The indicator measures the proportion of reclaimed water (from treated wastewater, rainwater, urban runoff, etc.) used in non-potable applications where previously drinking or freshwater was used. It is related to the total volume of water used for those purposes. This indicator provides valuable insight into the sustainable use of water resources by quantifying the extent to which reclaimed water is used for non-potable purposes.

Expected evolution of the indicator

The optimal value for the RWnpU indicator is as close to 100% as possible, indicating that the majority of non-potable water needs are met with reclaimed water, minimizing the demand for freshwater.

Possible relationship with other water indicators

Compliant reclaimed water, Water availability, Reclaimed water production, Water provision by the ecosystem.

Data obtention

Sampling plan:

- Volume of reclaimed water used for non-potable uses (e.g., irrigation, street cleaning, groundwater recharge) (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total volume of water used for non-potable uses, from all sources, including freshwater and reclaimed water (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.

Calculation formula

$$RWnpU = \frac{RW}{npW} \cdot 100$$

Where:

- RWnpU: Reclaimed Water in non-potable Uses (%),
- RW: Volume of reclaimed water used for non-potable uses (e.g., irrigation, street cleaning, groundwater recharge) (m^3/year),
- npW: Total volume of water used for non-potable uses, from all sources, including freshwater and reclaimed water (m^3/year).

Note: “used” may be “supplied” or “consumed” but must be consistent in RW and npW.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

1.1.2.4 Reclaimed Water Production (RWP)

- **Code**: Lesvos_Water03
- **Environmental Sector:** Water / Water Resource Recovery and Use
- **Units:** %

Meaning and importance of the indicator

The indicator measures the volume of reclaimed water produced, either for internal use or transfer to third parties, as a percentage of the total volume of treated wastewater, etc. This indicator aims to assess the level of environmental sustainability of the service in terms of circularity and the resources recovery, regarding the production of reclaimed water, obtained from the wastewater treatment. Reclaimed water means urban wastewater that has been treated in compliance with the requirements set out in Directive 91/271/EEC and which results from further treatment in a reclamation facility (EU Regulation 2020/741). However, based on further assessments, the approach to reclaimed water may need adjustment, particularly if the indicator for reclaimed water also includes treated rainwater or water from other sources. So, in this context, reclaimed water can also be considered treated water from other sources (i.e. rainwater/stormwater, greywater, etc.) which is suitable for its reuse.

Expected evolution of the indicator

The optimal value for the RWP indicator is as high as possible, ideally close to 100%, which would indicate that almost all treated wastewater (or other treated water sources) is further processed to produce reclaimed water. This contributes to more sustainable water management practices and to reduce the dependency on freshwater sources.

Possible relationship with other water indicators

Compliant reclaimed water, Water availability, Reclaimed water in non-potable uses, Effluent pollutant removal, Water footprint.

Data obtention

Required data:

- Volume of reclaimed water produced under the responsibility of the utility, and which is transferred to other entities for use or for its own uses (exclude the recirculation or recycling of water, when it occurs in a closed circuit within one or more processes) (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO. Only data that complies with reclaimed water suitable for its reuse will be selected.
- Volume of wastewater treated or treated water from other sources (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.

Calculation formula

$$RWP = \frac{V_{reclaimed}}{TWW} \cdot 100$$

Where:

- RWP: Reclaimed Water Production (%),
- $V_{reclaimed}$: Volume of reclaimed water produced under the responsibility of the utility, and which is transferred to other entities for use or for its own uses (exclude the recirculation or recycling of water, when it occurs in a closed circuit within one or more processes) (m^3/year),
- TWW: Volume of wastewater treated or treated water from other sources (if apply) (m^3/year).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

1.1.2.5 Water-Related Materials' Recovery (WR)

- **Code:** Lesvos_Water04
- **Environmental Sector:** Water / Water Resource Recovery and Use
- **Units:** %

Meaning and importance of the indicator

The indicator is defined as the percentage of a by-product* material or waste that is recovered and suitable for reuse after a treatment process or activity* to improve other activities within the same DEMO or other external sites (i.e. drinking water plant, wastewater treatment plant, industry, agroforestry, etc). **By-product*: a secondary product produced in the manufacturing, treatment or synthesis of something else. Some examples may be: nitrogen and phosphorus recovery for its reuse as biofertilizer, sludge recovery from wastewater as compost, harvested microalgal biomass as fertilizer, organic biomass from aquaculture as fertilizer and saturated filter media or adsorption materials for water filtration, purification of aqueous or gaseous mediums, and retention of contaminants. *Treatment process or activity*: the main infrastructure or technology where the DEMO or an external organization performs its main activities. If more than one waste stream is recovered, a weighting factor can be applied to obtain a single total indicator.

Expected evolution of the indicator

The optimal value is ideally close to 100%. A higher percentage indicates that more materials are being recovered, which suggests greater resource efficiency and reduced environmental impact.

Possible relationship with other water indicators

Reclaimed water production, Water footprint.

Data obtention

Sampling plan:

- Material recovered from the treatment process or activity and considered suitable for reuse (kg/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total potential recoverable material entering the treatment process or activity (kg/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.

Calculation formula

$$WR = \frac{W_{i,re}}{W_{i,in}} \cdot 100$$

Where:

- WR: Water-related materials' Recovery (%),
- $W_{i,re}$: Material recovered from the treatment process or activity and considered suitable for reuse (kg/year),
- $W_{i,in}$: Total potential recoverable material entering the treatment process or activity (including materials that are added and recovered during the process) (kg/year).

Note: some examples of recoverable material are: nitrogen and phosphorus for its reuse as biofertilizer, sludge from wastewater as compost, harvested microalgal biomass as fertilizer, organic biomass from aquaculture as fertilizer.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/
- European Union (2022). PLATFORM ON SUSTAINABLE FINANCE: TECHNICAL WORKING GROUP: PART B – Annex: Technical Screening Criteria. PLATFORM ON SUSTAINABLE FINANCE. https://finance.ec.europa.eu/system/files/2022-03/220330-sustainable-finance-platform-finance-report-remaining-environmental-objectives-taxonomy-annex_en.pdf
- OECD. The OECD Inventory of Circular Economy indicators, Retrieved September 13, 2024, from https://www.oecd.org/cfe/cities/InventoryCircularEconomyIndicators.pdf

1.1.2.6 Water Provision by The Ecosystem (Wavailable)

- **Code:** Lesvos_Water05
- **Environmental Sector:** Water / Freshwater Supply / Resource Efficiency
- **Units:** %

Meaning and importance of the indicator

The indicator measures the percentage of water available in the ecosystem for abstraction in the current year compared to the previous one. This indicator is important for understanding the sustainability of water resources over time and the ecosystem's ability to replenish and maintain water availability. This is a context indicator. Ecosystem is understood as a natural unit comprising living organisms and their physical environment, interacting as a system. In this way, it can include several scales related to the water sector. For example, hydrological basin, aquatic ecosystem, influencing area of the DEMO, municipality, riparian zone, wetland ecosystem, etc.). The indicator measures the development of water provision by the ecosystem. The underlying concept is the ecosystem service theory, manifested in specific ecosystem services selectable from CICES (EEA, 2018). Here, so-called provisioning ecosystem services are beneficial for human well-being. For water related regulating ecosystem services especially the ecosystem service from water provisioning for several usages is important (water for potable and non-potable uses, water for hydroelectricity, etc.).

Expected evolution of the indicator

The baseline for this indicator is the initial water available capacity, which may be 0% if there is no initial water availability in the ecosystem. A stable or increasing percentage would indicate a healthy ecosystem with sustainable water resources, while a decreasing value may signal over-extraction or ecosystem degradation.

Possible relationship with other water indicators

Water availability, Water footprint.

Data obtention

Sampling plan:

- Volume of water available for abstraction from the ecosystem during the current year (m^3/year) Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data.
- Volume of water available for abstraction from the ecosystem in the previous year (m^3/year) Cumulative values during the previous year to the current one will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data.

Data sources

Existing information on water use and abstraction per year, local GIS data or estimations/simulations with relation to ecosystem related protection (water retention in the area, water sources and volumes, etc.)

Calculation formula

$$W_{Available} = \left(\frac{W_t}{W_{t-1}}\right) \cdot 100$$

Where:

- $W_{Available}$: Water provision by the ecosystem (%),
- W_t: Water available for abstraction from the ecosystem in the year (m^3/year),
- W_{t-1}: Water available for abstraction from the ecosystem in the previous year (m^3/year).

Note: A scope for the "ecosystem" must be defined previously. The ecosystem can be the same hydrological basin or aquatic ecosystem where the DEMO activity takes place, the influencing area of the DEMO, the municipality, etc.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/
- EEA (2018). CICES V5.1, 18/03/2018. https://cices.eu/resources/
- Net surface water availability: European Commission, Directorate-General for Research and Innovation (2021). Evaluating the impact of nature-based solutions: a handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577

1.1.2.7 Water Availability (WA)

- **Code**: Lesvos_Water06
- **Environmental Sector:** Water / Freshwater Supply / Resource Efficiency
- **Units:** m^3/year

Meaning and importance of the indicator

The indicator refers to the volume of water available provided by the DEMO for its reuse in various applications (e.g. aquifer recharge, ecosystem restoration, on site reuse, irrigation, industrial activities, etc.). The water available should comply with quality standards required for different reuses as per current legislation.

Expected evolution of the indicator

The baseline for this indicator is the initial water availability capacity, which may start at 0 m^3/year. It is expected to increase over time once the DEMO is operating and optimized, reflecting an improvement in water availability for reuse and ecosystem services. Ensure that 100% of the water provided by the DEMO is available for reuse.

Possible relationship with other water indicators

Water footprint, Water provision by the ecosystem.

Data obtention

Sampling plan:

- Direct annual flow of the effluent or annual volume provided by the DEMO for specific purposes (e.g., aquifer recharge, ecosystem restoration, etc.) (m^3/year).
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total volume water available in the DEMO (WA) (m^3/year).

Calculation formula

$$WA = Water\ inflows\ (WI) - Water\ losses\ (WL)$$

Where:

- **WI:** Total water entering the DEMO system (e.g., precipitation, surface water, groundwater recharge, recycled water) (m^3)
- **WL:** Total water lost (due to evaporation … (m^3))

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

- United Nations Conference on Trade and Development (2023). Environmental indicators: Module B Core SDG Indicators for Entity Reporting Training Manual. https://unctad.org/system/files/information-document/UNCTAD_GCI_MANUAL_ENVIRONMENTAL-FINAL.pdf
- URBAN GreenUP (2019). D5. 3: City diagnosis and monitoring procedures. https://www.urbangreenup.eu/kdocs/1912498/urban_greenup_d5_3_city_diagnosis_and_monitoring_procedures.pdf
- U.S. Environmental Protection Agency (2024). Basic information about water reuse. https://www.epa.gov/waterreuse/basic-information-about-water-reuse

1.1.2.8 Water Footprint (WFP)

- **Code**: Lesvos_Water07
- **Environmental Sector:** Water / Water Resource Efficiency
- **Units:** m^3/m^3

Meaning and importance of the indicator

The Water Footprint (WFP) is a global indicator of freshwater resource appropriation, defined by the Water Footprint Network (WFN). It encompasses three types of water usage:

- Green water footprint: Associated with rainwater absorbed by vegetation.
- Blue water footprint: Relates to the consumption of surface and groundwater.
- Grey water footprint: Refers to the volume of freshwater required to assimilate pollutants, reflecting water contamination.

In various sectors, water footprint is mainly observed during production (blue water), contamination from chemicals (grey water), and raw material production (green, blue, and grey water). The water footprint of a product, process, or organization represents both direct and indirect water use. Direct water use refers to the water consumed and/or contaminated during production, including water incorporated in the final product. Indirect water use, on the other hand, includes water consumed for producing raw materials throughout the supply chain. For the consumption of $1m^3$ of drinking water or the treatment of $1m^3$ of wastewater, the WF accounts for both directly used water, such as that involved in production or treatment, and indirectly used water, which pertains to the water used in creating the systems, products, and processes supporting the production or treatment. Moreover, NBS can contribute by providing water for reuse, such as for aquifer recharge, surface discharge, ecosystem restoration, or onsite reuse, further shaping the water footprint.

Expected evolution of the indicator

The expected evolution of the WF indicator, as defined by the WFN, is geared towards refining and optimizing the assessment of freshwater use and its associated impacts. As methodologies and data collection techniques advance, more precise and comprehensive value ranges are anticipated to be established, aiding in better benchmarking and management practices. There will be a growing emphasis on reducing both direct and indirect water usage through improved efficiency and sustainability measures.

Possible relationship with other water indicators

Water Footprint (ISO), Water quality compliance: biological, physical and chemical parameters.

Data obtention

Sampling plan:

To assess the water footprint of a utility, the following data must be collected:

Drinking Water Production:

1. Direct water usage: The total water used by the utility to produce 1 m^3 of drinking water. This includes water used in the treatment plant, for network operation, and water lost through leakages.

2. Indirect water usage: Water used in producing resources and products necessary for drinking water production, such as:
    - Electricity and energy for treatment and distribution (pumping)
    - Chemicals for treatment
    - Equipment for treatment and distribution (e.g., pipes, pumps, valves)

Data is typically collected annually or more frequently through metering systems.

Wastewater Treatment and Reclamation:

1. Direct water usage: Total water used for collecting and treating 1 m^3 of wastewater and reclaimed water, including water used in the treatment plants and for network operation, and water lost through leakages.
2. Indirect water usage: Water used in producing resources for wastewater treatment, such as:
    - Electricity and energy for treatment and distribution (pumping)
    - Chemicals for treatment
    - Equipment for treatment and distribution

Additional Data:

- Conductivity, COD, TSS, TN, TP
- Temp; consumables (e.g. caustic soda, disinfectant, etc.);
- Energy consumption (GoO or not)
- Volume wastewater treated.

Calculation formula

$$WFPdw = \frac{WFdw}{DWP} \; or \; WFPww = \frac{WFww}{TWW}$$

Where:

- WFdw (Water footprint in the drinking water system) and WFWW (Water footprint in the wastewater system): should be collected for every process and product that is being used in the system (this includes water used in the whole of the treatment plant, water used for operation of the network, and water which is lost through leakages in the drinking water network) through a period of time (e.g., year) (m^3/year),
- DWP: Annual drinking water production; used for drinking water systems (m^3/year),
- TWW: Volume of wastewater treated; used for wastewater systems (m^3/year).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting, and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- Alegre, H., Baptista, J.M., Cabrera, E., Cubillo, F., Duarte, Hirner, W., Parena, R. (2016). Performance Indicators for Water Supply Services: Third Edition. IWA Publishing, Volume 15. DOI: https://doi.org/10.2166/9781780406336.

- Romeiko, X. X. (2019). Comprehensive water footprint assessment of conventional and four alternative resource recovery-based wastewater service options. Resources, Conservation and Recycling, 151, 104458. DOI: https://doi.org/10.1016/j.resconrec.2019.104458
- Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M. & Mekonnen, M.M. (2011) The water footprint assessment manual: Setting the global standard, Earthscan, London, UK. https://waterfootprint.org/en/resources/publications/water-footprint-assessment-manual/
- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

1.1.2.9 Water Footprint (ISO)

- **Code**: Lesvos_Water08
- **Environmental Sector:** Water / Water Resource Efficiency
- **Units:** m^3/ m^3

Meaning and importance of the indicator

The Water Footprint (WF), as defined by the ISO 14046 standard, is an indicator that quantifies the potential environmental impacts associated with the water use of a product, process, or organization. This standard adopts a Life Cycle Assessment (LCA) approach to evaluate both direct and indirect water use.

Key aspects of water footprint according to ISO 14046 include:

- Consumptive use: Refers to freshwater that is abstracted and either evaporates, is incorporated into products, or is returned to a different watershed or the sea after use.
- Degradative use: Involves the deterioration in water quality when the water is returned to the same basin from which it was abstracted.

The water footprint methodology evaluates the impact of water use both in terms of quantity (consumed or contaminated) and quality (degradation or restoration). It considers all inputs and outputs of water throughout the life cycle of the product, process, or organization.

Additionally, water footprint studies must consider direct water use, which refers to the amount of water used during production or treatment (e.g., drinking water, wastewater treatment), and indirect water use, which includes the water required for the production of resources (e.g., energy, chemicals, equipment) utilized in the process. Overall, the ISO 14046 standard provides a detailed framework for assessing both the quantity and the quality impacts of water use in a more comprehensive manner than traditional water footprint methodologies.

Expected evolution of the indicator

The focus will be on minimizing both consumptive and degradative water use, with an emphasis on sustainable water management and reducing the overall environmental impact. This evolution will ensure that the WF indicator becomes increasingly effective in guiding resource efficiency and mitigating water-related environmental impacts.

Possible relationship with other water indicators

Water Footprint (WFN), Water quality compliance: biological, physical and chemical parameters.

Data obtention

Sampling plan:

To assess the water footprint according to ISO 14046, the following data should be collected:

Drinking Water Production:

1. Direct water usage: The total water consumed directly by the utility for producing 1 m^3 of drinking water. This includes:
    - Water used in the entire treatment process
    - Water used for network operation (e.g., pumping)
    - Water lost through leakages in the drinking water network

2. Indirect water usage: Water required for producing the resources and materials used in drinking water production. This includes:
   - Energy consumption: Electricity and energy used in treatment and distribution processes
   - Chemicals: Used in water treatment processes
   - Infrastructure and equipment: Pipes, pumps, valves, and other treatment and distribution systems used in water production

Wastewater Treatment and Reclamation:

1. Direct water usage: The total water used for the collection, treatment, and reclamation of 1 m^3 of wastewater. This includes:
   - Water used in the treatment and reclamation facilities
   - Water used for network operations, including leakages in the reclaimed water network
2. Indirect water usage: Water used in the production of resources necessary for wastewater treatment and reclamation, such as:
   - Energy consumption: Electricity for treatment and distribution networks
   - Chemicals: Used in the wastewater treatment process
   - Equipment and infrastructure: Pipes, pumps, valves, and other materials involved in wastewater collection and treatment

Additional Environmental Impact Data:

- Raw materials and their origin; Conductivity, COD, TSS, TN, TP;
- Temp; consumables (e.g. caustic soda, disinfectant, etc.);
- Energy consumption (GoO or not);
- Volume wastewater treated or reclaimed.

Calculation formula

$$WFPdw = \frac{WFdw}{DWP} \; or \; WFPww = \frac{WFww}{TWW}$$

Where:

- WFdw (Water footprint in the drinking water system) and WFWW (Water footprint in the wastewater system): should be collected for every process and product that is being used in the system (this includes water used in the whole of the treatment plant, water used for operation of the network, and water which is lost through leakages in the drinking water network) through a period of time (e.g., year) (m^3/year),
- DWP: Annual drinking water production; used for drinking water systems (m^3/year),
- TWW: Volume of wastewater treated; used for wastewater systems (m^3/year).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- ISO 14046:2014(en). Environmental management — Water footprint — Principles, requirements and guidelines.
- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

1.1.2.10 Agricultural Water Withdrawal (AWW)

- **Code**: Lesvos_Water09
- **Environmental Sector:** Water / Water Consumption
- **Units:** %

Meaning and importance of the indicator

The Agricultural Water Withdrawal (AWW) indicator assesses the volume of freshwater or groundwater withdrawn and used by the agricultural sector as a percentage of the total water withdrawn for all purposes (agricultural, municipal, industrial, etc.). This indicator helps to understand the water-food relationship within the food-energy-water nexus, as agriculture is a major consumer of water resources. It provides insights into the sustainability of agricultural practices and helps identify trends in water use that could impact food security and water availability, particularly in arid and semi-arid regions. The AWW indicator is essential for evaluating the pressure exerted on water resources by agricultural activities and for guiding policies aimed at improving water use efficiency in agriculture.

Expected evolution of the indicator

Ideally, the percentage of water withdrawal for agriculture should decrease or stabilize as more efficient irrigation practices are adopted, and alternative water sources (e.g., reclaimed water) are utilized. If it's taken into account the possibility of using reclaimed water for irrigation, the 0% corresponds to the best expected value, since a decrease or zero consumption of freshwater and groundwater (i.e. drinking water) for agriculture would be the ideal case.

Possible relationship with other indicators

Water footprint.

Data obtention

Sampling plan:

- Agricultural water withdrawal (m^3/year)
    - Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total water withdrawal for all sectors (agricultural, municipal, industrial, etc.) (m^3/year)
    - Total water demand for all water uses in a year. This is a context value that can be obtained from water management authorities or companies, municipal reports, etc.

Calculation formula

$$AWW = \frac{Agricultural\ water\ withdrawal}{Total\ water\ withdrawal} \cdot 100$$

Where:

- AWW: Agricultural Water Withdrawal ratio (%),
- Agricultural water withdrawal: The total volume of water extracted and used for irrigation and other agricultural activities (m^3/year),

- Total water withdrawal: The sum of total water withdrawn for different uses, including agricultural, municipal, industrial, etc. (m^3/year).

References

- Nature4Cities project (2016). Nature Based Solutions for Re-naturing Cities: knowledge diffusion and decision support platform through new collaborative models. European Union's Horizon 2020 Research and Innovation programme. https://docs.wixstatic.com/ugd/55d29d_3b17947e40034c168796bfc9a9117109.pdf
- European Commission, Directorate-General for Research and Innovation (2021). Evaluating the impact of nature-based solutions: A handbook for practitioners. Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577

1.1.2.11 Water Storage Capacity (WSC)

- **Code**: Lesvos_Water10
- **Environmental Sector:** Water / Effectiveness of The Adaptive Change Towards Resilient Infrastructure
- **Units:** days

Meaning and importance of the indicator

The indicator assesses the resilience and efficiency of water supply systems. It is defined as the ratio between the total volume of available storage (e.g., water supply tanks, reservoirs for rainwater harvesting, and reclaimed water storage) and the average flow rate either provided to or demanded by the system. This flow rate encompasses all demands associated with distribution systems, rainwater harvesting infrastructure, and treatment facilities. The indicator provides insightful information about the number of days that the system can handle relying on the potential stored volume of water, not on the actual volume of stored water.

Expected evolution of the indicator

The WSC indicator will vary by region, depending on local water availability, climate conditions, and demand patterns in the DEMO. The optimal value is context-specific, but generally, a higher WSC indicates a more resilient water supply system capable of withstanding longer periods without external water inputs. However, as water supply systems integrate more non-conventional water sources (e.g., rainwater harvesting, reclaimed water, etc.), the WSC is expected to increase, improving the system's sustainability and resilience.

Possible relationship with other water indicators

Water availability, Captured runoff.

Data obtention

Sampling plan:

- Total operational volume of storage capacity, such as supply tanks, reservoirs, and reclaimed water storage (m^3)
  Fixed value of the operational volume of the storage capacity.
- Daily average inflow entering or being demanded to the DEMO system (m^3/day)
  The average can be done from data obtained from sampling at the DEMO.

Calculation formula

$$WSC = \frac{V_t}{Q_S}$$

Where:

- WSC: Water Storage Capacity (days),
- V_t: Total operational volume of storage capacity (m^3),
- Q_s: Daily average inflow entering or being demanded to the system (m^3/day).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/
- Carollo, M., Butera, I., & Revelli, R. (2022). Water savings and urban stormwater management: Evaluation of the potentiality of rainwater harvesting systems from the building to the city scale. PLOS ONE, 17(11), e0278107. https://doi.org/10.1371/journal.pone.0278107
- Donatello S., Dodd N. & Cordella M. (2021). Level(s) indicator 3.1: Use stage water consumption user manual: introductory briefing, instructions and guidance (Publication version 1.1). JRC, European Commission.

1.1.2.12 Compliant Reclaimed Water (CtotalRW)

- **Code**: Lesvos_Water11
- **Environmental Sector:** Water / Safe and Secure Fit-For-Purpose Water Provision
- **Units:** %

Meaning and importance of the indicator

This indicator represents the percentage of reclaimed water that adheres to the required quality standards at the specified compliance location, ensuring it meets the necessary criteria.
'Reclaimed water' means urban wastewater that has been treated in compliance with the requirements set out in Directive 91/271/EEC (Urban Wastewater Treatment Directive), and which results from further treatment in a reclamation facility; in accordance with Section 2 of Annex I to this Regulation: 'Point of compliance' means the point where a reclamation facility operator or alternative water supplier delivers reclaimed and/or non-potable water to the next actor in the chain. 'Non-compliance with reclaimed water quality standards per type of use' is defined in accordance with the agreements under EU or national legislation, such as Regulation (EU) 2020/741 of the European Parliament and of the Council on minimum requirements for water reuse for agriculture uses.

Expected evolution of the indicator

The optimal target for the CtotalRW indicator is 100%, indicating that all reclaimed water produced meets the required quality standards at the point of compliance.
The target could be assessed based on local policies and directives that establish the water quality limits depending on its use. One example for reclaimed water for uses of A quality reuse (Water Directive 2020/741) would be: E. coli ≤ 10 CFU/100 mL, BOD (Biochemical Oxygen Demand) ≤ 10 mg/l, TSS (Total Suspended Solids) ≤ 10 mg/L ,Turbidity ≤ 5 NTU, legionella current country legislation and bacteriophages <1000 UFC/100mL, contaminants according to the environmental quality standards.

Possible relationship with other water indicators

Reclaimed water production, Environmental flow requirement compliance rate, Safe drinking water, Effluent pollutant removal, Water quality compliance: biological, physical, and chemical parameters.

Data obtention

Sampling plan:

- Total number of samples with exceedance (i.e. sum of samples with microbial, chemical or indicator parameter exceedance); total number of samples analysed in assessment period.

Calculation formula

$$CtotalRW = \left(1 - \frac{ne_{totalRW}}{n_{totalRW}}\right) \cdot 100$$

Where:

- $C_{totalRW}$: = Percentage of total compliance for safe reclaimed water (%),
- $ne_{totalRW}$: Total number of samples of reclaimed water with exceedance, i.e., sum of samples with microbial, chemical or indicator parameter exceedance (No./year),
    - $ne_{totalRW} = \sum_{i=A} (nMi + nCi + nIi)$, with

- nM = number of samples with microbial exceedance
- nC= number of samples with chemical exceedance
- nI= number of samples with indicator exceedance
- i = Class A, B, C, D

- $n_{totalRW}$: Total number of reclaimed water samples analyzed in assessment period (No./year).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- EU regulation 2020/741 of the European Parliament and of the Council of 25 May 2020 on minimum requirements for water reuse. Official Journal of the European. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020R0741&from=EN
- Boletín Oficial del Estado (2020). Reglamento (UE) 2020/741 del parlamento europeo y del consejo de 25 de mayo de 2020 relativo a los requisitos mínimos para la reutilización del agua. https://www.boe.es/doue/2020/177/L00032-00055.pdf
- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

1.1.2.13 Effluent Pollutant Removal (EPR)

- **Code**: Lesvos_Water12
- **Environmental Sector:** Water / Water Treatment / Water Quality
- **Units:** %

Meaning and importance of the indicator

The indicator measures the average removal ratio between incoming and outgoing pollution load of the NBS. It can be evaluated for any pollutant. It is used to assess the effectiveness of water treatment processes in reducing pollution before discharge into the environment or wastewater treatment plant or its reuse.
*If there are additional water treatments in combination with the NBS, we recommend sampling before and after each treatment to have a better understanding of the role of each one in the treatment process.

Expected evolution of the indicator

The target can be determined based on design requirements (e.g., why the NBS is necessary, which pollutant needs to be addressed, and the desired removal efficiency) or according to local regulations and guidelines that define water quality standards depending on its intended use (such as for consumption, discharge, or reuse). For reclaimed water (as per Water Directive 2020/741), the goals would be: 95% removal of microbiological and emerging contaminants, 60-95% removal of nutrient pollutants, and 95% removal of physico-chemical parameters (such as turbidity). For treated wastewater (under RD 509/1996 and RD 11/1995), the objectives would include 70-80% reduction of nutrient pollutants and 90% removal of physico-chemical parameters (such as turbidity). For drinking water (in line with RD 3/2023), the goals would involve: 99-100% elimination of microbiological contaminants, 80-99% reduction of chemical pollutants, and 95% removal of physical and chemical parameters (such as turbidity) and nutrients.

Possible relationship with other water indicators

Reclaimed water production, Environmental flow requirement compliance rate, Safe drinking water, Water quality compliance: biological, physical and chemical parameters.

Data obtention

Sampling plan:

- Average influent concentration (mg/L).
- Average effluent concentration (mg/L).
- Water quality parameters:
- Physical-chemical properties data:
    - - pH (unitless)
    - - Temperature (ºC)
    - - Electrical Conductivity (EC) (µS/cm)
    - - Turbidity (NTU)
    - - TSS (Total Suspended Solids) (mg/L)
- Biological data:
    - - DO (Dissolved Oxygen) (mg/L O_2)
    - - BOD (Biochemical Oxygen Demand) (mg/L O_2)
    - - COD (Chemical Oxygen Demand) (mg/L O_2)

- Chemical pollutant data:
  - - Heavy metals (µg/L)
  - - Total pesticides (µg/L)
- Nutrient data:
  - - TN (Total Nitrogen) (mg/L N)
  - - NO_3 (Nitrates) (mg/L)
  - - TP (Total Phosphorus) (mg/L P)
  - - PO_4 (Phosphates) (mg/L)
- Microbiological data:
  - - E. Coli (CFU/100 mL)
- Other specific pollutants data:
  - - Contaminants of emerging concern
  - - Pollutants from industrial effluents will be added if necessary.

Calculation formula

$$\%Re = \frac{(Ci - Ce)}{Ci} \cdot 100$$

Where:

- %Re: average effluent pollutant removal (%),
- Ci: average influent concentration (mg/L),
- Ce: average effluent concentration (mg/L).

*To be evaluated for each pollutant.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

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1.1.2.14 Rate of Evapotranspiration (ETrate)

- **Code**: Lesvos_Water13
- **Environmental Sector:** Water / Water Management / Resource Efficiency
- **Units:** mm/m^2 day

Meaning and importance of the indicator

The rate of evapotranspiration (ETrate) measures the amount of water vapor released into the atmosphere from both soil and plant surfaces over a given period of time. This indicator helps to understand the water balance within the urban environment and assess the effectiveness of the NBS, crops, forest, soils, etc. in managing water resources. Evapotranspiration plays a significant role in the hydrological cycle, influencing local climate conditions, water availability, and thermal comfort in urban areas. By monitoring the ETrate, the impact of vegetation, green spaces, and other NBS on water conservation, irrigation needs, and heat mitigation can be assessed. This indicator can be assessed, for example, in constructed wetlands, soils, fields, etc.

Expected evolution of the indicator

The ETrate is expected to vary with seasonal changes, vegetation cover, and weather conditions. In urban areas with well-implemented NBS, a higher ETrate is generally desirable during warmer months as it indicates effective cooling through latent heat flux. However, in water-scarce regions, the optimal ETrate would balance cooling needs with water conservation, preventing excessive water loss. The ideal range will depend on the specific urban context, including climate, vegetation type, and water availability.
The following table shows the normal good levels of evapotranspiration in mm/year depending on the region or geographical context where it is found in the world.

Region/Context	Good annual levels, mm/year
Arid regions	200-500
Temperate regions	500-700
Humid/tropical regions	800-1500

Note: Allen, R. G. et al. (1998).

For example, urban parks which are considered temperate regions, have good levels of evapotranspiration at the range of 500-800 mm/year. Another example are agricultural fields (e.g., corn), which levels are between 400-700 mm/year.

The table below provides estimates of annual evapotranspiration values (mm/year) in different climate regions, categorized by temperature and humidity conditions. This helps to illustrate how evapotranspiration varies not only by thermal regime but also by region type, whether tropical, subtropical, or temperate:

Region/Temperature	Cold (10ºC), mm/year	Moderate (20ºC), mm/year	Warm (30ºC), mm/year
Humid and sub-humid (tropics/subtropics)	730 - 1095	1095 - 1825	1825 – 2555
Arid and semi-arid (tropics/subtropics)	730 - 1460	1460 - 2190	2190 – 2920
Humid and sub-humid (temperature zone)	365 - 730	730 - 1460	1460 – 2555
Arid and semi-arid (temperature zone)	365 - 1095	1460 - 2555	2190 – 3285

Note: Cherlinka, V. (2023).

Possible relationship with other water indicators

Water footprint, Rainfall interception of NBS, Rainfall storage/absorption capacity of NBS.

Data obtention

Sampling plan:

- Amount of water that is lost by evapotranspiration over the period (mm),
- Area of study or the NBS from the DEMO (m^2),
- Time period for the study (days).

Calculation formula

$$ETrate = \frac{ETt}{A \cdot t}$$

Where:

- ETrate: Rate of evapotranspiration ($mm/m^2 \cdot day$),
- ETt: Total evapotranspiration over the period (mm),
- t: Time period (days),
- A: Area of study or the NBS (m^2).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

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1.1.3 Energy Indicators

1.1.3.1 Biogas Generation Due To Wastewater Treatment

- **Code**: Lesvos_Energy01
- **Environmental sector**: Energy/Biogas or wastewater treatment
- **Units**: m^3 biogas/m^3 wastewater

Meaning and importance of the indicator

"Biogas generation due to wastewater treatment" measures the amount of biogas (a biofuel) produced as a byproduct of treating wastewater. This biogas, primarily composed of methane and carbon dioxide, is generated during the anaerobic digestion process where microorganisms break down organic matter in the absence of oxygen. The importance of this indicator lies in its dual environmental and economic benefits. Environmentally, biogas production reduces greenhouse gas emissions by capturing methane that would otherwise be released into the atmosphere, contributing to climate change mitigation. Economically, biogas serves as a renewable energy source that can be used for heating, electricity generation, or as a vehicle fuel, thereby reducing reliance on fossil fuels and promoting energy sustainability. Additionally, the process supports waste management by treating wastewater efficiently and reducing the volume of sludge. Overall, this indicator is vital for assessing the sustainability and effectiveness of wastewater treatment processes and their contributions to renewable energy production and environmental protection.

Expected evolution of the indicator

The expected evolution of the indicator "Biogas generation due to wastewater treatment" is towards increasing biogas production efficiency and capacity. The tendency is driven by advancements in anaerobic digestion technology, improvements in the operational management of wastewater treatment plants, and increased regulatory and policy support for renewable energy and waste-to-energy initiatives.

Data obtention method

Online measurement of amounts of biogas production and wastewater treated.

Frequency

Continuous (flowrate)
1 per month (composition)

1.1.3.2 Energy Consumption for Wastewater Treatment

- **Code**: Lesvos_Energy02
- **Environmental** sector: Energy
- **Units**: kWh/m^3 wastewater

Meaning and importance of the indicator

"Energy Consumption for Wastewater Treatment" measures the amount of energy (electricity and heat) used in the processes involved in treating wastewater to make it safe for discharge or reuse. The to-be-measured energy consists of electricity and heat, and the measure energy values will be aggregated but also shown separately. This indicator is crucial for evaluating the sustainability and efficiency of wastewater treatment facilities. High energy consumption can indicate inefficiencies and result in increased operational costs and higher carbon emissions, which are detrimental to both economic and environmental goals. Conversely, optimizing energy use in wastewater treatment can lead to significant cost savings, lower greenhouse gas emissions, and a reduced environmental footprint. Monitoring this indicator helps in identifying opportunities for implementing energy-saving technologies and practices, such as using more efficient equipment, improving process controls, and integrating renewable energy sources. Ultimately, reducing energy consumption in wastewater treatment supports broader sustainability objectives by minimizing resource use and contributing to climate change mitigation.

Expected evolution of the indicator

The expected evolution of the indicator "Energy Consumption for Wastewater Treatment" is towards decreasing energy use per unit of treated wastewater, reflecting improvements in efficiency and sustainability of treatment processes. This evolution is driven by technological advancements, better operational practices, and increased regulatory and policy pressures to reduce environmental impact.

Data obtention method

Field measurement or assessment based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

Frequency

Once per month with field measurements or once per year when electrical capacities are used

1.1.3.3 Energy Use in Agriculture

- **Code**: Lesvos_Energy03
- **Environmental** sector: Energy
- **Units**: kWh/m^2 land

Meaning and importance of the indicator

"Energy use in agriculture" measures the amount of electrical, fuel and heat energy consumed in agricultural activities, including irrigation, lighting, heating, cooling, and operating machinery and equipment. This indicator is crucial for assessing the energy efficiency and environmental impact of agricultural practices. High energy consumption can indicate inefficiencies, leading to increased operational costs and higher carbon emissions. Conversely, optimizing energy use enhances sustainability by reducing greenhouse gas emissions and lowering production costs, which is vital for the economic viability of farming. Monitoring this indicator helps identify opportunities for implementing energy-saving technologies and practices, such as precision agriculture, renewable energy integration, and efficient irrigation systems. Ultimately, reducing electricity use in agriculture supports broader sustainability goals, including resource conservation, climate change mitigation, and the promotion of eco-friendly farming practices.

Expected evolution of the indicator

The expected evolution of the indicator "Electricity use in agriculture" is towards greater efficiency and sustainability, driven by technological advancements, economic considerations, and environmental regulations.

Data obtention

Sampling plan:

Field measurement or assessment based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

1.1.3.4 Energy Footprint Per Kg of Food

- **Code**: Lesvos_Energy04
- **Environmental** sector: Energy
- **Units**: kWh/kg food

Meaning and importance of the indicator

"Energy footprint per kg of food" measures the total amount of energy consumed throughout the entire lifecycle of producing one kilogram of food, including energy used in farming, processing, transportation, and storage. This indicator is vital for assessing the environmental and economic sustainability of food production systems. A high energy footprint suggests inefficiencies and greater environmental impact, contributing to increased greenhouse gas emissions and higher production costs. Conversely, a lower energy footprint indicates more efficient and sustainable practices, reducing the overall environmental burden and conserving energy resources. By monitoring this indicator, stakeholders can identify areas for improvement, adopt energy-saving technologies, and implement best practices to enhance the sustainability of food production. Ultimately, reducing the energy footprint per kg of food supports global efforts towards sustainable agriculture, climate change mitigation, and resource conservation.

Expected evolution of the indicator

The expected evolution of the indicator "Energy footprint per kg of food" is towards a decreasing trend, reflecting improvements in the efficiency and sustainability of food production systems.

Data obtention

Sampling plan:

Field measurement or based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

Frequency

Once per month with field measurements or once per year when electrical capacities are used

1.1.3.5 Operational Energy Consumption

- **Code**: Lesvos_Energy05
- **Environmental** sector: Energy
- **Units**: kWh

Meaning and importance of the indicator

"Operational energy consumption" of a wastewater treatment system measures the amount of energy required to run all processes involved in treating wastewater, sludge to produce compost, and producing and upgrading biogas to biomethane. This indicator is crucial for evaluating the efficiency and sustainability of wastewater treatment operations. High operational energy consumption can indicate inefficiencies and lead to increased operational costs and higher greenhouse gas emissions. Conversely, optimizing energy consumption enhances the sustainability of the treatment process by reducing costs, minimizing environmental impact, and conserving energy resources. Monitoring this indicator helps identify areas for improvement, enabling the implementation of energy-saving technologies and practices. Ultimately, reducing operational energy consumption supports broader sustainability goals, including resource conservation, climate change mitigation, and the promotion of eco-friendly infrastructure.

Expected evolution of the indicator

The expected evolution of the indicator "Energy consumption" for a wastewater treatment system is towards a reduction in energy use per unit of wastewater input, driven by technological advancements, process optimization, and regulatory and market pressures for greater sustainability.

Data obtention

Sampling plan:

Field measurement or assessment based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

Frequency

Once per month with field measurements or once per year when electrical capacities are used

DEMO1.2: Mykonos

Two NbS systems were implemented to harvest rainwater for irrigation and domestic uses in the Ano Mera village in Mykonos Island (Greece). In the first system, a sub-surface rainwater collector was constructed to collect rainwater and store it in underground storage tanks, which is then used to irrigate a nearby field planted with aromatic plants (lavender). The harvested plants are given to local agrotourism, or used to produce essential oil. This NbS system helps to mitigate flood risks, while providing economic value with the production of aromatic herbs and essential oil.

The second system is composed of three subsystems, a smart residential water management, a slow sand filter, and a bioswale. A rainwater harvesting system incorporates a bioswale that captures stormwater runoff from rooftops and residential yards. This water is stored in detention vaults and tanks, primarily for non-potable domestic uses, while some is used to irrigate a 0.2 hectare lavender field. Smart irrigation systems, monitored online, ensure water efficiency for the irrigation of lavender fields. Additionally, the system replenishes the aquifer during wet seasons and provides a water source for non potable uses during dry periods. Smart sensors for online monitoring, ensure optimal resource use.

1.2.1 Soil Indicators

1.2.1.1 Soil Physical and Chemical Fertility

- **Code**: Mykonos_Soil01
- **Environmental Sector**: Soil / Soil Health
- **Units:** Multi-component indicator. Diverse units for specific components

Meaning and importance of the indicator

Soil productive capacity (a key soil ecosystem service) is the result of complex interactions between biological, chemical and physical properties. Achieving and maintaining appropriate levels of physical and chemical soil fertility is of paramount importance for sustainable cropland management and, at large scale, for food security. Nutrients naturally arrive to soil from geological materials, from water, from atmospheric deposition and from decomposition of plant and animal residues. Nutrient availability to crops is significantly affected by soil acidity (pH), and nutrient presence in the soil solution is highly dependent on soil texture and soil cation exchange capacity; water provision to plants is notably improved by soil organic matter. Soil electrical conductivity warns about soil salinity, a serious risk for crops under Mediterranean conditions. Soil analysis is the basic tool to evaluate soil fertility and to guide farmers towards sustainable management.

Expected evolution of the indicator

There are recommended ranges and critical values for most of the soil components to be analyzed. For a given crop (aromatic plants in this case), these values are available from local and regional farmer associations. Most generally, together with the results of soil analyses, agricultural laboratories provide an evaluation of the level of each analyzed parameter (deficient – correct – excessive or similar). The value of each parameter should evolve towards these reference values.

Data Obtention

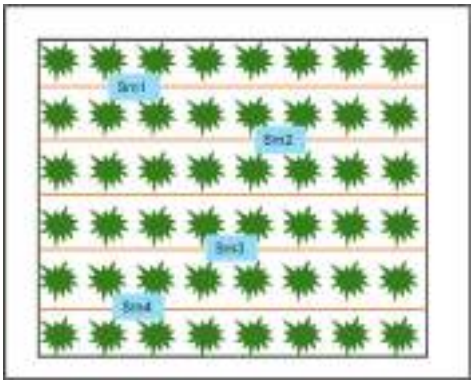
Required data:

- To be analysed only the first time: soil texture (% sand; % clay; % silt); textural class.

- To be analysed at each soil sampling campaign: pH; Electrical conductivity; Total organic carbon (%, dry soil basis); Carbonates; Total nitrogen (Kjeldahl); NH4-N, Exchangeable Phosphorus; Cation exchange capacity; Interchangeable bases (Ca, Mg, Na and K); Micronutrients (Fe, Zn, Mn, Cu, B).

Sampling plan:

The samples will always be taken at the same month of the year, preferably in spring. In the lavender fields, soil will be sampled with the **15 cm** depth soil sampler described in the "equipment" section. At each field, 4 soil samples will be taken (at 15 cm) from 4 points randomly chosen outside the planting lines and avoiding the external fringe of the fields (an example is provided in the graph). The four samples of each field will be pooled in pairs into two plastic zip bags duly labelled with the sampling date and the name of the field (oregano/lavender). The resulting 4 soil samples (2 for oregano, 2 for lavender) will be sent to an expert lab for analysis as soon as possible. The soil lab must have been previously consulted for instructions about the preparation of the samples before shipping. The base line of the oregano field was assessed for soil fertility in 2019. The same analyses realized at this initial moment must be done at each sampling campaign. It is highly recommended to add Total Nitrogen to the analyses.



Sampling calendar

The two fields will be sampled in the proposed date every two years for 10 years (5 times).

Equipment

Samples will be extracted from soil with soil borers of known and constant (the same for all samples at each sampling campaign) depth and diameter. The borer should be **15 cm** long and the recommended diameter is 5 cm.

Some indicative providers of these soil samplers are: https://www.ams-samplers.com/soil-augers/; https://www.vanwalt.com/equipment/telescoping-augers/. Any other equivalent sampler of these dimensions is acceptable (but try to respect the 15 cm depth)

Some small field materials, such as zip bags.

External subcontracting required

Yes. A trustable lab delivering soil fertility analyses must be hired.

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- For soil fertility in gardens: https://extension.umaine.edu/gardening/manual/soils/interpreting-soil-tests/

1.2.1.2 Water Holding Capacity (WHC)

- **Code:** Mykonos_Soil02
- **Environmental Sector:** Soil / Soil Health /
- **Units:** %

Meaning and importance of the indicator

The water holding capacity (WHC) is an important agronomic characteristic. The WHC of a soil is the maximum amount of water a soil can hold under standard conditions. Water holding capacity is affected by soil texture (sand, silt, and clay proportion) and soil structure (pore size, porosity, pores connectivity distribution and characteristics are essential determinants). A soil with a limited WHC reaches sooner the saturation than a soil with a higher WHC, especially between sandy soils as they tend to have low water storage capacity.

Expected evolution of the indicator

Soil structure can be improved by adding organic matter content to stimulate the soil porosity, which increases the water holding capacity. Also, a better water holding capacity of the soil can be accomplished by increasing the soil organic carbon. However, deforestation and farming activities may decrease soil water holding capacity.

Data obtention

Required data: Field sampling followed by lab analyses (See Mykonos_Soil01).
Sampling plan: Collect the sample using a soil core, air dry it, break the aggregates and pass through a 2.0 mm sieve. Place the core containing soil in a water tray for saturation overnight and then place the sample in an oven at 105º C for 24-48 h. Finally, weight the core sample. For further instructions go to the Practical manual on measurement of soil physical properties, on page 34.

Sampling calendar

This indicator will be produced every two years for a total of 10 years, coinciding with the evaluation of soil physical and chemical fertility (See Mykonos_Soil01).

Equipment

Additional field materials: A soil cylinder /core, a tray, filter papers, a spatula, a sieve, water try, a balance and a drying oven (See Mykonos_Soil01).

External subcontracting

If a reliable scale and an oven are available, WHC can be obtained very simply without the need of an expert lab. If not, a trustable lab delivering soil fertility analyses must be hired (See Mykonos_Soil01).

Calculation formula

$$WHC\ \% = (Vw/Vt) * 100$$

Where:

- Vw is volume of water and Vt, is total volume of saturated soil.

References

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1.2.2 Water Indicators

1.2.2.1 Water Monitoring Plan (Mykonos 1.2A)

Sampling points

The Rainwater Harvesting when Nature Inspires: A novel rainwater harvesting NBS in remote, water scarce areas.

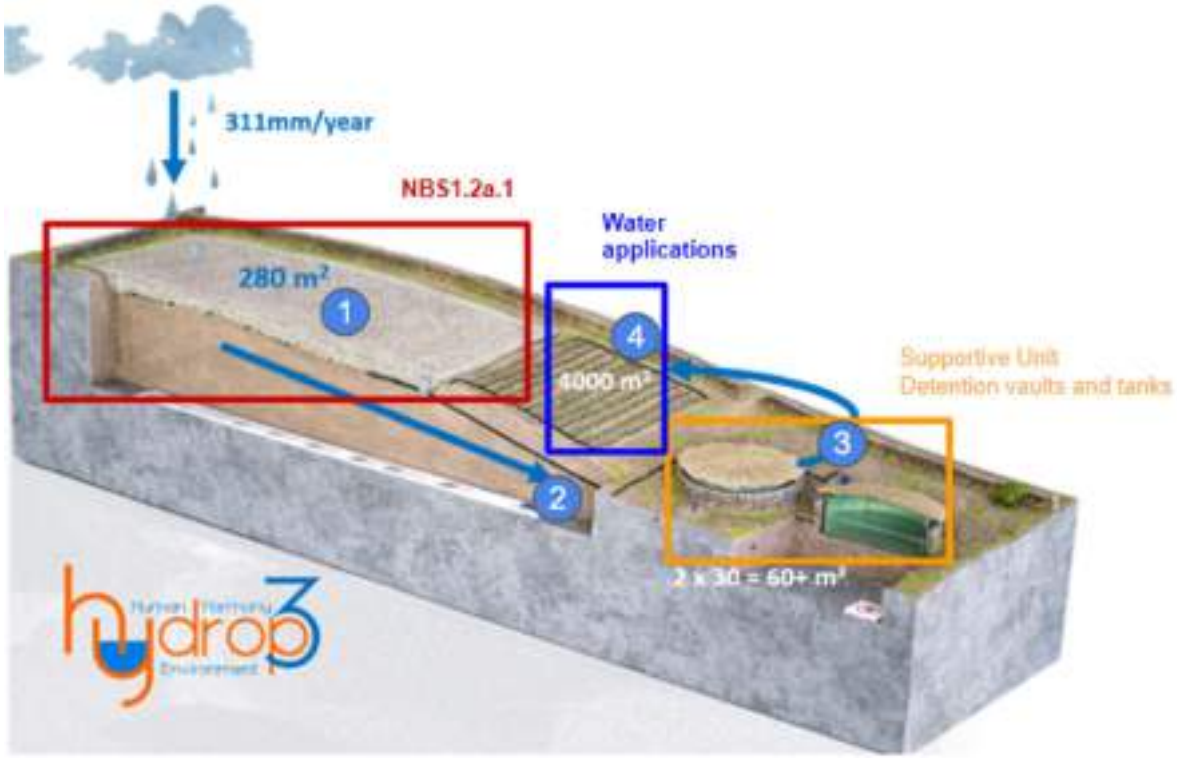

Figure 6

Sampling point	Location	Purpose
SP-01	Inlet and/or surface of NBS1.2a.1	Monitor the rainfall/stormwater (volume)
SP-02	Outlet of the subsurface collector	Monitor reclaimed water quality and availability (efficiency of the whole treatment, nutrient content and volume)
SP-03	Outlet of the storage water tank	Monitor reclaimed water availability for irrigation (volume)
SP-04	Main connection to agroforestry irrigation (i.e. outlet of the irrigation tank)	Monitor total volume of water used for irrigation (volume)

Parameters to be analyzed

Parameter	Applicable Sampling Point	Related indicators	Type
Volume of rainfall over the NBS	SP-01	WA; WSC; RI	water flow measurements [volume/time]
Volume of reclaimed water produced	SP-03	RWnpU; WA; WSC	water flow measurements [volume/time]
Volume of reclaimed water used for irrigation	SP-04	RWnpU; WA	water flow measurements [volume/time]
Water quality parameters: Conductivity, pH, redox, COD, BOD_5, TSS, TN, TP, TOC, temperature, turbidity, E. coli, heavy metals, anions and cations	SP-02, SP-04	RWnpU	water quality parameters

Sampling method

Water flow measurements:

Direct measurement of volume provided during a time period or water flow with flow meters and/or water level sensors.

a) Automatic method

Automatic flow meters can be installed at the recommended sampling points (SP). For the automatization process, it is recommended to register the measurements with a datalogger/digital control system in the DEMO, located in those SP.

Data should be stored in a datalogger/digital control system and then be able to be exported in a spreadsheet to calculate the associated indicators. When this is not possible, manual readings of the flow meters can be done instead.

b) Manual method

This could be applied as the last option if there is no possibility to apply the automatic method.

- Periodic manual measurements.
- If no devices are available to measure, correct and reliable estimates must be made to assess the indicator.
- Measure the volume at the point of reuse or approximate the value based on the amount of water demand met by agroforestry for reuse.

Rainwater/stormwater data:

For the registration of rainwater or stormwater data, it is more recommended to apply online and automatic methods.

a) Automatic method

Tele-detection through drones or similar automatization technologies can be used. Also, information from nearby meteorological/weather stations.

b) Manual method

Manual simple measurements using rain gauges could be used as the last option. These methods can give less accurate data.

Water quality parameters:

Automatic measurement methods (a) or manual sampling campaigns (water sampling + laboratory analysis) (b) can be employed, with specific requirements for different types of pollutants.

a) Automatic method

Advanced sensors of water quality can be installed in the recommended sampling points (SP) to continuously monitor and measure various water quality parameters, such as temperature, pH, turbidity, dissolved oxygen, NO_3, etc. These sensors collect data in real-time, providing continuous and accurate information about water quality. The data is often transmitted wirelessly to a central database, or sensors can be also connected to a datalogger. The data is often transmitted wirelessly to a central database, or sensors can be also connected to a datalogger.

b) Manual method

As the DEMO is already implemented, mature and operating, sampling campaigns will be carried out periodically to control the operation and performance of the treatment system. Samples will be collected at the recommended sampling points (SP). Two types of water quality analysis have been defined: **basic** and **complete**. Basic analysis will include all water quality parameters that are required to monitor by legislation for reclaimed water reuse for irrigation: turbidity, BOD_5, E. coli, TSS (other if required by legislation). Complete analysis includes other water quality parameters for general monitoring and indicators' assessment: conductivity, pH, redox, COD, TN, TP, TOC, temperature, heavy metals, anions and cations. Samples can be obtained manually or using automatic sampling equipment. An automatic sampler is a device that can be refrigerated or non-refrigerated and include automatic sampling pumps and upward stage samplers. The process involves collecting water samples intended for laboratory analysis of water quality parameters. However, there are limitations associated with automatic sampling, such as intermediate sampling containers, sampling from a fixed point, and sample storage and preservation, which must be considered and documented. Personnel using these methods should have training and prior experience in the use and calibration of automatic sampling equipment. The laboratory analysis is done following current ISO laboratory protocols for each different parameter.

Sampling calendar

Water flow measurements and water level variation:

Data should be collected frequently for a relevant time period (e.g., daily, weekly, monthly) to allow for accumulation over the entire reporting period (yearly). This high frequency is also relevant to study seasonal variations.

Water quality parameters:

During the operation, the recommended frequency of water quality analysis is 1 basic analysis per week (as reclaimed water is being used in agroforestry) and 1 complete analysis per month.

Rainwater/stormwater data:

Data should be collected every time there is a rain event.

Equipment

a) Water flow measurements:

Water flow meters are essential tools for monitoring and assessing the efficiency of these systems, as they provide real-time data on water movement and usage through the treatment processes and the different pipes, helping to determine the volume of water at those particular locations. Some indicative providers of these water flow meters are:

- Endress+Hauser
- Systec Controls
- Aobo instrument

Any equivalent water flow meter is acceptable, these are given as examples.

b) Water quality parameters:

The automatic sampling method requires simple or multiparametric sensors for water quality and data loggers or digital control systems for data recording. It also requires personnel for data collection and treatment. The manual sampling campaign requires laboratory and field personnel for manual sampling and analysis and also reagents and laboratory material depending on the current ISO laboratory protocols for each parameter.

Some indicative providers for water quality parameters are:

- ANISE sensor (NH_4 and NO_3) - Hach
- Conductivity meter - METTLER TOLEDO
- pH meter - METTLER TOLEDO
- Multi-parameter water quality analyser (temperature, pH, conductivity, DO, turbidity, BOD, COD, ammonia nitrogen, NO_3, colour, chloride, depth, etc.) - BOQU instruments

Any equivalent water level sensor is acceptable, this is given as an example.

c) Rainwater/stormwater data:

In this DEMO, the main water flow measurements would be rainwater/stormwater, so there are different rain gauges that can be used for it. Some indicative providers of are:

- OMEGA
- Amazon

Any equivalent water level sensor is acceptable, this is given as an example.

External subcontracting

Not needed if internal technical resources are available.

1.2.2.2 Water Monitoring Plan (Mykonos 1.2B)

Sampling points

From Rain to Resilience: A Decentralised Combination of Residential Rainwater Harvesting, flood protection Bioswale system and Subsurface Rainwater Storage and Recovery for Arid Communities.

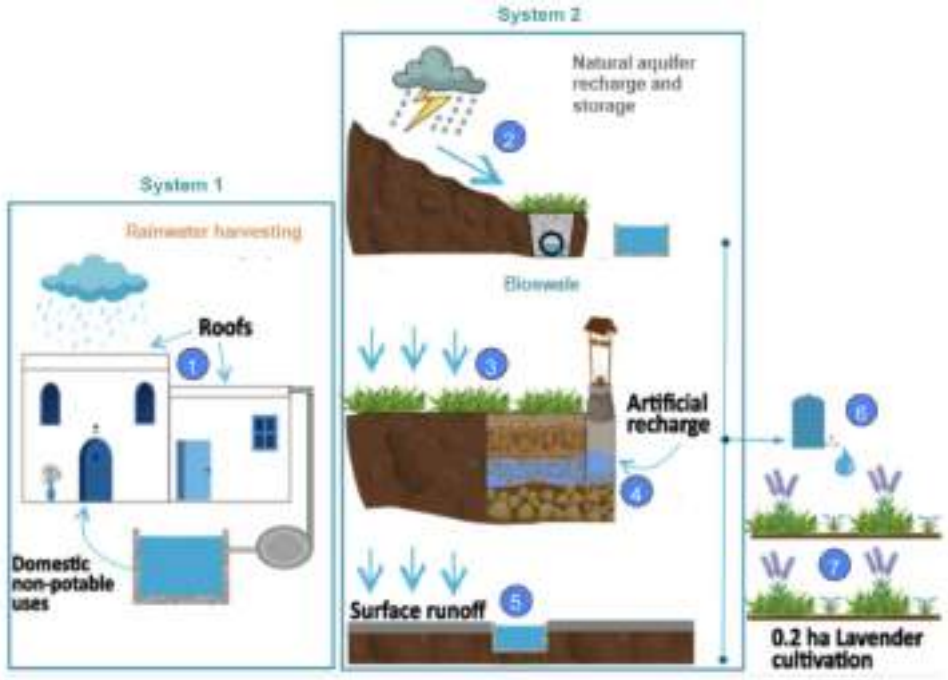

Figure 7

Sampling point	Location	Purpose
SP-01	Inlet and/or surfaces of the rooftops of the houses for harvest the rainwater	Monitor the rainfall/stormwater (volume)
SP-02	Surface of the System 2 bioswale	Monitor the rainfall/stormwater (volume)
SP-03	Surface of the System 2 artificial recharge	Monitor the rainfall/stormwater (volume)
SP-04	Piezometer	Monitor reclaimed water quality and recharge of the aquifer (i.e. nutrients content)
SP-05	Surface runoff System 2	Monitor the rainfall/stormwater (volume)
SP-06	Main connection to agroforestry irrigation (i.e. outlet of the irrigation tank)	Monitor total volume of water used for irrigation through reclaimed water

Parameters to be analyzed

Parameter	Applicable Sampling Point	Related indicators	Type
Volume of rainfall over the NBS	SP-01, SP-02, SP-03, SP-05	WA, RI	water flow measurements [volume/time]
Volume of reclaimed water produced	SP-06	RWnpU; WA; WSC	water flow measurements [volume/time]
Volume of groundwater recharge	SP-04	GWR	water level variation [volume/time]
Water quality parameters: Nitrogen content (TN, NO_3 or NH_3), total phosphorus (TP) content, conductivity, pH, redox, COD, BOD_5, TSS, TOC, temperature, turbidity, E. coli, heavy metals, anions and cations	SP-03, SP-04, SP-05, SP-06	RI; WQC; ASREN	water quality parameters

Sampling method

Water flow measurements:

Direct measurement of volume provided during a time period or water flow with flow meters and/or water level sensors.

a) Automatic method

Automatic flow meters can be installed at the recommended sampling points (SP). For the automatisation process, it is recommended to register the measurements with a datalogger/digital control system in the DEMO. It is recommended to measure the flow at the recommended sampling points (SP).

Data should be stored in a datalogger/digital control system and then be able to be exported in a spreadsheet to calculate the associated indicators. When this is not possible, manual readings of the flow meters can be done instead.

b) Manual method

This could be applied as the last option if there is no possibility to apply the automatic method.

- Periodic manual measurements.
- If no devices are available to measure, correct and reliable estimates must be made to assess the indicator.
- Measure the volume at the point of reuse or approximate the value based on the amount of water demand met by agroforestry for reuse.

Rainwater/stormwater data:

For the registration of rainwater or stormwater data, it is more recommended to apply online and automatic methods.

a) Automatic method

Tele-detection through drones or similar automatization technologies can be used. Also, information from nearby meteorological/weather stations.

b) Manual method

Manual simple measurements using rain gauges could be used as the last option. These methods can give less accurate data.

Water quality parameters:

Automatic measurement methods (a) or manual sampling campaigns (water sampling + laboratory analysis) (b) can be employed, with specific requirements for different types of pollutants.

a) Automatic method

Advanced sensors of water quality can be installed in the recommended sampling points (SP) to continuously monitor and measure various water quality parameters, such as temperature, pH, turbidity, dissolved oxygen, NO_3, etc. These sensors collect data in real-time, providing continuous and accurate information about water quality. The data is often transmitted wirelessly to a central database, or sensors can be also connected to a datalogger. The data is often transmitted wirelessly to a central database, or sensors can be also connected to a datalogger.

b) Manual method

As the DEMO is already implemented, mature and operating, sampling campaigns will be carried out periodically to control the operation and performance of the treatment system. Samples will be collected at the recommended sampling points (SP). Two types of water quality analysis have been defined: **basic** and **complete**. Basic analysis will include all water quality parameters that are required to monitor by legislation for reclaimed water reuse for irrigation: turbidity, COD/BOD_5, E. coli, TSS (other if required by legislation). Complete analysis includes other water quality parameters for general monitoring and indicators' assessment: conductivity, pH, redox, COD, TN, TP, TOC, temperature, heavy metals, anions and cations. Samples can be obtained manually or using automatic sampling equipment. An automatic sampler is a device that can be refrigerated or non-refrigerated and include automatic sampling pumps and upward stage samplers. The process involves collecting water samples intended for laboratory analysis of water quality parameters. However, there are limitations associated with automatic sampling, such as intermediate sampling containers, sampling from a fixed point, and sample storage and preservation, which must be considered and documented. Personnel using these methods should have training and prior experience in the use and calibration of automatic sampling equipment. The laboratory analysis is done following current ISO laboratory protocols for each different parameter.

Groundwater level measurements:

The variation in the water level of the aquifer can be done manually or through automatic methods.

a) Automatic method

For the groundwater recharge of the aquifer, the DEMO already has water level sensors or remote sensing through hydrological models that can be used.

b) Manual method

For the groundwater recharge of the aquifer, direct water level measurements in a period of time can be done. Measure water depth of the aquifer at the initial time and after a period of time (e.g. minutes, hours, days, etc.).

Sampling calendar

Water flow measurements and water level variation:

Data should be collected frequently for a relevant time period (e.g., daily, weekly, monthly) to allow for accumulation over the entire reporting period (yearly). This high frequency is also relevant to study seasonal variations.

Water quality parameters:

During the operation, the recommended frequency of water quality analysis is 1 basic analysis per month and 1 complete analysis bimonthly.

Rainwater/stormwater data:

Data should be collected every time there is a rain event.

Equipment

a) Water flow measurements:

Water flow meters are essential tools for monitoring and assessing the efficiency of these systems, as they provide real-time data on water movement and usage through the treatment processes and the different pipes, helping to determine the volume of water at those particular locations.
Some indicative providers of these water flow meters are:

- Endress+Hauser
- Systec Controls
- Aobo instrument

Any equivalent water flow meter is acceptable, these are given as examples.

b) Rainwater/stormwater data:

In this DEMO, the main water flow measurements would be rainwater/stormwater, so there are different rain gauges that can be used for it.
Some indicative providers of are:

- OMEGA
- Amazon

Any equivalent water level sensor is acceptable, this is given as an example.

c) Water quality parameters:

The automatic sampling method requires simple or multiparametric sensors for water quality and data loggers or digital control systems for data recording. It also requires personnel for data collection and treatment.
The manual sampling campaign requires laboratory and field personnel for manual sampling and analysis and also reagents and laboratory material depending on the current ISO laboratory protocols for each parameter.
Some indicative providers for water quality parameters are:

- ANISE sensor (NH_4 and NO_3) - Hach
- Conductivity meter - METTLER TOLEDO
- pH meter - METTLER TOLEDO
- Multi-parameter analyser and sensor measure groundwater quality (DO, turbidity, conductivity, pH, salinity, temperature) - BOQU instruments
- Multi-parameter water quality analyser (temperature, pH, conductivity, DO, turbidity, BOD, COD, ammonia nitrogen, NO_3, colour, chloride, depth, etc.) - BOQU instruments

Any equivalent water level sensor is acceptable, this is given as an example.

d) Groundwater level measurements:

Some indicative providers of a water level sensor is:

- Sensor - OTT PLS-C
- Staff gauge - Fondriest

Any equivalent water level sensor is acceptable, this is given as an example.

External subcontracting

Not needed if internal technical resources are available.

1.2.2.3 Reclaimed Water in Non-Potable Uses (Rwnpu)

- **Code:** Mykonos_Water01
- **Environmental Sector:** Water / Water resource recovery and use
- **Units:** %

Meaning and importance of the indicator

The indicator measures the proportion of reclaimed water (from treated wastewater, rainwater, urban runoff, etc.) used in non-potable applications where previously drinking or freshwater was used. It is related to the total volume of water used for those purposes. This indicator provides valuable insight into the sustainable use of water resources by quantifying the extent to which reclaimed water is used for non-potable purposes.

Expected evolution of the indicator

The optimal value for the RWnpU indicator is as close to 100% as possible, indicating that the majority of non-potable water needs are met with reclaimed water, minimizing the demand for freshwater.

Possible relationship with other water indicators

Compliant reclaimed water, Water availability, Reclaimed water production, Water provision by the ecosystem.

Data obtention

Sampling plan:

- Volume of reclaimed water used for non-potable uses (e.g., irrigation, street cleaning, groundwater recharge) (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total volume of water used for non-potable uses, from all sources, including freshwater and reclaimed water (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.

Calculation formula

$$RWnpU = \frac{RW}{npW} \cdot 100$$

Where:

- RWnpU: Reclaimed Water in non-potable Uses (%),
- RW: Volume of reclaimed water used for non-potable uses (e.g., irrigation, street cleaning, groundwater recharge) (m^3/year),
- npW: Total volume of water used for non-potable uses, from all sources, including freshwater and reclaimed water (m^3/year).

Note: “used” may be “supplied” or “consumed” but must be consistent in RW and npW.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

1.2.2.4 Water Availability (WA)

- **Code**: Mykonos_Water02
- **Environmental Sector:** Water / Freshwater Supply / Resource Efficiency
- **Units:** m^3/year

Meaning and importance of the indicator

The indicator refers to the volume of water available provided by the DEMO for its reuse in various applications (e.g. aquifer recharge, ecosystem restoration, on site reuse, irrigation, industrial activities, etc.). The water available should comply with quality standards required for different reuses as per current legislation.

Expected evolution of the indicator

The baseline for this indicator is the initial water availability capacity, which may start at 0 m^3/year. It is expected to increase over time once the DEMO is operating and optimized, reflecting an improvement in water availability for reuse and ecosystem services. Ensure that 100% of the water provided by the DEMO is available for reuse.

Possible relationship with other water indicators

Water footprint, Water provision by the ecosystem.

Data obtention

Sampling plan:

- Direct annual flow of the effluent or annual volume provided by the DEMO for specific purposes (e.g., aquifer recharge, ecosystem restoration, etc.) (m^3/year).
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total volume water available in the DEMO (WA) (m^3/year).

Calculation formula

$$WA = Water\ inflows\ (WI) - Water\ losses\ (WL)$$

Where:

- WI: Total water entering the DEMO system (e.g., precipitation, surface water, groundwater recharge, recycled water) (m^3)
- WL: Total water lost (due to evaporation (m^3))

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

- United Nations Conference on Trade and Development (2023). Environmental indicators: Module B Core SDG Indicators for Entity Reporting Training Manual. https://unctad.org/system/files/information-document/UNCTAD_GCI_MANUAL_ENVIRONMENTAL-FINAL.pdf
- URBAN GreenUP (2019). D5. 3: City diagnosis and monitoring procedures. https://www.urbangreenup.eu/kdocs/1912498/urban_greenup_d5_3_city_diagnosis_and_monitoring_procedures.pdf
- U.S. Environmental Protection Agency (2024). Basic information about water reuse. https://www.epa.gov/waterreuse/basic-information-about-water-reuse

1.2.2.5 Water Storage Capacity (WSC)

- **Code:** Mykonos_Water03
- **Environmental Sector:** Water / Effectiveness of the adaptive change towards resilient infrastructure
- **Units:** Days

Meaning and importance of the indicator

The indicator assesses the resilience and efficiency of water supply systems. It is defined as the ratio between the total volume of available storage (e.g., water supply tanks, reservoirs for rainwater harvesting, and reclaimed water storage) and the average flow rate either provided to or demanded by the system. This flow rate encompasses all demands associated with distribution systems, rainwater harvesting infrastructure, and treatment facilities. The indicator provides insightful information about the number of days that the system can handle relying on the potential stored volume of water, not on the actual volume of stored water.

Expected evolution of the indicator

The WSC indicator will vary by region, depending on local water availability, climate conditions, and demand patterns in the DEMO. The optimal value is context-specific, but generally, a higher WSC indicates a more resilient water supply system capable of withstanding longer periods without external water inputs. However, as water supply systems integrate more non-conventional water sources (e.g., rainwater harvesting, reclaimed water, etc.), the WSC is expected to increase, improving the system's sustainability and resilience.

Possible relationship with other water indicators

Water availability, Captured runoff.

Data obtention

Sampling plan:

- Total operational volume of storage capacity, such as supply tanks, reservoirs, and reclaimed water storage (m^3)
  Fixed value of the operational volume of the storage capacity.
- Daily average inflow entering or being demanded to the DEMO system (m^3/day)
  The average can be done from data obtained from sampling at the DEMO.

Calculation formula

$$WSC = \frac{V_t}{Q_s}$$

Where:

- WSC: Water Storage Capacity (days),
- V_t: Total operational volume of storage capacity (m^3),
- Q_s: Daily average inflow entering or being demanded to the system (m^3/day).

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/
- Carollo, M., Butera, I., & Revelli, R. (2022). Water savings and urban stormwater management: Evaluation of the potentiality of rainwater harvesting systems from the building to the city scale. PLOS ONE, 17(11), e0278107. https://doi.org/10.1371/journal.pone.0278107
- Donatello S., Dodd N. & Cordella M. (2021). Level(s) indicator 3.1: Use stage water consumption user manual: introductory briefing, instructions and guidance (Publication version 1.1). JRC, European Commission.

1.2.2.6 Water Quality Compliance (WQC): Biological, Physical and Chemical Parameters

- **Code:** Mykonos_Water04
- **Environmental Sector:** Water / Water quality
- **Units:** [Compliant with regulatory standards: Yes/No]

Meaning and importance of the indicator

The indicator provides a simplified view of regulatory compliance regarding water quality, taking into account various parameters. It is especially important to validate quality standards required by current regulations. It can be evaluated for each water quality parameter: pH, temperature, DO, BOD, COD, electrical conductivity (EC), total suspended solids (TSS), total dissolved solids (TDS), nitrogen (N), ammonium (NH_4^+), phosphorus (P), metals (Cadmium (Cd) - Copper (Cu) - Lead (Pb) - Mercury (Hg) - Nickel (Ni) - Zinc (Zn), etc.), other ions (Chloride (Cl^-) - Sulphate (SO_4^{2-}) - Sodium (Na) - Potassium (K) - Calcium (Ca) - Magnesium (Mg)), total faecal coliform bacteria, PAH content, total organic carbon (TOC), Organic micropollutants such as pesticides and chemicals (polychlorinated bisphenols (PCBs) - Hexachlorocyclohexane (HCH) group compounds - Polycyclic aromatic hydrocarbons (PAHs)), other depending on legislation and needs.

Expected evolution of the indicator

The indicator should show that all measured parameters meet or exceed regulatory compliance standards over time. Optimal values vary depending on the specific parameter and local environmental regulations but should indicate no exceedance of legal thresholds for water quality. One example is:
The target could be assessed based on local policies and directives that establish the water quality limits depending on its use (water consumption, discharge, reuse, etc.).
For reclaimed water (Water Directive 2020/741), the targets would be: E. coli ≤ 10 CFU/100 m/L, BOD (Biochemical Oxygen Demand) ≤ 10 mg/L, TSS (Total Suspended Solids) ≤ 10 mg/L and Turbidity ≤ 5 NTU.
For treated wastewater (RD 509/1996 and RD 11/1995), the targets would be: TN (Total Nitrogen) 15 mg/L N (from 10,000 to 100,000 h-e) 10 mg/l N (more than 100,000 h-e), TP (Total Phosphorus) 2 mg/L P (from 10,000 to 100,000 h-e) 1 mg/L P (more than 100,000 h-e), BOD (Biochemical Oxygen Demand) 25 mg/L O_2, COD (Chemical Oxygen Demand) 125 mg/L O_2, TSS (Total Suspended Solids) 35 mg/L.
For drinking water (RD 3/2023), the targets would be: E. coli 0 CFU/100 mL, pH 6.5-9.5, Electrical Conductivity (EC) 2500 µS/cm at 20 ºC, Turbidity 4.0 NTU, Total Organic Carbon (TOC) 5.0 mg/L, Polycyclic Aromatic Hydrocarbons (PAHs) 0.10 µg/L, Arsenic 10 µg/L, Cadmium 5.0 µg/L, Chromium 25 µg/L, Mercury 1.0 µg/L, Nickel 20 µg/L, Lead 5.0 µg/L, Antimony 10 µg/L, Selenium 20 µg/L, Nitrate 50 mg/L, Nitrite 0.50 mg/L and individual pesticide 0.10 µg/L."

Possible relationship with other water indicators

Reclaimed water production, Compliant reclaimed water.

Data obtention

Sampling plan:
The quality parameters required by the current regulations or permits associated:

- Physical Parameters: pH, temperature, EC, TSS, turbidity, alkalinity, etc.
- Chemical Parameters: COD, BOD, nutrients (nitrogen, phosphorus), metals (Cd, Cu, Pb, Hg, Ni, Zn), and other ions (Cl^-, SO_4^{2-}, Na, K, Ca, Mg).

- Biological Parameters: DO, total coliform bacteria, E. coli, Legionella spp., etc.
- Organic Micropollutants: Pesticides, PCBs, polycyclic aromatic hydrocarbons (PAHs), etc.

Calculation formula

Compare Ce to Creg:
If Ce < Creg, then WQC = Yes
If Ce > Creg, then WQC = No

Where:

- Ce: average effluent concentration in pollutant concentration units.
- Creg: regulated pollutant concentration for water use in pollutant concentration units.

*To be evaluated for each pollutant.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- Boletín Oficial del Estado (1995). Real Decreto 11/1995, de 28 de diciembre, por el que se establecen las normas aplicables al tratamiento de las aguas residuales urbanas. Boletín Oficial del Estado, núm. 312, 37517-37519. https://www.boe.es/boe/dias/1995/12/30/pdfs/A37517-37519.pdf
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- Boletín Oficial del Estado (2023). Real Decreto 3/2023, de 10 de enero, por el que se establecen los criterios técnico-sanitarios de la calidad del agua de consumo, su control y suministro. https://www.boe.es/buscar/pdf/2023/BOE-A-2023-628-consolidado.pdf
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1.2.2.7 Rainfall Interception of NBS (RI)

- **Code:** Mykonos_Water05
- **Environmental Sector:** Water / Rainwater Management and Flood Protection
- **Units:** Mm/H

Meaning and importance of the indicator

The indicator measures the rate at which rainfall is intercepted by the NBS. This indicator is important for assessing the effectiveness of NBS in managing rainwater, reducing surface runoff, and mitigating flood risks. The interception capacity of NBS directly influences the hydrological balance and contributes to water retention in the ecosystem, thereby playing a vital role in flood prevention and sustainable water management.

Expected evolution of the indicator

Baseline: Initial interception capacity of the NBS.

Target: The optimal value would be a higher rate of rainfall interception compared to the baseline scenario and conventional infrastructure, leading to reduced surface runoff and enhanced groundwater recharge. This should ideally increase over time as the NBS matures and vegetation coverage expands.

Possible relationship with other water indicators

Captured runoff, Flood excess volume, Avoided floods.

Data obtention

Sampling plan:

- Volume of rainfall intercepted by the NBS (mm)

Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.

- Time duration of the rainfall event (h)

Calculation formula

$$RI = \frac{Vrainfall\ NBS}{t}$$

- RI: Rainfall Interception Rate (mm/h),
- Vrainfall NBS: The total volume of rainfall intercepted by the NBS during a given time period (mm),
- t: time duration of the rainfall event (h).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: a handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577

1.2.3 Biodiversity Indicators

1.2.3.1 Insect Sampling

- **Code:** Mykonos_Bio01
- **Environmental Sector:** Biodiversity / Insects / Pollination activity
- **Units:** Number of insects (per species or group) per trap, diversity indices

Meaning and Importance of the Indicator

Insects are crucial components of ecosystems, performing essential roles such as pollination, nutrient cycling, and natural pest control. Monitoring insect populations through both ground-dwelling and flying insect sampling gives valuable insights into ecosystem health. Pitfall traps are effective for sampling ground-dwelling insects like beetles and ants, while yellow dish traps are useful for flying insects such as flies, aphids, and small pollinators, which are attracted to the color yellow. The combination of these two methods allows for a comprehensive assessment of insect biodiversity, providing early indications of environmental stressors (e.g., pollution, habitat degradation, or pesticide application). Flying insects are often used as bioindicators for detecting changes in agricultural landscapes or ecosystems.

Expected Evolution of the Indicator

Over time, insect abundance and diversity are expected to fluctuate due to natural cycles and external pressures such as agricultural practices, climate change, or habitat modification. Healthy ecosystems should show a stable or increasing number of beneficial insects and biodiversity, while a decrease might indicate environmental stress. In this case, the presence of crops such oregano and lavender would cause for an increase in insect abundance and diversity, especially among pollination insects such as flies, bees, and coleoptera.

Data obtention

Required data:

- Number of ground-dwelling insects caught in pitfall traps, sorted by species or functional group.
- Number of flying insects trapped in yellow water traps, sorted by species or functional group.

Sampling plan:

Sampling will involve both pitfall traps for ground-dwelling insects and yellow water traps for flying insects.

Pitfall Traps:

- Pitfall traps will be buried flush with the ground surface and filled with a preservative fluid (e.g., 70% ethanol or ethylene glycol) to capture ground-dwelling insects.
- A minimum of 10 traps will be placed randomly or in a grid pattern, covering different microhabitats. Traps will remain active for 24-72 hours.

Yellow Traps (with Dish Soap Solution):

- Shallow, yellow plates or bowls (about 10-15 cm in diameter) will be filled with water and a few drops of dish soap (to break the surface tension).
- A minimum of 5 traps will be placed per site, at 1-2 meters height, suspended near areas of insect activity, such as near flowering plants, shrubs, or crops.

- The yellow color attracts flying insects, which fall into the water and are trapped due to the soap's effect on surface tension. Traps should remain active for 24-72 hours and be checked regularly to prevent overflowing or excessive insect accumulation.

Sampling Calendar

Sampling will occur monthly during peak insect activity (spring to late summer, May to September). Both pitfall traps and yellow water traps will be set up at the same time for each sampling event.

Equipment

- **Pitfall Traps:**
  - Plastic or metal cups (7-10 cm diameter, 10-15 cm deep).
  - Preservative fluid (70% ethanol or ethylene glycol).
  - GPS device for recording trap locations.
  - Labels, zip bags for sample collection, forceps, and fine brushes.
- **Yellow Water Traps:**
  - Bright yellow plates or bowls (10-15 cm diameter).
  - Water and dish soap solution.
  - Poles or stakes for placing the traps at 1-2 meters height.
  - GPS device for recording trap locations.
  - Zip bags or plastic containers for transporting collected insects to the lab.

Trap Setup:

- Pitfall traps should be buried flush with the soil surface to allow insects to fall into the trap.
- Yellow water traps should be suspended at 1-2 meters height where flying insects are most active (near plants or open spaces). After collection, insects caught in both types of traps will be transferred to labeled bags for identification. The water from yellow traps should be strained through fine mesh to collect insects for further analysis.

External Subcontracting

Yes, subcontracting may be required for taxonomic identification of insects caught in both pitfall and yellow water traps. Basic counting and identification by functional group can be done by field staff, but detailed species-level identification should be performed by entomologists or specialized labs.

References

- Southwood, T.R.E., Henderson, P.A. (2000). *Ecological Methods*. 3rd ed. Blackwell Science Ltd.
- Luff, M.L. (1975). *Some Features Influencing the Efficiency of Pitfall Traps*. Oecologia, 19(4), 345-357.
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- Moericke, V. (1951). *Yellow Water Traps as a Method for Monitoring Flying Insect Populations*. Entomological Review, 36(2), 43-51.
- Lundgren, J.G. (2009). *Relationships of Natural Enemies and Non-Prey Foods*. Springer.

1.2.4 Energy Indicators

1.2.4.1 Energy Uses in Agriculture

- **Code:** Mykonos_Energy01
- **Environmental sector:** Energy
- **Units:** kWh/m^2 land

Meaning and importance of the indicator

"Energy use in agriculture" measures the amount of energy consumed in agricultural activities, including irrigation, lighting, heating, cooling, and operating machinery and equipment. This indicator is crucial for assessing the energy efficiency and environmental impact of agricultural practices. High electricity consumption can indicate inefficiencies, leading to increased operational costs and higher carbon emissions. Conversely, optimizing electricity use enhances sustainability by reducing greenhouse gas emissions and lowering production costs, which is vital for the economic viability of farming. Monitoring this indicator helps identify opportunities for implementing energy-saving technologies and practices, such as precision agriculture, renewable energy integration, and efficient irrigation systems. Ultimately, reducing electricity use in agriculture supports broader sustainability goals, including resource conservation, climate change mitigation, and the promotion of eco-friendly farming practices.

Expected evolution of the indicator

The expected evolution of the indicator is towards greater efficiency and sustainability, driven by technological advancements, economic considerations, and environmental regulations.

Data obtention

Sampling plan:

Field measurement or assessment based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

Energy measurements would ideally be differentiated between rainwater/stormwater collection process(es) and agricultural activities. In Figure 8 (for sub-DEMO 1.2a), energy monitoring regarding water collection (if any) should be measured in SP-01 and SP-02 while, energy monitoring regarding agricultural activities should be measured in SP-03 and SP-04. In Figure 9 (for sub-DEMO 1.2b), energy monitoring regarding water collection should be measured in SP-01 (for domestic non-potable uses) considering any pumps or other equipment required to collect and distribute water to the houses, in SP-02-SP-05 (for other non-potable purposes) considering any pumps or other equipment required to collect and distribute water to the tanks and aquifer, and in SP-06-SP-07 (for agricultural activities) considering electricity, fuel and/or heat required for the agricultural activities (e.g. irrigation system, operating machinery and equipment, etc.).

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

1.2.4.2 Energy Footprint Per Kg of Food

- **Code:** Mykonos_Energy02
- **Environmental sector:** Energy
- **Units:** kWh/kg food

Meaning and importance of the indicator

"Energy footprint per kg of food" measures the total amount of energy consumed throughout the entire lifecycle of producing one kilogram of food, including energy used in farming, processing, transportation, and storage. This indicator is vital for assessing the environmental and economic sustainability of food production systems. A high energy footprint suggests inefficiencies and greater environmental impact, contributing to increased greenhouse gas emissions and higher production costs. Conversely, a lower energy footprint indicates more efficient and sustainable practices, reducing the overall environmental burden and conserving energy resources. By monitoring this indicator, stakeholders can identify areas for improvement, adopt energy-saving technologies, and implement best practices to enhance the sustainability of food production. Ultimately, reducing the energy footprint per kg of food supports global efforts towards sustainable agriculture, climate change mitigation, and resource conservation.

Expected evolution of the indicator

The expected evolution of the indicator "Energy footprint per kg of food" is towards a decreasing trend, reflecting improvements in the efficiency and sustainability of food production systems.

Data obtention method

Sampling plan:

Field measurement or based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

DEMO1.3: Sifnos

A network of 120 stone-built weirs in the Kamares catchment area, Sifnos Island (Greece) will be constructed with the aim of flood mitigation and aquifer recharge. Two water streams will be selected for the construction of small-scale stone dams which will lower the risk of floods by collecting the water in small dams and letting the water infiltrate into the ground rather than flow downstream. This increased infiltration rate will recharge the aquifers. In addition to the dams, small water storage ponds will further aid water retention for agricultural irrigation, while low rock barriers enhance water management and soil erosion control.

1.3.1 Water Indicators

1.3.1.1 Water Monitoring Plan

Sampling points

Revitalising Island Streams: Stone Dams for Flood Mitigation and Surface Water Valorisation.

Figure 8

Sampling points:

Sampling point	Location	Purpose
SP-01	Inlet and/or surface of the NBS 1 & 2	Monitor the rainfall/stormwater (volume) and the flood events (number)
SP-02	Piezometer	Monitor aquifer recharge

Parameters to be analyzed

Parameter	Applicable	Related indicators	Type

	Sampling Point		
Volume of water captured and available for other uses (i.e. aquifer recharge)	SP-01	WA; WSC; GWR	water flow measurements [volume/time]
Volume of rainfall over the NBS	SP-01	RI	water flow measurements [volume/time]
Rainwater/stormwater events	SP-01	AF	rainwater/stormwater data
Volume of groundwater recharge	SP-02	GWR	water flow measurements [volume/time] or groundwater level measurements

Sampling method

Water flow measurements:

Direct measurement of volume provided during a time period or water flow with flow meters and/or water level sensors.

a) Automatic method

Automatic flow meters can be installed at the recommended sampling points (SP). For the automatization process, it is recommended to register the measurements with a datalogger/digital control system in the DEMO. It is recommended to measure the flow at the recommended sampling points (SP).

Data should be stored in a datalogger/digital control system and then be able to be exported in a spreadsheet to calculate the associated indicators. When this is not possible, manual readings of the flow meters can be done instead.

b) Manual method

This could be applied as the last option if there is no possibility to apply the automatic method.

- Periodic manual measurements
- If no devices are available to measure, correct and reliable estimates must be made to assess the indicator.
- Measure the volume at the point of reuse or approximate the value based on the amount of water demand met by NBS for reuse.

Rainwater/stormwater data:

For the registration of rainwater or stormwater data, it is more recommended to apply online and automatic methods.

a) Automatic method

Arduino-based cameras that can detect floods, drone-derived orthophotos or satellite data can be used. Also, information from nearby meteorological/weather stations.

b) Manual method

Manual simple measurements using rain gauges could be used as the last option. These methods can give less accurate data.

Groundwater level measurements:

The variation in the water level of the aquifer can be done manually or through automatic methods.

a) Automatic method

For the groundwater recharge of the aquifer, water level sensors or remote sensing through hydrological models can be used.

b) Manual method

For the groundwater recharge of the aquifer, direct water level measurements in a period of time can be done. Measure water depth of the aquifer at the initial time and after a period of time (e.g. minutes, hours, days, etc.).

Sampling calendar

Water flow measurements and groundwater level measurements:

Data should be collected frequently for a relevant time period (e.g., daily, weekly, monthly) to allow for accumulation over the entire reporting period (yearly). This high frequency is also relevant to study seasonal variations.

Rainwater/stormwater data:

Data should be collected every time there is a rain event.

Equipment

a) Water flow measurements:

Water flow meters are essential tools for monitoring and assessing the efficiency of these systems, as they provide real-time data.

Some indicative providers of water flow meters are:

- Endress+Hauser
- Systec Controls
- Aobo instrument

Any equivalent water flow meter is acceptable, these are given as examples.

b) Rainwater/stormwater data:

In this DEMO, the main water flow measurements would be rainwater/stormwater, so there are different rain gauges that can be used for it.

Some indicative providers of are:

- OMEGA
- Amazon

c) Groundwater level measurements:

Some indicative providers of water level sensors:

- Sensor - OTT PLS-C
- Staff gauge - Fondriest

Any equivalent water level sensor is acceptable, this is given as an example.

External subcontracting

Not needed if internal technical resources are available.

1.3.1.2 Water Availability (WA)

- **Code**: Sifnos_Water01
- **Environmental Sector:** Water / Freshwater supply / Resource efficiency
- **Units:** m^3/year

Meaning and importance of the indicator

The indicator refers to the volume of water available provided by the DEMO for its reuse in various applications (e.g. aquifer recharge, ecosystem restoration, on site reuse, irrigation, industrial activities, etc.). The water available should comply with quality standards required for different reuses as per current legislation.

Expected evolution of the indicator

The baseline for this indicator is the initial water availability capacity, which may start at 0 m^3/year. It is expected to increase over time once the DEMO is operating and optimized, reflecting an improvement in water availability for reuse and ecosystem services. Ensure that 100% of the water provided by the DEMO is available for reuse.

Possible relationship with other water indicators

Water footprint, Water provision by the ecosystem.

Data obtention

Sampling plan:

- Direct annual flow of the effluent or annual volume provided by the DEMO for specific purposes (e.g., aquifer recharge, ecosystem restoration, etc.) (m^3/year).
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total volume water available in the DEMO (WA) (m^3/year).

Calculation formula

$$WA = Water\ inflows\ (WI) - Water\ losses\ (WL)$$

Where:

- WI: Total water entering the DEMO system (e.g., precipitation, surface water, groundwater recharge, recycled water) (m^3)
- WL: Total water lost (due to evaporation (m^3))

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

- United Nations Conference on Trade and Development (2023). Environmental indicators: Module B Core SDG Indicators for Entity Reporting Training Manual. https://unctad.org/system/files/information-document/UNCTAD_GCI_MANUAL_ENVIRONMENTAL-FINAL.pdf
- URBAN GreenUP (2019). D5. 3: City diagnosis and monitoring procedures. https://www.urbangreenup.eu/kdocs/1912498/urban_greenup_d5_3_city_diagnosis_and_monitoring_procedures.pdf
- U.S. Environmental Protection Agency (2024). Basic information about water reuse. https://www.epa.gov/waterreuse/basic-information-about-water-reuse

1.3.1.3 Water Storage Capacity (WSC)

- **Code:** Sifnos_Water02
- **Environmental Sector:** Water / Effectiveness of the adaptive change towards resilient infrastructure
- **Units:** days

Meaning and importance of the indicator

The indicator assesses the resilience and efficiency of water supply systems. It is defined as the ratio between the total volume of available storage (e.g., water supply tanks, reservoirs for rainwater harvesting, and reclaimed water storage) and the average flow rate either provided to or demanded by the system. This flow rate encompasses all demands associated with distribution systems, rainwater harvesting infrastructure, and treatment facilities. The indicator provides insightful information about the number of days that the system can handle relying on the potential stored volume of water, not on the actual volume of stored water.

Expected evolution of the indicator

The WSC indicator will vary by region, depending on local water availability, climate conditions, and demand patterns in the DEMO. The optimal value is context-specific, but generally, a higher WSC indicates a more resilient water supply system capable of withstanding longer periods without external water inputs. However, as water supply systems integrate more non-conventional water sources (e.g., rainwater harvesting, reclaimed water, etc.), the WSC is expected to increase, improving the system's sustainability and resilience.

Possible relationship with other water indicators

Water availability, Captured runoff.

Data obtention

Sampling plan:

- Total operational volume of storage capacity, such as supply tanks, reservoirs, and reclaimed water storage (m^3)
  Fixed value of the operational volume of the storage capacity.
- Daily average inflow entering or being demanded to the DEMO system (m^3/day)
  The average can be done from data obtained from sampling at the DEMO.

Calculation formula

$$WSC = \frac{V_t}{Q_s}$$

Where:

- WSC: Water Storage Capacity (days),
- V_t: Total operational volume of storage capacity (m^3),
- Q_s: Daily average inflow entering or being demanded to the system (m^3/day).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/
- Carollo, M., Butera, I., & Revelli, R. (2022). Water savings and urban stormwater management: Evaluation of the potentiality of rainwater harvesting systems from the building to the city scale. PLOS ONE, 17(11), e0278107. https://doi.org/10.1371/journal.pone.0278107
- Donatello S., Dodd N. & Cordella M. (2021). Level(s) indicator 3.1: Use stage water consumption user manual: introductory briefing, instructions and guidance (Publication version 1.1). JRC, European Commission.

1.3.1.4 Rainfall Interception of NBS (RI)

- **Code**: Sifnos_Water03
- **Environmental Sector:** Water / Rainwater management and flood protection
- **Units:** mm/h

Meaning and importance of the indicator

The indicator measures the rate at which rainfall is intercepted by the NBS. This indicator is important for assessing the effectiveness of NBS in managing rainwater, reducing surface runoff, and mitigating flood risks. The interception capacity of NBS directly influences the hydrological balance and contributes to water retention in the ecosystem, thereby playing a vital role in flood prevention and sustainable water management.

Expected evolution of the indicator

Baseline: Initial interception capacity of the NBS.

Target: The optimal value would be a higher rate of rainfall interception compared to the baseline scenario and conventional infrastructure, leading to reduced surface runoff and enhanced groundwater recharge. This should ideally increase over time as the NBS matures and vegetation coverage expands.

Possible relationship with other water indicators

Captured runoff, Flood excess volume, Avoided floods.

Data obtention

Sampling plan:

- Volume of rainfall intercepted by the NBS (mm)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Time duration of the rainfall event (h)

Calculation formula

$$RI = \frac{Vrainfall\ NBS}{t}$$

Where:

- RI: Rainfall Interception Rate (mm/h),
- Vrainfall NBS: The total volume of rainfall intercepted by the NBS during a given time period (mm),
- t: time duration of the rainfall event (h).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: a handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577

1.3.1.5 Increased Groundwater Recharge (GWR)

- **Code**: Sifnos_Water04
- **Environmental Sector:** Water / Water management
- **Units:** m^3

Meaning and importance of the indicator

The indicator provides information about the water volume available for groundwater recharge in comparison to the recharge without the solution, over a year. It shows how the NBS contributes to groundwater recharge.

Expected evolution of the indicator

Baseline: Initial recharge capacity.
Target: An increased recharge volume compared to the scenario without the NBS, demonstrating the effectiveness and positive impact of the NBS on groundwater recharge.

Possible relationship with other water indicators

Rainfall interception of NBS and Rainfall storage/absorption capacity of NBS, and Infiltration rate.

Data obtention

Sampling plan:

- Water captured available for recharge (m^3)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Water level in aquifer (m)
- Aquifer incoming water flow (m^3/s)

Calculation formula

If not possible and if the source is rainwater, apply "capture and infiltration method" based on annual rainfall and catchment runoff coefficient to estimate water captured for recharge.
The indicator is the sum of all volumes captured by the aquifer over the year:

$$GWR = \sum V_c$$

V_c can be determined in 2 ways:

a) From NBS water level

V_c is a function of aquifer water level. It should be determined from the aquifer design relationship between water level (WL) and volume, during the entire recharge event. WL is monitored with a water level sensor:

$V_c = \sum f(WL)$ for all time steps of recharge event

b) From available water supply

Another way to proceed is to evaluate the water flow incoming (Q_{in}) to the aquifer throughout the year:

$V_c = \sum Q_{in}$ for all time steps of recharge event.

Where:

- GWR: Increased Groundwater Recharge (m^3),
- V_c: Water captured available for recharge (m^3),
- WL: Water level in aquifer (m),
- Q_{in}: Aquifer incoming water flow (m^3/s).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- EEA (2018): CICES V5.1, 18/03/2018. https://cices.eu/resources/
- Brill, Gregg, Tien Shiao, Cora Kammeyer, Sarah Diringer, Kari Vigerstol, Naabia Ofosu-Amaah, Michael Matosich, Carla Müller-Zantop, Wendy Larson and Tim Dekker (2021). Benefit Accounting of Nature-Based Solutions for Watersheds: Guide United Nations CEO Water Mandate and Pacific Institute. Oakland, California. www.ceowatermandate.org/nbs/guide
- Reig, P. et al., (2019). Volumetric Water Benefit Accounting (VWBA): A Method for Implementing and Valuing Water Stewardship Activities. Working Paper. Washington, DC: World Resources Institute. https://www.wri.org/publication/volumetric-water-benefit-accounting

1.3.1.6 Avoided Floods (AF)

- **Code**: Sifnos_Water05
- **Environmental Sector:** Water / Rainwater management and flood protection
- **Units:** %/year

Meaning and importance of the indicator

The indicator measures the effectiveness of NBS in reducing the occurrence of flood events. It is expressed as the percentage of flood events that have been avoided due to the implementation of NBS, compared to the number of floods that would have occurred in the absence of these interventions. This indicator is applicable to NBS that are designed to retain and/or store a certain volume of stormwater/runoff. NBS retention capacity: the maximum volume of stormwater/runoff that the NBS is designed to manage. When stormwater/runoff volume exceeds the NBS capacity, it cannot be expected to retain all, and flooding may occur.

Expected evolution of the indicator

The baseline for this indicator is the averaged total number of flood events per year (minimum of 5 years) before the implementation of NBS. Ideally, the indicator should show a decrease in the number of flood events over time, reflecting the effectiveness of the NBS. The optimal value would approach 100%, indicating that all potential floods have been successfully avoided due to the NBS.

Possible relationship with other water indicators

Flood excess volume.

Data obtention

Sampling plan:

- The number of floods that did not occur due to the presence of NBS,
- The actual number of flood events observed during the period after the implementation of NBS.

Calculation formula

$$Nf = \frac{100 \cdot Nf_o}{Nf_t}$$

Where:

- Nf: Number of avoided Flood (%/year),
- Nf_t: Number of avoided flood events (n/year),
- Nf_o: Observed number of flood events (n/year).

*Only events under the capacity of the infrastructure are considered, annually.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- Barraud S., Moura P., Cherqui F. (2008). Rapport sur les indicateurs et sur les méthodes de constructions des indicateurs de performances des ouvrages d'infiltration. Agence Nationale de la Recherche, Programme PRECODD-Ecopluies. https://www.graie.org/ecopluies/delivrables/D-D2-v1.pdf

1.3.2 Biodiversity Indicators

1.3.2.1 Marsh Frog Abundance

- **Code**: Sifnos_Bio01
- **Environmental Sector**: Biodiversity / Fauna
- **Units:** Marsh frog individuals and egg masses – N

Meaning and importance of the indicator

This indicator measures the presence of the only amphibian species present in the island, the marsh frog (*Pelophylax ridibundus*). Amphibian presence is a key metric for assessing the ecological success of the habitats, as it reflects the ability of the ecosystems to support a variety of species and serves as a proxy for the presence and health of other fauna groups. Monitoring the presence of the marsh frog helps in understanding the overall impact of the restored two main streams, namely Rema Skafis Taxiarchi and Rema Tria Pigadia, on local biodiversity and ecosystem functionality.

Expected evolution of the indicator

Over time, as the ecosystems mature and the habitat conditions improve, an increase in the marsh frog abundance and reproduction in the area. The goal is to reach a stable and well-structured population that reflects the habitat's capacity to support a variety of fauna species.

Possible relationship with other indicators

The presence and abundance of amphibian's species can be influenced by the traditionally built stone weirs that will be created by the CARDIMED project, the area of fauna habitats, and other factors such as vegetation density, surface water provisioning over time, and the level of human disturbance.

Data obtention

Required data:

Number of individuals (adults and larvae), or number of egg lays observed in the Rema Skafis Taxiarchi (SE of the study area), and the Rema Tria Pigadia (NW of the study area) streams. The required data can be obtained through visual, auditive and dip net sampling to assess marsh frog abundance in the two restored streams:

- Transects along the two main streams conducting visual and auditive surveys during the day, especially early morning and late afternoon when frogs are more active. Any adult, juvenile or tadpole detected, should be recorded. Binoculars must be used to enhance visibility and detect individuals from distance before approaching the habitat**.** Listening for calling males, particularly during peak calling times and using audio recording devices can be useful for detection in low visibility areas.
- In the ponds or retained water, a more detailed survey using dip net is required in other to detect tadpoles, juveniles or adults underwater. Depending on the pond size, from one to three passes of the net dip should be conducted. After each pass, all contents must be transferred into a tray, where it should be examined to count and record any egg mass, tadpoles, juveniles or adult frogs present.

- Before and after each survey, equipment needs to be disinfected with Virkon or other virus-killing agents to prevent the diseases spread.

Figure 1. Tadpole and adult *Pelophylax ridibundus* (Author: Sergey Titov and Ookami, under creative commons license)

Sampling plan:

- **Sampling points**: Complete sampling transect along the streams are recommended. If it is not possible to sample the whole stream longitude, focus on the intervened areas and the sites with more suitable conditions for marsh frog presence, especially areas with ponds and stagnant water.
- **Time of the day**: Surveys must be conducted in the early morning (typically within 3 hours after sunrise), or late afternoon, when amphibians are most active.
- **Season:** Surveys should be conducted between April and May when amphibian activity is at its peak and is the breading season for *P. ridibundus*.

Sampling calendar

Sampling should be conducted annually to assess changes in abundance.

Equipment

Binoculars, field data sheet, GPS device or smartphone, dip net, trays or containers to examine net contents and waterproof boots (optional).

External subcontracting

No. As is the only frog species in the area, it cannot be confused by any other species.

Data sources

For baseline information, online databases can provide valuable data.

Calculation formula

N individuals = number of tadpoles + number of juveniles + number of adults

N egg mass= number of egg mass detected. Each egg mass can contain thousands of eggs.

References

- European Comission. 2021. Evaluating the Impact of Nature-based Solutions: A Handbook for Practitioners. Luxembourg. *Indicator 10.25.1 Abundance of functional groups*. doi:10.2777/244577
- Fundación Biodiversidad. 2022. Guía para la medición y seguimiento de indicadores. Convocatoria de subvenciones de la Fundación Biodiversidad F.S.P., para el fomento de actuaciones dirigidas a larenaturalización y resiliencia en ciudades españolas,

correspondiente al año 2022, en el marco del Plan de Recuperación, Transformación y Resiliencia. *Indicator BDU-006*. https://fundacion-biodiversidad.es/wp-content/uploads/2022/10/guia_indicadores_renaturb_2022_0.pdf

- LIFE MedWetRIVERS. 2015. Manual de muestreo y seguimiento de amfibios. http://lifemedwetrivers.eu/sites/default/files/documentos/02_lifemwr_anfibios_manual.pdf
- Wilkinson. 2015. Amphibian survey and monitoring handbook. Pelagic Publishing, Exeter, 120 p. ISBN 978-1-78427-003-2

1.3.2.2 Area of Mediterranean Temporary Ponds Created

- **Code**: Sifnos_Bio02
- **Environmental Sector**: Fauna habitats
- **Units:** Square meters (m^2) of mediterranean temporary ponds (3170 – Habitats Directive)

Meaning and importance of the indicator

This indicator measures the establishment of new permanent or semipermanent ponds, that provide functional habitats for fauna (e.g. birds, amphibians, and rare aquatic plant species), created by the DEMO in the basin of Kamares, the largest basin of the Sifnos area. The created stone weirs are expected to detain water, allowing it to stand still in the soil long enough providing thus a crucial habitat for important species across several different taxonomic groups. Small ponds, as in the case of the priority habitat type 3170 *Mediterranean temporary ponds* of the Habitats Directive 92/43/EEC, are expected to be created promoting biodiversity. This metric is critical for understanding the ecological value of the two restored streams, namely Rema Skafis Taxiarchi and Rema Tria Pigadia, in supporting biodiversity, serving as a key indicator of the Kamares basin ecological performance.

Expected evolution of the indicator

The total cover new 3170 habitat is expected to increase, until reaching the optimal scenario where the two restored streams serve as functional mediterranean temporary ponds in the sites where stone weirs have been created, contributing effectively to biodiversity enhancement and habitat provision.

Possible relationship with other analyses

Habitat creation may depend on the site topography, soil drainage and water retention capacity, rainfall and substrate quality, among others.

Data obtention

Required data:

Total area of new 3170 habitat created (m^2). The required data should be obtained through field sampling, supported by aerial images and GIS analysis:

- Field sampling: The visual inspection should consist in estimation of new mediterranean temporary ponds created in the sites where stone weirs have been constructed. For small ponds, a measuring tape or laser-meter can be used to estimate the total area. For larger habitats, aerial images taken by drone can be an extremely useful tool to rapidly assessing changes in habitat cover over the years. The position and height of the drone during photography should be recorded to ensure repeatability and comparability across years.
- GIS analysis using satellite imagery can be used to estimate changes in aquatic habitats at a larger scale and may help to complement field information.

Sampling plan:

- **Sampling points**: Sampling points should be stablished in the sites where stone weirs have been constructed.
- **Season:** Measures should be done during the spring month (may or early June) to enhance the possibility to detect ponds and water presence.

Sampling calendar

This indicator will be produced every year for a total of 10 years.

Equipment

Tape measure for manual measurements and sheet for noting the results, including the date, environmental conditions and observer's name. Drone with camera for aerial images.

External subcontracting

No

Data sources

Aereal images and satellite images.

Calculation formula

Total area of mediterranean temporary ponds created (m^2).

References

- Connecting nature. 2020. Nature-based solution evaluation indicators: Environmental Indicators Review. *Indicator Env56. Blue space area*.https://connectingnature.eu/sites/default/files/images/inline/CN_Env_Indicators_Review_0.pdf
- European Comission. 2021. Evaluating the Impact of Nature-based Solutions: A Handbook for Practitioners. Luxembourg. *Indicator 10.2 Area of habitats restored* doi:10.2777/244577
- Fundación Biodiversidad. 2022. Guía para la medición y seguimiento de indicadores. Convocatoria de subvenciones de la Fundación Biodiversidad F.S.P., para el fomento de actuaciones dirigidas a la renaturalización y resiliencia en ciudades españolas, correspondiente al año 2022, en el marco del Plan de Recuperación, Transformación y Resiliencia. *Indicators BDU-006 and BDU-018*. https://fundacion-biodiversidad.es/wp-content/uploads/2022/10/guia_indicadores_renaturb_2022_0.pdf
- LIFE ForOpenFotest. 2015. Monitoring protocol for the temporary pond (3170*) plant communities. https://foropenforests.org/sites/foropenforests.org/files/reports/A3_3_Monitoring%20protocol%20for%20the%20temporary%20pond%20(3170)%20plant%20communities.pdf

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CARDIMED

CLIMATE ADAPTATION AND RESILIENCE
DEMONSTRATED IN THE MEDITERRANEAN REGION

Deliverable 2.2

ANNEX B: DEMO2

DEMO2: Halcor

A smart water management system is implemented using nature-based solutions in Oinofyta (Greece). The solutions are developed and implemented at the Halcor premises, a metal industrial complex in Central Greece. The design aims to achieve a reduction in water demands, by combining the reuse of harvested of rainwater/stormwater and treated industrial wastewater.

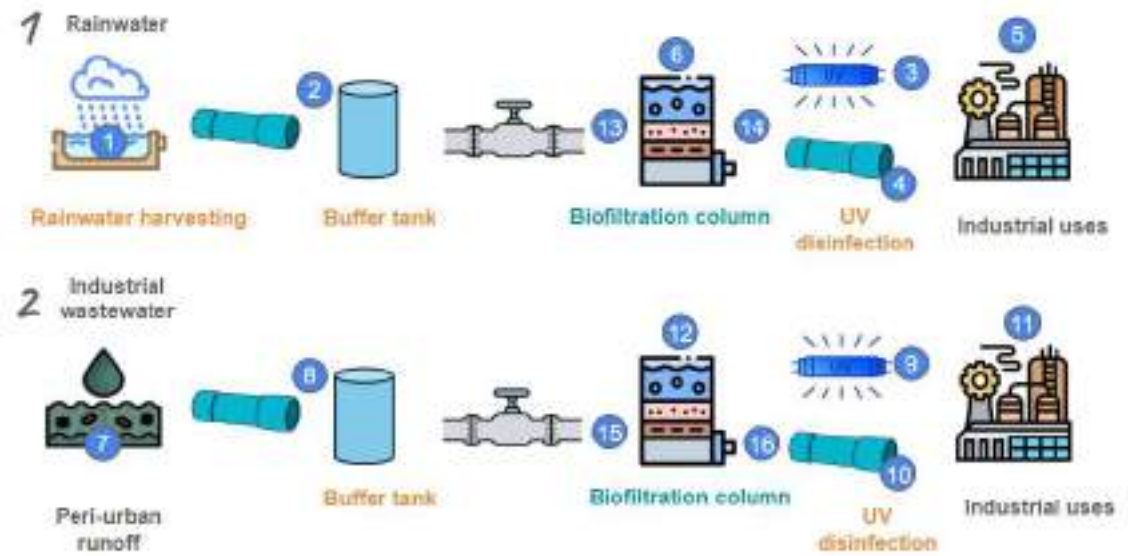
DEMO2: Halcor	Sector	Code
Effective Wastewater Treatment (WWTeff)	Water	Halcor_Water01
Effective Stormwater Treatment (SWTeff)	Water	Halcor_Water02
Reclaimed Water in Non-Potable Uses (RWnpU)	Water	Halcor_Water03
Reclaimed Water Production (RWP)	Water	Halcor_Water04
Water Availability (WA)	Water	Halcor_Water05
Water Footprint (ISO)	Water	Halcor_Water06
Water Footprint (WFP)	Water	Halcor_Water07
Water Storage Capacity (WSC)	Water	Halcor_Water08
Effluent Pollutant Removal (EPR)	Water	Halcor_Water09
Rainfall Interception of NBS (RI)	Water	Halcor_Water10
Rate of Evapotranspiration (ETrate)	Water	Halcor_Water11
Water Quality Compliance (WQC)	Water	Halcor_Water12
Avoided Floods (AF)	Water	Halcor_Water13
Captured Runoff (Vrunoff)	Water	Halcor_Water14
Flood-Excess Volume (FEV)	Water	Halcor_Water15
Linear Water Losses (LWL)	Water	Halcor_Water16
Energy Consumption for Wastewater Treatment	Energy	Halcor_Energy01
Operational energy consumption	Energy	Halcor_Energy02

2.1.1 Water Indicators

Water Monitoring Plan Halcor System A

Sampling points

Industrial symbiosis through smart water management.



Sampling point	Location	Purpose
SP-01	Inlet of the rainwater harvesting system	Monitor the rainfall interception, rainwater to be treated (efficiency of the whole treatment), and captured runoff
SP-02	Inlet of the buffer tank (Rainwater line)	Monitor water storage capacity
SP-03	Outlet of the UV disinfection (Rainwater line)	Monitor reclaimed water quality and availability (efficiency of the line treatment and volume)
SP-04	Inside the pipe to industrial uses (Rainwater line)	Monitor water losses
SP-05	Inlet of reclaimed water to industrial uses (Rainwater line)	Monitor reclaimed water quality and availability (volume)
SP-06	In the biofiltration column (Rainwater line)	Monitor evapotranspiration
SP-07	Inlet of wastewater to the treatment system (Wastewater line)	Monitor wastewater to be treated (efficiency of the whole treatment)
SP-08	Inlet of the buffer tank (Wastewater line)	Monitor wastewater to be treated (efficiency of the whole line)
SP-09	Outlet of the UV disinfection (Wastewater line)	Monitor reclaimed water quality and availability (efficiency of the line treatment and volume)
SP-10	Inside the pipe to industrial uses (Wastewater line)	Monitor water losses
SP-11	Inlet of reclaimed water to industrial uses (Rainwater line)	Monitor reclaimed water quality and availability (volume)
SP-12	In the biofiltration column (Wastewater line)	Monitor evapotranspiration
SP-13 (optional)	Inlet of the biofiltration column (Rainwater line)	Monitor biofiltration column efficiency
SP-14 (optional)	Outlet of the biofiltration column (Rainwater line)	Monitor biofiltration column efficiency
SP-15 (optional)	Inlet of the biofiltration column (Wastewater line)	Monitor biofiltration column efficiency

SP-16 (optional)	Outlet of the biofiltration column (Wastewater line)	Monitor biofiltration column efficiency

Parameters to be analyzed

Parameter	Applicable Sampling point	Related indicators	Type
Volume of rainwater treated	SP01, SP-03	RWP; WA; WFP Vrunoff; RI; FEV	water flow measurements [volume/time]
Volume of wastewater (WW) treated	SP-07, SP-09	WWTeff; RWP; WA; WFP; FEV	water flow measurements [volume/time]
Volume of reclaimed water produced	SP-03, SP-09	RWnpU; RWP; WA; WFP; WSC	water flow measurements [volume/time]
Volume of water to the buffer tank	SP-02, SP-08	WSC	water flow measurements [volume/time]
Volume of reclaimed water used for industrial purposes	SP-05, SP-11	RWnpU; WFP; WSC	water flow measurements [volume/time]
Total volume of water used for industrial purposes (reclaimed water and tap water or groundwater)	SP-05, SP-11 + external water point/s	RWnpU; WFP	water flow measurements [volume/time]
Volume of rainfall/runoff captured by the NBS (rainwater harvesting)	SP-01	RI; Vrunoff	water flow measurements [volume/time]
Rainwater/stormwater events	SP-01	AF; FEV	rainwater/stormwater data
Water quality parameters: Conductivity, pH, redox, COD, BOD5, TSS, TN, TP, TOC, temperature, turbidity, E. coli, heavy metals, anions and cations.	SP-01, SP-03, SP-07, SP-09	EPR; WQC; WFP	water quality parameters

Amount of water that is lost by evapotranspiration over a period	SP-06, SP-12	ETrate; WFP	water depth variation [mm]
Water losses in pipes	SP-04, SP-10	LWL; WFP	water flow measurements [volume/time]

Sampling method

Water flow measurements:

Direct measurement of volume provided during a time period or water flow with flow meters and/or water level sensors.

a) Automatic method

Automatic flow meters can be installed at the recommended sampling points (SP). For the automatization process, it is recommended to register the measurements with a datalogger/digital control system in the DEMO. It is recommended to measure the flow at the recommended sampling points (SP).

Data should be stored in a datalogger/digital control system and then be able to be exported in a spreadsheet to calculate the associated indicators. When this is not possible, manual readings of the flow meters can be done instead.

b) Manual method

This could be applied as the last option if there is no possibility to apply the automatic method.

- Periodic manual measurements
- If no devices are available to measure, correct and reliable estimates must be made to assess the indicator.
- Measure the volume at the point of reuse or approximate the value based on the amount of water demand met by NBS for reuse.

Water quality parameters:

Automatic measurement methods (a) or manual sampling campaigns (water sampling + laboratory analysis) (b) can be employed, with specific requirements for different types of pollutants.

a) Automatic method

Advanced sensors of water quality can be installed in the recommended sampling points (SP) to continuously monitor and measure various water quality parameters, such as temperature, pH, turbidity, dissolved oxygen, NO_3, etc. These sensors collect data in real-time, providing continuous and accurate information about water quality. The data is often transmitted wirelessly to a central database, or sensors can be also connected to a datalogger. The data is often transmitted wirelessly to a central database, or sensors can be also connected to a datalogger.

b) Manual method

As the DEMO has not been implemented yet, different sampling campaigns will be carried out periodically to control the operation and performance of the treatment system. Samples will be collected at the recommended sampling points (SP).

Two types of water quality analysis have been defined: basic and complete. Different sampling and analysis periodicities will be suggested during the start-up phase, stabilization phase and mature operation.

Basic analysis will include all water quality parameters that are required to be monitored by legislation

for reclaimed water reuse for industrial purposes: turbidity, BOD_5, E. coli, TSS (other if required by legislation).

Complete analysis includes other water quality parameters for general monitoring and indicators' assessment: conductivity, pH, redox, COD, TN, TP, TOC, temperature, heavy metals, anions and cations.

Samples can be obtained manually or using automatic sampling equipment. An automatic sampler is a device that can be refrigerated or non-refrigerated and include automatic sampling pumps and upward stage samplers. The process involves collecting water samples intended for laboratory analysis of water quality parameters. However, there are limitations associated with automatic sampling, such as intermediate sampling containers, sampling from a fixed point, and sample storage and preservation, which must be considered and documented. Personnel using these methods should have training and prior experience in the use and calibration of automatic sampling equipment.

The laboratory analysis is done following current ISO laboratory protocols for each different parameter.

Rainwater/stormwater data:

For the registration of rainwater or stormwater data, it is more recommended to apply online and automatic methods.

a) Automatic method

Drone-derived orthophotos or satellite data can be used. Also, information from nearby meteorological/weather stations.

b) Manual method

Manual simple measurements using rain gauges could be used as the last option. These methods can give less accurate data.

Water depth variation:

The variation in the water content of the biofiltration column can be done manually or through automatic methods.

a) Automatic method

Water level sensors, remote sensing through hydrological models.

b) Manual method

Direct water level measurements in a period of time. Measure water depth at the initial time and after a period of time (e.g. minutes, hours, 1 day, etc.)

Sampling calendar

Water flow measurements and water depth variation:

Data should be collected frequently for a relevant time period (e.g., daily, weekly, monthly) to allow for accumulation over the entire reporting period (yearly). This high frequency is also relevant to study seasonal variations.

Water quality parameters:

As the DEMO has not been implemented yet, different sampling and analysis periodicities will be suggested during the start-up phase, stabilization phase and mature operation:

- Start-up phase: the first 3 months of operation of the DEMO it is recommended to increase the frequency of the analysis to 1 basic analysis per week and 1 complete analysis biweekly.
- Stabilization phase: from month 4 to month 12 of operation it is recommended to do 1 basic analysis per week and 1 complete analysis per month.

- Mature operation: from month 13, the recommended frequency of water quality analysis is 1 basic analysis per week (as reclaimed water is being used in industrial activities) and 1 complete analysis bimonthly.

Rainwater/stormwater data:
Data should be collected every time there is a rain event.

Equipment

a) Water flow measurements:

Water flow meters are essential tools for monitoring and assessing the efficiency of these systems, as they provide real-time data on water movement and usage through the treatment processes and the different pipes, helping to determine the volume of water at those particular locations.
Some indicative providers of these water flow meters are:

- Endress+Hauser
- Systec Controls
- Aobo instrument

Any equivalent water flow meter is acceptable, these are given as examples.

b) Water quality parameters:

The automatic sampling method requires simple or multiparametric sensors for water quality and data loggers or digital control systems for data recording. It also requires personnel for data collection and treatment.
The manual sampling campaign requires laboratory and field personnel for manual sampling and analysis and also reagents and laboratory material depending on the current ISO laboratory protocols for each parameter.

c) Rainwater/stormwater data:

In this DEMO, the manual rainwater/stormwater data can be collected through rain gauges. Some indicative providers of are:

- OMEGA
- Amazon

d) Water depth variation:

Some indicative providers are:

- Sensor - LI-COR
- Water level sensor - ATMI

External subcontracting

Yes. A trustable laboratory delivering water quality analyses must be hired if not available internally.

Water Monitoring Plan Halcor System B

Sampling points

Industrial symbiosis through smart water management

Sampling point	Location	Purpose
SP-01	Inlet of the bioswale	Monitor the rainfall/stormwater, storage and captured runoff
SP-02	Outlet of the bioswale	Monitor reclaimed water (volume)

Parameters to be analyzed

Parameter	Applicable Sampling point	Related indicators	Type
Volume of rainfall/stormwater	SP-01	SWTeff; RWP; Vrunoff; RSAC; RI; FEV	water flow measurements [volume/time]
Volume of reclaimed water produced	SP-02	RWnpU; RWP; WSC	water flow measurements [volume/time]
Rainwater/stormwater events	SP-01	AF; FEV	rainwater/stormwater data

Sampling method

Water flow measurements:

Direct measurement of volume provided during a time period or water flow with flow meters and/or water level sensors.

a) Automatic method

Automatic flow meters can be installed at the recommended sampling points (SP). For the automatization process, it is recommended to register the measurements with a datalogger/digital control system in the DEMO. It is recommended to measure the flow at the recommended sampling points (SP).

Data should be stored in a datalogger/digital control system and then be able to be exported in a spreadsheet to calculate the associated indicators. When this is not possible, manual readings of the flow meters can be done instead.

b) Manual method

This could be applied as the last option if there is no possibility to apply the automatic method.

- Periodic manual measurements
- If no devices are available to measure, correct and reliable estimates must be made to assess the indicator.
- Measure the volume at the point of reuse or approximate the value based on the amount of water demand met by NBS for reuse.

Rainwater/stormwater data:

For the registration of rainwater or stormwater data, it is more recommended to apply online and automatic methods.

a) Automatic method

Drone-derived orthophotos or satellite data can be used. Also, information from nearby meteorological/weather stations.

b) Manual method

Manual simple measurements using rain gauges could be used as the last option. These methods can give less accurate data.

Sampling calendar

Water flow measurements:

Data should be collected frequently for a relevant time period (e.g., daily, weekly, monthly) to allow for accumulation over the entire reporting period (yearly). This high frequency is also relevant to study seasonal variations.

Rainwater/stormwater data:

Data should be collected every time there is a rain event.

Equipment

a) Water flow measurements:

Water flow meters are essential tools for monitoring and assessing the efficiency of these systems, as they provide real-time data on water movement and usage through the treatment processes and the different pipes, helping to determine the volume of water at those particular locations.

Some indicative providers of these water flow meters are:

- Endress+Hauser
- Systec Controls
- Aobo instrument

Any equivalent water flow meter is acceptable, these are given as examples.

a) Rainwater/stormwater data:

In this DEMO, the manual rainwater/stormwater data can be collected through rain gauges. Some indicative providers of are:

- OMEGA
- Amazon

External subcontracting

Not needed if internal technical resources are available.

2.1.1.1 Effective Wastewater Treatment (WWTeff)

- **Code**: Halcor_Water01
- **Environmental Sector:** Water / Safeguarded water ecosystems
- **Units:** %

Meaning and importance of the indicator

The indicator measures the percentage of wastewater that is treated in compliance with legal and regulatory standards out of the total volume of wastewater treated. Includes the wastewater treatment coverage and volumetric efficiency. The concept is based on having an overview of the share of customers that is connected to the public wastewater system or is having a local legal treatment system in place. Based on population data, the share of total generated wastewater that is being treated can then be estimated. This indicator is used to have an overview of how much wastewater is generated in an area and it's important because untreated wastewater or not complying treated wastewater will have a negative impact on ecosystems in all kinds of water bodies.

Expected evolution of the indicator

The range is from 0 to 100%, the optimal value for the WWTeff indicator is ideally 100%, indicating that all treated wastewater meets or exceeds legal standards. However, achieving and maintaining values above 90-95% is considered very good and indicative of a highly effective wastewater treatment system.

Possible relationship with other indicators

Water quality compliance: biological, physical and chemical parameters, Reclaimed Water in non-potable Uses.

Data obtention

Sampling plan:

- Volume of treated wastewater complying with legal requirements (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO. Only data that complies with legal requirements will be selected.
- Volume of wastewater generated and treated in the DEMO (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.

Calculation formula

$$WWTeff = \frac{V_{Treatment}}{WW} \cdot 100$$

Where:

- WWTeff: Effective wastewater treatment (%),
- $V_{Treatment}$: Volume of treated wastewater complying with legal requirements (m^3/year),
- WW: Volume of treated wastewater (m^3/year).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- European Commission, Directorate-General for Research and Innovation (2021). Evaluating the impact of nature-based solutions: A handbook for practitioners. Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577
- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

2.1.1.2 Effective Stormwater Treatment (SWTeff)

- **Code**: Halcor_Water02
- **Environmental Sector:** Water / Safeguarded water ecosystems
- **Units:** %

Meaning and importance of the indicator

The SWTeff indicator measures the percentage of stormwater that is treated in compliance with legal requirements before being discharged into natural water bodies, such as lakes, rivers, seas, or groundwater or being reused. This metric provides critical insight into the extent to which polluted stormwater generated in a given area is directly released into the environment without adequate treatment. The untreated polluted stormwater will have a negative impact on ecosystems in all kinds of water bodies, and the share of polluted stormwater that is treated is therefore a measure of the level of protection of water bodies.

Expected evolution of the indicator

The range is from 0 to 100%, the optimal value for the SWTeff indicator is ideally 100%, indicating that all polluted stormwater in the assessed area is treated to meet or exceed legal standards before discharge. Achieving this would mean no untreated stormwater is released into the environment, thus ensuring maximum protection for water bodies.

Possible relationship with other water indicators

Water quality compliance: biological, physical and chemical parameters, Compliant reclaimed water, Effluent pollutant removal, Avoided floods.

Data obtention

Sampling plan:

- Identified potential stormwater pollution areas where suitable treatment is implemented (m^2 or ha). Only data that corresponds to areas where suitable treatment has been implemented in the DEMO will be selected. Total potential stormwater pollution area identified (m^2 or ha).

Field area measuring and/or geographic information systems (GIS).
In order to have data on this indicator it is necessary to have three categories of data:

1. It is necessary to have an overview of all the installed and built local stormwater treatment systems, through an inventory and evaluation of the infrastructure.
2. In case of combined wastewater systems (where both stormwater and sewer are sent to treatment plants for treatment), it is necessary to have an overview of areas where stormwater is not effectively connected to the combined system, and where the stormwater instead is discharged (untreated).
3. GIS modeling procedures. It is necessary to know the areas where solutions described under point 1 and/or 2 are implemented. GIS can be used to assess the size of these areas and thus also the size of the areas not having in place a system for stormwater treatment. This way the share of the area of a city/municipality that has treatment systems in place can be estimated.

Calculation formula

$$SWTeff = \frac{A_{Treatment}}{A_{Total}} \cdot 100$$

Where:

- SWTeff: Effective stormwater treatment (%),
- $A_{Treatment}$: Identified potential stormwater pollution areas where suitable treatment is implemented (m^2 or ha),
- A_{Total}: Total potential stormwater pollution area identified (m^2 or ha).

Note: both $A_{Treatment}$ and A_{Total} must be consistent and select the same units.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- Indicator adapted from Effective Wastewater treatment (WWTeff). B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

2.1.1.3 Reclaimed Water in Non-Potable Uses (RWnpU)

- **Code**: Halcor_Water03
- **Environmental Sector:** Water / Water resource recovery and use
- **Units:** %

Meaning and importance of the indicator

The indicator measures the proportion of reclaimed water (from treated wastewater, rainwater, urban runoff, etc.) used in non-potable applications where previously drinking or freshwater was used. It is related to the total volume of water used for those purposes. This indicator provides valuable insight into the sustainable use of water resources by quantifying the extent to which reclaimed water is used for non-potable purposes.

Expected evolution of the indicator

The optimal value for the RWnpU indicator is as close to 100% as possible, indicating that the majority of non-potable water needs are met with reclaimed water, minimizing the demand for freshwater.

Possible relationship with other water indicators

Compliant reclaimed water, Water availability, Reclaimed water production, Water provision by the ecosystem.

Data obtention

Sampling plan:

- Volume of reclaimed water used for non-potable uses (e.g., irrigation, street cleaning, groundwater recharge) (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total volume of water used for non-potable uses, from all sources, including freshwater and reclaimed water (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.

Calculation formula

$$RWnpU = \frac{RW}{npW} \cdot 100$$

Where:

- RWnpU: Reclaimed Water in non-potable Uses (%),
- RW: Volume of reclaimed water used for non-potable uses (e.g., irrigation, street cleaning, groundwater recharge, industrial uses) (m^3/year),
- npW: Total volume of water used for non-potable uses, from all sources, including freshwater and reclaimed water (m^3/year).

Note: “used” may be “supplied” or “consumed” but must be consistent in RW and npW.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

2.1.1.4 Reclaimed Water Production (RWP)

- **Code**: Halcor_Water04
- **Environmental Sector:** Water / Water resource recovery and use
- **Units:** %

Meaning and importance of the indicator

The indicator measures the volume of reclaimed water produced, either for internal use or transfer to third parties, as a percentage of the total volume of treated wastewater, etc. This indicator aims to assess the level of environmental sustainability of the service in terms of circularity and the resources recovery, regarding the production of reclaimed water, obtained from the wastewater treatment. Reclaimed water means urban wastewater that has been treated in compliance with the requirements set out in Directive 91/271/EEC and which results from further treatment in a reclamation facility (EU Regulation 2020/741). However, based on further assessments, the approach to reclaimed water may need adjustment, particularly if the indicator for reclaimed water also includes treated rainwater or water from other sources. So, in this context, reclaimed water can also be considered treated water from other sources (i.e. rainwater/stormwater, greywater, etc.) which is suitable for its reuse.

Expected evolution of the indicator

The optimal value for the RWP indicator is as high as possible, ideally close to 100%, which would indicate that almost all treated wastewater (or other treated water sources) is further processed to produce reclaimed water. This contributes to more sustainable water management practices and to reduce the dependency on freshwater sources.

Possible relationship with other water indicators

Compliant reclaimed water, Water availability, Reclaimed water in non-potable uses, Effluent pollutant removal, Water footprint.

Data obtention

Sampling plan:

- Volume of reclaimed water produced under the responsibility of the utility, and which is transferred to other entities for use or for its own uses (exclude the recirculation or recycling of water, when it occurs in a closed circuit within one or more processes) (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO. Only data that complies with reclaimed water suitable for its reuse will be selected.
- Volume of wastewater treated or treated water from other sources (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.

Calculation formula

$$RWP = \frac{V_{reclaimed}}{TWW} \cdot 100$$

Where:

- RWP: Reclaimed Water Production (%),
- $V_{reclaimed}$: Volume of reclaimed water produced under the responsibility of the utility, and which is transferred to other entities for use or for its own uses (exclude the recirculation or recycling of water, when it occurs in a closed circuit within one or more processes) (m^3/year),
- TWW: Volume of wastewater treated or treated water from other sources (m^3/year).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

2.1.1.5 Water Availability (WA)

- **Code**: Halcor_Water05
- **Environmental Sector:** Water / Freshwater supply / Resource efficiency
- **Units:** m^3/year

Meaning and importance of the indicator

The indicator refers to the volume of water available provided by the DEMO for its reuse in various applications (e.g. aquifer recharge, ecosystem restoration, on site reuse, irrigation, industrial activities, etc.). The water available should comply with quality standards required for different reuses as per current legislation.

Expected evolution of the indicator

The baseline for this indicator is the initial water availability capacity, which may start at 0 m^3/year. It is expected to increase over time once the DEMO is operating and optimized, reflecting an improvement in water availability for reuse and ecosystem services. Ensure that 100% of the water provided by the DEMO is available for reuse.

Possible relationship with other water indicators

Water footprint, Water provision by the ecosystem.

Data obtention

Sampling plan:

- Direct annual flow of the effluent or annual volume provided by the DEMO for specific purposes (e.g., aquifer recharge, ecosystem restoration, etc.) (m^3/year).
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total volume water available in the DEMO (WA) (m^3/year).

Calculation formula

$$WA = Water\ inflows\ (WI) - Water\ losses\ (WL)$$

Where:

- WI: Total water entering the DEMO system (e.g., precipitation, surface water, groundwater recharge, recycled water) (m^3)
- WL**:** Total water lost (due to evaporation (m^3))

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

- United Nations Conference on Trade and Development (2023). Environmental indicators: Module B Core SDG Indicators for Entity Reporting Training Manual. https://unctad.org/system/files/information-document/UNCTAD_GCI_MANUAL_ENVIRONMENTAL-FINAL.pdf
- URBAN GreenUP (2019). D5. 3: City diagnosis and monitoring procedures. https://www.urbangreenup.eu/kdocs/1912498/urban_greenup_d5_3_city_diagnosis_and_monitoring_procedures.pdf
- U.S. Environmental Protection Agency (2024). Basic information about water reuse. https://www.epa.gov/waterreuse/basic-information-about-water-reuse

2.1.1.6 Water Footprint (ISO)

- **Code:** Halcor_Water06
- **Environmental Sector:** Water / Water resource efficiency
- **Units:** m^3/ m^3

Meaning and importance of the indicator

The Water Footprint (WF), as defined by the ISO 14046 standard, is an indicator that quantifies the potential environmental impacts associated with the water use of a product, process, or organization. This standard adopts a Life Cycle Assessment (LCA) approach to evaluate both direct and indirect water use. Key aspects of water footprint according to ISO 14046 include:

- Consumptive use: Refers to freshwater that is abstracted and either evaporates, is incorporated into products, or is returned to a different watershed or the sea after use.
- Degradative use: Involves the deterioration in water quality when the water is returned to the same basin from which it was abstracted.

The water footprint methodology evaluates the impact of water use both in terms of quantity (consumed or contaminated) and quality (degradation or restoration). It considers all inputs and outputs of water throughout the life cycle of the product, process, or organization.

Additionally, water footprint studies must consider direct water use, which refers to the amount of water used during production or treatment (e.g., drinking water, wastewater treatment), and indirect water use, which includes the water required for the production of resources (e.g., energy, chemicals, equipment) utilized in the process. Overall, the ISO 14046 standard provides a detailed framework for assessing both the quantity and the quality impacts of water use in a more comprehensive manner than traditional water footprint methodologies.

Expected evolution of the indicator

The focus will be on minimizing both consumptive and degradative water use, with an emphasis on sustainable water management and reducing the overall environmental impact. This evolution will ensure that the WF indicator becomes increasingly effective in guiding resource efficiency and mitigating water-related environmental impacts.

Possible relationship with other water indicators

Water Footprint (WFN), Water quality compliance: biological, physical and chemical parameters.

Data obtention

Sampling plan:

To assess the water footprint according to ISO 14046, the following data should be collected:

Drinking Water Production:

1. Direct water usage: The total water consumed directly by the utility for producing 1 m^3 of drinking water. This includes:
   - Water used in the entire treatment process
   - Water used for network operation (e.g., pumping)
   - Water lost through leakages in the drinking water network

2. Indirect water usage: Water required for producing the resources and materials used in drinking water production. This includes:
    - Energy consumption: Electricity and energy used in treatment and distribution processes
    - Chemicals: Used in water treatment processes
    - Infrastructure and equipment: Pipes, pumps, valves, and other treatment and distribution systems used in water production

Wastewater Treatment and Reclamation:

1. Direct water usage: The total water used for the collection, treatment, and reclamation of 1 m^3 of wastewater. This includes:
    - Water used in the treatment and reclamation facilities
    - Water used for network operations, including leakages in the reclaimed water network

2. Indirect water usage: Water used in the production of resources necessary for wastewater treatment and reclamation, such as:
    - Energy consumption: Electricity for treatment and distribution networks
    - Chemicals: Used in the wastewater treatment process
    - Equipment and infrastructure: Pipes, pumps, valves, and other materials involved in wastewater collection and treatment

Additional Environmental Impact Data:

- Raw materials and their origin; Conductivity, COD, TSS, TN, TP
- Temp; consumables (e.g. caustic soda, disinfectant, etc.);
- Energy consumption (GoO or not)
- Volume wastewater treated or reclaimed

Calculation formula

$$WFPdw = \frac{WFdw}{DWP} \; or \; WFPww = \frac{WFww}{TWW}$$

Where:

- WFdw (Water footprint in the drinking water system) and WFWW (Water footprint in the wastewater system): should be collected for every process and product that is being used in the system (this includes water used in the whole of the treatment plant, water used for operation of the network, and water which is lost through leakages in the drinking water network) through a period of time (e.g., year) (m^3/year),
- DWP: Annual drinking water production; used for drinking water systems (m^3/year),
- TWW: Volume of wastewater treated; used for wastewater systems (m^3/year).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- ISO 14046:2014(en). Environmental management — Water footprint — Principles, requirements and guidelines.
- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

2.1.1.7 Water Footprint (WFP)

- **Code:** Halcor_Water07
- **Environmental Sector:** Water / Water resource efficiency
- **Units:** m^3/m^3

Meaning and importance of the indicator

The Water Footprint (WFP) is a global indicator of freshwater resource appropriation, defined by the Water Footprint Network (WFN). It encompasses three types of water usage:
- Green water footprint: Associated with rainwater absorbed by vegetation.
- Blue water footprint: Relates to the consumption of surface and groundwater.
- Grey water footprint: Refers to the volume of freshwater required to assimilate pollutants, reflecting water contamination.

In various sectors, water footprint is mainly observed during production (blue water), contamination from chemicals (grey water), and raw material production (green, blue, and grey water). The water footprint of a product, process, or organization represents both direct and indirect water use. Direct water use refers to the water consumed and/or contaminated during production, including water incorporated in the final product. Indirect water use, on the other hand, includes water consumed for producing raw materials throughout the supply chain.

For the consumption of $1m^3$ of drinking water or the treatment of $1m^3$ of wastewater, the WF accounts for both directly used water, such as that involved in production or treatment, and indirectly used water, which pertains to the water used in creating the systems, products, and processes supporting the production or treatment. Moreover, NBS can contribute by providing water for reuse, such as for aquifer recharge, surface discharge, ecosystem restoration, or onsite reuse, further shaping the water footprint.

Expected evolution of the indicator

The expected evolution of the WF indicator, as defined by the WFN, is geared towards refining and optimizing the assessment of freshwater use and its associated impacts. As methodologies and data collection techniques advance, more precise and comprehensive value ranges are anticipated to be established, aiding in better benchmarking and management practices. There will be a growing emphasis on reducing both direct and indirect water usage through improved efficiency and sustainability measures.

Possible relationship with other water indicators

Water Footprint (ISO), Water quality compliance: biological, physical and chemical parameters.

Data obtention

Sampling plan:

To assess the water footprint of a utility, the following data must be collected:

Drinking Water Production:

1. Direct water usage: The total water used by the utility to produce 1 m^3 of drinking water. This includes water used in the treatment plant, for network operation, and water lost through leakages.
2. Indirect water usage: Water used in producing resources and products necessary for drinking water production, such as:

- Electricity and energy for treatment and distribution (pumping)
- Chemicals for treatment
- Equipment for treatment and distribution (e.g., pipes, pumps, valves)
- Data is typically collected annually or more frequently through metering systems.

Wastewater Treatment and Reclamation:

1. Direct water usage: Total water used for collecting and treating 1 m^3 of wastewater and reclaimed water, including water used in the treatment plants and for network operation, and water lost through leakages.
2. Indirect water usage: Water used in producing resources for wastewater treatment, such as:
   - Electricity and energy for treatment and distribution (pumping)
   - Chemicals for treatment
   - Equipment for treatment and distribution

Additional Data:

- Conductivity, COD, TSS, TN, TP
- Temp; consumables (e.g. caustic soda, disinfectant, etc.);
- Energy consumption (GoO or not)
- Volume wastewater treated.

Calculation formula

$$WFPdw = \frac{WFdw}{DWP} \; or \; WFPww = \frac{WFww}{TWW}$$

Where:

- WFdw (Water footprint in the drinking water system) and WFWW (Water footprint in the wastewater system): should be collected for every process and product that is being used in the system (this includes water used in the whole of the treatment plant, water used for operation of the network, and water which is lost through leakages in the drinking water network) through a period of time (e.g., year) (m^3/year),
- DWP: Annual drinking water production; used for drinking water systems (m^3/year),
- TWW: Volume of wastewater treated; used for wastewater systems (m^3/year).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- Alegre, H., Baptista, J.M., Cabrera, E., Cubillo, F., Duarte, Hirner, W., Parena, R. (2016). Performance Indicators for Water Supply Services: Third Edition. IWA Publishing, Volume 15. DOI: https://doi.org/10.2166/9781780406336.
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2.1.1.8 Water Storage Capacity (WSC)

- **Code:** Halcor_Water08
- **Environmental Sector:** Water / Effectiveness of the adaptive change towards resilient infrastructure
- **Units:** days

Meaning and importance of the indicator

The indicator assesses the resilience and efficiency of water supply systems. It is defined as the ratio between the total volume of available storage (e.g., water supply tanks, reservoirs for rainwater harvesting, and reclaimed water storage) and the average flow rate either provided to or demanded by the system. This flow rate encompasses all demands associated with distribution systems, rainwater harvesting infrastructure, and treatment facilities. The indicator provides insightful information about the number of days that the system can handle relying on the potential stored volume of water, not on the actual volume of stored water.

Expected evolution of the indicator

The WSC indicator will vary by region, depending on local water availability, climate conditions, and demand patterns in the DEMO. The optimal value is context-specific, but generally, a higher WSC indicates a more resilient water supply system capable of withstanding longer periods without external water inputs. However, as water supply systems integrate more non-conventional water sources (e.g., rainwater harvesting, reclaimed water, etc.), the WSC is expected to increase, improving the system's sustainability and resilience.

Possible relationship with other water indicators

Water availability, Captured runoff.

Data obtention

Sampling plan:

- Total operational volume of storage capacity, such as supply tanks, reservoirs, and reclaimed water storage (m^3)
  Fixed value of the operational volume of the storage capacity.
- Daily average inflow entering or being demanded to the DEMO system (m^3/day)
  The average can be done from data obtained from sampling at the DEMO.

Calculation formula

$$WSC = \frac{V_t}{Q_S}$$

Where:

- WSC: Water Storage Capacity (days),
- V_t: Total operational volume of storage capacity (m^3),
- Q_s: Daily average inflow entering or being demanded to the system (m^3/day).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/
- Carollo, M., Butera, I., & Revelli, R. (2022). Water savings and urban stormwater management: Evaluation of the potentiality of rainwater harvesting systems from the building to the city scale. PLOS ONE, 17(11), e0278107. https://doi.org/10.1371/journal.pone.0278107
- Donatello S., Dodd N. & Cordella M. (2021). Level(s) indicator 3.1: Use stage water consumption user manual: introductory briefing, instructions and guidance (Publication version 1.1). JRC, European Commission.

2.1.1.9 Effluent Pollutant Removal (EPR)

- **Code**: Halcor_Water09
- **Environmental Sector:** Water / Water treatment / Water quality
- **Units:** %

Meaning and importance of the indicator

The indicator measures the average removal ratio between incoming and outgoing pollution load of the NBS. It can be evaluated for any pollutant. It is used to assess the effectiveness of water treatment processes in reducing pollution before discharge into the environment or wastewater treatment plant or its reuse.

*If there are additional water treatments in combination with the NBS, we recommend sampling before and after each treatment to have a better understanding of the role of each one in the treatment process.

Expected evolution of the indicator

The target can be determined based on design requirements (e.g., why the NBS is necessary, which pollutant needs to be addressed, and the desired removal efficiency) or according to local regulations and guidelines that define water quality standards depending on its intended use (such as for consumption, discharge, or reuse). For reclaimed water (as per Water Directive 2020/741), the goals would be: 95% removal of microbiological and emerging contaminants, 60-95% removal of nutrient pollutants, and 95% removal of physico-chemical parameters (such as turbidity). For treated wastewater (under RD 509/1996 and RD 11/1995), the objectives would include 70-80% reduction of nutrient pollutants and 90% removal of physico-chemical parameters (such as turbidity).

Possible relationship with other water indicators

Reclaimed water production, Environmental flow requirement compliance rate, Safe drinking water, Water quality compliance: biological, physical and chemical parameters.

Data obtention

Sampling plan:

- Average influent concentration (mg/L).
- Average effluent concentration (mg/L).

Water quality parameters:

- Physical-chemical properties data:
  - - pH (unitless)
  - - Temperature (ºC)
  - - Electrical Conductivity (EC) (µS/cm)
  - - Turbidity (NTU)
  - - TSS (Total Suspended Solids) (mg/L)
- Biological data:
  - - DO (Dissolved Oxygen) (mg/L O_2)
  - - BOD (Biochemical Oxygen Demand) (mg/L O_2)
  - - COD (Chemical Oxygen Demand) (mg/L O_2)
  - - TOC (Total Organic Carbon) (mg/L O_2)
- Chemical pollutant data:

- - Heavy metals (µg/L)

- Total hydrocarbons (µg/L)

- Nutrients data:
  - - TN (Total Nitrogen) (mg/L N)
  - - NO_3 (Nitrates) (mg/L)
  - - TP (Total Phosphorus) (mg/L P)
  - - PO_4 (Phosphates) (mg/L)
- Microbiological data:
  - - E. Coli (CFU/100 mL)
- Other specific pollutants data:
  - - Contaminants of emerging concern
  - - Pollutants from industrial effluents will be added if necessary.

Calculation formula

$$\%Re = \frac{(Ci - Ce)}{Ci} \cdot 100$$

Where:

- %Re: average effluent pollutant removal (%),
- Ci: average influent concentration (mg/L),
- Ce: average effluent concentration (mg/L).

*To be evaluated for each pollutant.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: A handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577
- Boletín Oficial del Estado (2023). Real Decreto 3/2023, de 10 de enero, por el que se establecen los criterios técnico-sanitarios de la calidad del agua de consumo, su control y suministro. https://www.boe.es/buscar/pdf/2023/BOE-A-2023-628-consolidado.pdf
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- Boletín Oficial del Estado (1996). Real Decreto 509/1996, de 15 de marzo, de desarrollo del Real Decreto-ley 11/1995, de 28 de diciembre, por el que se establecen las normas aplicables al tratamiento de las aguas residuales urbanas. https://www.boe.es/buscar/pdf/1996/BOE-A-1996-7159-consolidado.pdf
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2.1.1.10 Rainfall Interception of NBS (RI)

- **Code**: Halcor_Water10
- **Environmental Sector:** Water / Rainwater management and flood protection
- **Units:** mm/h

Meaning and importance of the indicator

The indicator measures the rate at which rainfall is intercepted by the NBS. This indicator is important for assessing the effectiveness of NBS in managing rainwater, reducing surface runoff, and mitigating flood risks. The interception capacity of NBS directly influences the hydrological balance and contributes to water retention in the ecosystem, thereby playing a vital role in flood prevention and sustainable water management.

Expected evolution of the indicator

Baseline: Initial interception capacity of the NBS.

Target: The optimal value would be a higher rate of rainfall interception compared to the baseline scenario and conventional infrastructure, leading to reduced surface runoff and enhanced groundwater recharge. This should ideally increase over time as the NBS matures and vegetation coverage expands.

Possible relationship with other water indicators

Captured runoff, Flood excess volume, Avoided floods.

Data obtention

Sampling plan:

- Volume of rainfall intercepted by the NBS (mm)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Time duration of the rainfall event (h)

Calculation formula

$$RI = \frac{Vrainfall\ NBS}{t}$$

Where:

- RI: Rainfall Interception Rate (mm/h),
- Vrainfall NBS: The total volume of rainfall intercepted by the NBS during a given time period (mm),
- t: time duration of the rainfall event (h).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: a handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577

2.1.1.11 Rate of Evapotranspiration (ETrate)

- **Code**: Halcor_Water11
- **Environmental Sector:** Water / Water management / Resource efficiency
- **Units:** mm/m^2 day

Meaning and importance of the indicator

The rate of evapotranspiration (ETrate) measures the amount of water vapor released into the atmosphere from both soil and plant surfaces over a given period of time. This indicator helps to understand the water balance within the urban environment and assess the effectiveness of the NBS, crops, forest, soils, etc. in managing water resources. Evapotranspiration plays a significant role in the hydrological cycle, influencing local climate conditions, water availability, and thermal comfort in urban areas. By monitoring the ETrate, the impact of vegetation, green spaces, and other NBS on water conservation, irrigation needs, and heat mitigation can be assessed. This indicator can be assessed, for example, in constructed wetlands, soils, fields, etc.

Expected evolution of the indicator

The ETrate is expected to vary with seasonal changes, vegetation cover, and weather conditions. In urban areas with well-implemented NBS, a higher ETrate is generally desirable during warmer months as it indicates effective cooling through latent heat flux. However, in water-scarce regions, the optimal ETrate would balance cooling needs with water conservation, preventing excessive water loss. The ideal range will depend on the specific urban context, including climate, vegetation type, and water availability. The following table shows the normal good levels of evapotranspiration in mm/year depending on the region or geographical context where it is found in the world.

Region/Context	Good annual levels, mm/year
Arid regions	200-500
Temperate regions	500-700
Humid/tropical regions	800-1500

Note: Allen, R. G. et al. (1998).

For example, urban parks which are considered temperate regions, have good levels of evapotranspiration at the range of 500-800 mm/year. Another example are agricultural fields (e.g., corn), which levels are between 400-700 mm/year.

The table below provides estimates of annual evapotranspiration values (mm/year) in different climate regions, categorized by temperature and humidity conditions. This helps to illustrate how evapotranspiration varies not only by thermal regime but also by region type, whether tropical, subtropical, or temperate:

Region/Temperature	Cold (10ºC), mm/year	Moderate (20ºC), mm/year	Warm (30ºC), mm/year
Humid and sub-humid (tropics/subtropics)	730 - 1095	1095 - 1825	1825 – 2555
Arid and semi-arid (tropics/subtropics)	730 - 1460	1460 - 2190	2190 – 2920
Humid and sub-humid (temperature zone)	365 - 730	730 - 1460	1460 – 2555
Arid and semi-arid (temperature zone)	365 - 1095	1460 - 2555	2190 – 3285

Note: Cherlinka, V. (2023).

Possible relationship with other water indicators

Water footprint, Rainfall interception of NBS, Rainfall storage/absorption capacity of NBS.

Data obtention

Sampling plan:

- Amount of water that is lost by evapotranspiration over the period (mm),
- Area of study or the NBS from the DEMO (m^2),
- Time period for the study (days).

Calculation formula

$$ETrate = \frac{ETt}{A \cdot t}$$

Where:

- ETrate: Rate of evapotranspiration ($mm/m^2 \cdot day$),
- ETt: Total evapotranspiration over the period (mm),
- t: Time period (days),
- A: Area of study or the NBS (m^2).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- Allen, R. G., Pereira, L. S., Raes, D., Smith, M. (1998). Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage paper. Food and Agriculture Organization of the United Nations. Rome https://www.fao.org/4/x0490e/x0490e00.htm
- Cherlinka, V. (2023). Evapotranspiration in agriculture and its measuring methods. EOS Data Analytics. https://eos.com/blog/evapotranspiration/

- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: a handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577
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2.1.1.12 Water Quality Compliance (WQC): Biological, Physical and Chemical Parameters

- **Code:** Halcor_Water12
- **Environmental Sector:** Water / Water quality
- **Units:** [Compliant with regulatory standards: Yes/No]

Meaning and importance of the indicator

The indicator provides a simplified view of regulatory compliance regarding water quality, taking into account various parameters. It is especially important to validate quality standards required by current regulations. It can be evaluated for each water quality parameter: pH, temperature, DO, BOD, COD, electrical conductivity (EC), total suspended solids (TSS), total dissolved solids (TDS), nitrogen (N), ammonium (NH_4^+), phosphorus (P), metals (Cadmium (Cd) - Copper (Cu) - Lead (Pb) - Mercury (Hg) - Nickel (Ni) - Zinc (Zn), etc.), other ions (Chloride (Cl^-) - Sulphate (SO_4^{2-}) - Sodium (Na) - Potassium (K) - Calcium (Ca) - Magnesium (Mg)), total faecal coliform bacteria, PAH content, total organic carbon (TOC), Organic micropollutants such as pesticides and chemicals (polychlorinated bisphenols (PCBs) - Hexachlorocyclohexane (HCH) group compounds - Polycyclic aromatic hydrocarbons (PAHs)), other depending on legislation and needs.

Expected evolution of the indicator

The indicator should show that all measured parameters meet or exceed regulatory compliance standards over time. Optimal values vary depending on the specific parameter and local environmental regulations but should indicate no exceedance of legal thresholds for water quality. One example is:
The target could be assessed based on local policies and directives that establish the water quality limits depending on its use (water consumption, discharge, reuse, etc.).
For reclaimed water (Water Directive 2020/741), the targets would be: E. coli ≤ 10 CFU/100 m/L, BOD (Biochemical Oxygen Demand) ≤ 10 mg/L, TSS (Total Suspended Solids) ≤ 10 mg/L and Turbidity ≤ 5 NTU.
For treated wastewater (RD 509/1996 and RD 11/1995), the targets would be: TN (Total Nitrogen) 15 mg/L N (from 10,000 to 100,000 h-e) 10 mg/l N (more than 100,000 h-e), TP (Total Phosphorus) 2 mg/L P (from 10,000 to 100,000 h-e) 1 mg/L P (more than 100,000 h-e), BOD (Biochemical Oxygen Demand) 25 mg/L O_2, COD (Chemical Oxygen Demand) 125 mg/L O_2, TSS (Total Suspended Solids) 35 mg/L.

Possible relationship with other water indicators

Reclaimed water production, Compliant reclaimed water.

Data obtention

Sampling plan:
The quality parameters required by the current regulations or permits associated:
Physical Parameters: pH, temperature, EC, TSS, turbidity, alkalinity, etc.
Chemical Parameters: COD, BOD, nutrients (nitrogen, phosphorus), metals (Cd, Cu, Pb, Hg, Ni, Zn), and other ions (Cl^-, SO_4^{2-}, Na, K, Ca, Mg).
Biological Parameters: DO, total coliform bacteria, E. coli, Legionella spp., etc.
Organic Micropollutants: Pesticides, PCBs, polycyclic aromatic hydrocarbons (PAHs), etc.
See more information at the individual DEMO Monitoring Plan.

Calculation formula

Compare Ce to Creg:
If Ce < Creg, then WQC = Yes
If Ce > Creg, then WQC = No

Where:
Ce: average effluent concentration in pollutant concentration units.
Creg: regulated pollutant concentration for water uses in pollutant concentration units.
*To be evaluated for each pollutant.
For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- Boletín Oficial del Estado (1995). Real Decreto 11/1995, de 28 de diciembre, por el que se establecen las normas aplicables al tratamiento de las aguas residuales urbanas. Boletín Oficial del Estado, núm. 312, 37517-37519. https://www.boe.es/boe/dias/1995/12/30/pdfs/A37517-37519.pdf
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2.1.1.13 Avoided Floods (AF)

- **Code**: Halcor_Water13
- **Environmental Sector:** Water / Rainwater management and flood protection
- **Units:** %/year

Meaning and importance of the indicator

The indicator measures the effectiveness of NBS in reducing the occurrence of flood events. It is expressed as the percentage of flood events that have been avoided due to the implementation of NBS, compared to the number of floods that would have occurred in the absence of these interventions. This indicator is applicable to NBS that are designed to retain and/or store a certain volume of stormwater/runoff. NBS retention capacity: the maximum volume of stormwater/runoff that the NBS is designed to manage. When stormwater/runoff volume exceeds the NBS capacity, it cannot be expected to retain all and flooding may occur.

Expected evolution of the indicator

The baseline for this indicator is the averaged total number of flood events per year (minimum of 5 years) before the implementation of NBS. Ideally, the indicator should show a decrease in the number of flood events over time, reflecting the effectiveness of the NBS. The optimal value would approach 100%, indicating that all potential floods have been successfully avoided due to the NBS.

Possible relationship with other water indicators

Flood excess volume.

Data obtention

Sampling plan:

The number of floods that did not occur due to the presence of NBS,

The actual number of flood events observed during the period after the implementation of NBS.

Calculation formula

$$Nf = \frac{100 \cdot Nf_o}{Nf_t}$$

Where:

- Nf: Number of avoided Flood (%/year),
- Nf_t: Number of avoided flood events (n/year),
- Nf_o: Observed number of flood events (n/year).

*Only events under the capacity of the infrastructure are considered, annually.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- Barraud S., Moura P., Cherqui F. (2008). Rapport sur les indicateurs et sur les méthodes de constructions des indicateurs de performances des ouvrages d'infiltration. Agence Nationale de la Recherche, Programme PRECODD-Ecopluies. https://www.graie.org/ecopluies/delivrables/D-D2-v1.pdf

2.1.1.14 Captured Runoff (Vrunoff)

- **Code**: Halcor_Water14
- **Environmental Sector:** Water / Rainwater management and flood protection
- **Units:** %/year

Meaning and importance of the indicator

This indicator provides the volume of stormwater runoff captured by the NBS, based on the NBS design capacity. This is essential for assessing the effectiveness of NBS in managing stormwater, preventing floods, and improving water quality. Capturing runoff effectively helps to mitigate the risk of flooding, reduce the burden on conventional drainage systems, and enhance the sustainability of water resources by promoting infiltration and storage of rainwater.

Expected evolution of the indicator

The ideal value for this indicator is 100%, indicating that the NBS is capturing runoff efficiently, in line with its design capacity. Over time, the indicator should approach or maintain a value close to 100%, reflecting the successful management of runoff by the NBS.

Possible relationship with other water indicators

Avoided floods, Flood excess volume.

Data obtention

Sampling plan:

- Annual volume of runoff captured by NBS over a year (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total number of runoff events per year (nº)
  See more information at the individual DEMO Monitoring Plan.
- NBS capture capacity (m^3)
  The total volume of the NBS that is able to receive runoff. The total volume of the NBS that is able to receive runoff, rainwater, stormwater, or any other water flow with runoff potential. It should be a constant value. But maybe some clogging may occur during the operation of the NBS and the capacity can decrease over time, so it should be measured periodically.

Calculation formula

$$Vrunoff = \left(\frac{V_C}{V_S \cdot N}\right)$$

Where:

- Vrunoff: Captured runoff (%/year),
- V_c: Annual runoff captured by NBS (m^3/year),
- N: Number of runoff events per year (n),
- V_s: NBS capture capacity (m^3).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

2.1.1.15 Flood-Excess Volume (FEV)

- **Code**: Halcor_Water15
- **Environmental Sector:** Water / Rainwater management and flood protection
- **Units:** m^3

Meaning and importance of the indicator

The indicator helps to quantify the volume of water that contributes to flooding, and therefore the volume of flood water that should be mitigated (i.e. reduced to zero) by the cumulative effect of various flood mitigation measures (i.e. NBS implementation). This indicator is useful as a complementary way of classifying flood events and evidence-based decision-making for flood-mitigation schemes.

Expected evolution of the indicator

Over time, the FEV should decrease as more effective flood mitigation measures, including NBS, are implemented. The last goal is to reduce the FEV to 0 m^3, indicating that all excess water is managed without causing flooding.

Possible relationship with other water indicators

Avoided floods, Rainfall interception.

Data obtention

Sampling plan:

Total volume of water potential to cause flood (m^3)

Continuous monitoring of runoff and rainwater/stormwater events.

Capacity of the infrastructure (i.e. NBS, DEMO) to manage water before flooding occurs (m^3)

The total volume of the NBS that is able to receive runoff, rainwater, stormwater, or any other water flow with flooding potential. It should be a constant value. But maybe some clogging may occur during the operation of the NBS and the capacity can decrease over time, so it should be measured periodically.

Calculation formula

$$FEV = V_{flood} - V_{capacity}$$

Where:

- FEV: Flood Excess Volume (m^3),
- V_{floodl}: Total volume of water potential to cause flood (m^3),
- $V_{capacity}$: Capacity of the infrastructure (i.e. NBS, DEMO) to manage water before flooding occurs (m^3).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: a handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577

- Kelmanson, M. A., & Bokhove, O. (2018). Using flood-excess volume to quantify and communicate flood-mitigation schemes. DARE. University of Reading. https://research.reading.ac.uk/dare/2018/09/27/using-flood-excess-volume-to-quantify-and-communicate-flood-mitigation-schemes/
- O. Bokhove, M. Kelmanson, T. Kent (2018): Using flood-excess volume in flood mitigation to show that upscaling beaver dams for protection against extreme floods proves unrealistic. Subm. evidence-synthesis article: Proc. Roy. Soc. A https://eartharxiv.org/repository/view/1283/

2.1.1.16 Linear Water Losses (LWL)

- **Code**: Halcor_Water16
- **Environmental Sector:** Water / Effectiveness of the adaptive change towards resilient infrastructure
- **Units:** m^3/year·km

Meaning and importance of the indicator

The Linear Water Losses (LWL) indicator measures the efficiency of a water supply system by quantifying the volume of water lost per kilometer of supply and/or distribution pipeline over a year. Water losses can occur due to leaks, pipe breaks, or other inefficiencies within the distribution network.

Expected evolution of the indicator

The baseline value should be established by assessing the initial water loss rates in the supply and distribution network at the beginning of the monitoring period. The ideal trend for the LWL indicator is a decrease over time, indicating improved efficiency and reduced water losses in the distribution network. The optimal value for this indicator would be as low as possible, ideally approaching 0 m^3/year·km, signifying minimal water loss across the network.

Possible relationship with other water indicators

Water provision by the ecosystem (Wavailable).

Data obtention

Sampling plan:

Volume of annual water losses (m^3/year)

Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.

Total length of the supply and distribution pipelines, excluding the user branches (or connection pipelines), at the assessment date of the assessment year (km)

Calculation formula

$$LWL = \frac{V_{loss}}{L_{net}}$$

Where:

- LWL: Linear Water Losses (m^3/year$^-$·km),
- V_{loss}: Total volume of water lost over the course of the year (m^3/year),
- L_{net}: Total length of the supply and distribution pipelines, excluding user branches (km).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

2.1.2 Energy Indicators

2.1.2.1 Energy Consumption for (Waste)water Treatment

- **Code**: Halcor_Energy01
- **Environmental Sector**: Energy
- **Units**: kWh/m^3 wastewater

Meaning and importance of the indicator

"Energy Consumption for (Waste)water Treatment" measures the amount of energy (mainly electricity) used in the processes involved in treating (waste)water to make it safe for discharge or reuse. This indicator is crucial for evaluating the sustainability and efficiency of (waste)water treatment facilities. High energy consumption can indicate inefficiencies and result in increased operational costs and higher carbon emissions, which are detrimental to both economic and environmental goals. Conversely, optimizing energy use in (waste)water treatment can lead to significant cost savings, lower greenhouse gas emissions, and a reduced environmental footprint. Monitoring this indicator helps in identifying opportunities for implementing energy-saving technologies and practices, such as using more efficient equipment, improving process controls, and integrating renewable energy sources. Ultimately, reducing energy consumption in (waste)water treatment supports broader sustainability objectives by minimizing resource use and contributing to climate change mitigation.

Expected evolution of the indicator

The expected evolution of the indicator "Energy Consumption for (Waste)water Treatment" is towards decreasing energy use per unit of treated (waste)water, reflecting improvements in efficiency and sustainability of treatment processes. This evolution is driven by technological advancements, better operational practices, and increased regulatory and policy pressures to reduce environmental impact.

Data acquisition

Field measurement or assessment based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.
Energy consumed for treating the different water sources in this sub-DEMO should be differentiated – e.g. kWh/m^3 of WW, kWh/m^3 of rainwater, kWh/m^3 of stormwater.

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

2.1.2.2 Operational energy consumption

- **Code**: Halcor_Energy02
- **Environmental Sector**: Energy
- **Units**: kWh

Meaning and importance of the indicator

"Operational energy consumption" of a (waste)water treatment system measures the amount of energy required to run all processes involved in collecting, treating (waste)water and producing reclaimed water for industrial applications. This indicator is crucial for evaluating the efficiency and sustainability of (waste)water treatment and production operations. High operational energy consumption can indicate inefficiencies and lead to increased operational costs and higher greenhouse gas emissions. Conversely, optimizing energy consumption enhances the sustainability of the treatment process by reducing costs, minimizing environmental impact, and conserving energy resources. Monitoring this indicator helps identify areas for improvement, enabling the implementation of energy-saving technologies and practices. Ultimately, reducing operational energy consumption supports broader sustainability goals, including resource conservation, climate change mitigation, and the promotion of eco-friendly infrastructure.

Expected evolution of the indicator

The expected evolution of the indicator "Energy consumption" for a (waste)water treatment system is towards a reduction in energy use per unit of wastewater input, driven by technological advancements, process optimization, and regulatory and market pressures for greater sustainability.

Data obtention

Required data

Field measurement or assessment based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

The total operational energy consumption of the company (i.e. energy required to run all processes in order to generate their products) should also be provided to ensure the energy required for water treatment and production does not significantly increases the total energy requirements of the company.

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

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ANNEX C: DEMO3

DEMO3: Sardinia

The wastewater plant of San Marco, Sardinia Island (Italy) is treating water to be reused in agriculture.

The treated effluents will be stored in tanks to be used when needed, following two different pathways. First, agricultural runoff will be treated through a riparian buffer before it is discharged into the river or nearby surface waters. Water quality will be monitored. Second, to another agricultural zone in which agricultural runoff will be treated in a free water surface constructed wetland. Once the agricultural runoff water has been treated by the constructed wetland, a part of the effluent will be used to grow fish in fish tanks. A solar energy plant will provide the energy for wastewater treatment and irrigation systems. In the two agricultural zones, a five-year rotation has been designed in which a winter cereal (wheat), a summer cereal (corn or rice), and a perennial crop (alfalfa) will alternate. The crop rotation will be managed according to the principles of integrated agricultural systems. Moreover, livestock effluents will be used for soil fertilization. This NbS system is aimed to reduce the water stress and the water consumption of the crops while improving its physiology and increase water productivity.

DEMO3: Sardinia	Sector	Code
Soil Physical and Chemical Fertility	Soil	Sardinia_Soil01
Hydrological Regulation	Soil	Sardinia_Soil02
Soil Organic Carbon Content	Soil	Sardinia_Soil03
Water Holding Capacity	Soil	Sardinia_Soil04
Soil Biodiversity	Soil	Sardinia_Soil05
Agricultural Water Withdrawal (AWW)	Water	Sardinia_Water01
Compliant Reclaimed Water (CtotalRW)	Water	Sardinia_Water02
Effluent Pollutant Removal (EPR)	Water	Sardinia_Water03
Reclaimed Water in Non-Potable Uses (RWnpU)	Water	Sardinia_Water04
Reclaimed Water Production (RWP)	Water	Sardinia_Water05
Water Availability (WA)	Water	Sardinia_Water06
Water Footprint (ISO)	Water	Sardinia_Water07
Water-Related Materials' Recovery (WR)	Water	Sardinia_Water08
KPI2 - Energy Recovered/Saved	Energy	Sardinia_Energy01
KPI3 - Reduction of The Energy Footprint Per Unit of Water	Energy	Sardinia_Energy02
KPI4 - Energy / CO2 Footprint of Irrigation Systems	Energy	Sardinia_Energy03
KPI5 - Water-Energy-Food-Carbon Footprint of The Integrated System	Energy	Sardinia_Energy04
KPI6 - Energy Saving from Rainwater Removed from Combined Sewer and Not Treated in Centralized Wastewater Treatment Plant	Energy	Sardinia_Energy05
KPI7 – Renewable Energy Sources (RES) Units Integrated and Capacity	Energy	Sardinia_Energy06
KPI8 - Gross Renewable Consumption Relative to Total Gross Final Consumption	Energy	Sardinia_Energy07
KPI9 - Increase in Renewable Energy Use in the Area	Energy	Sardinia_Energy08
Sustainable Energy Practices	Energy	Sardinia_Energy09
Energy Consumption for Wastewater Treatment	Energy	Sardinia_Energy10
Energy Footprint Per Kg of Food	Energy	Sardinia_Energy11

3.1.1 Soil Indicators

3.1.1.1 Soil Physical and Chemical Fertility

- **Code:** Sardinia_Soil01
- **Environmental Sector:** Soil / Soil Health
- **Units:** A Multi-Component Indicator. Diverse Units for Specific Components

Meaning and importance of the indicator

Soil productive capacity (a key soil ecosystem service) is the result of complex interactions between biological, chemical and physical properties. Achieving and maintaining appropriate levels of physical and chemical soil fertility is of chief importance for sustainable cropland management and, at large scale, for food security. Nutrients naturally arrive to soil from geological materials, water, atmospheric deposition, and decomposition of plant and animal residues. Nutrient availability to crops is significantly affected by soil acidity (pH), and nutrient presence in the soil solution is highly dependent on soil texture and soil cation exchange capacity; water provision to plants is notably improved by soil organic matter. Soil electrical conductivity warns about soil salinity, a serious risk for crops under Mediterranean conditions. Soil analysis is the basic tool to evaluate soil fertility and to guide farmers towards sustainable management.

Expected evolution of the indicator

There are recommended ranges and critical values for most of the soil components to be analyzed. For a given crop (the five-year rotation scheme including a winter cereal, a summer cereal, and a perennial forage crop, in this case), these values should be available from local and regional farmer associations. Most generally, together with the results of soil analyses, agricultural laboratories provide an evaluation of the level of each analysed parameter (deficient – correct – excessive or similar). The value of each parameter should evolve towards these reference values. The exception is "Texture", a soil property that is not expected to be significantly affected by changes in irrigation.

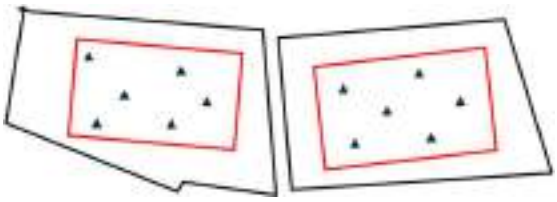
Data obtention

Required data:

- To be analysed only the first Time: soil texture (% sand; % clay; % silt); textural class.
- To be analysed at each soil sampling campaign: pH; Electrical conductivity (CEC); Total organic carbon (%, dry soil basis); Carbonates; Total nitrogen (Kjeldahl); Available phosphorus (Olsen); Cation exchange capacity; Interchangeable bases (Ca, Mg, Na and K); Micronutrients (Fe, Zn, Mn).

Sampling plan:

Field sampling followed by lab analyses. Soil will be always sampled for fertility at the same period of the year and in the same day for the two experimental fields and external controls. Whatever the month you choose (we suggest spring months), try to sample soil before (or as late as possible after) any agricultural operations that disturb soil physical structure (e.g. ploughing, tillage …) or chemistry (e.g. fertilizer supply). The intention of monitoring soil in this study case is to assess the effect of irrigation with treated water on soil quality. Unfortunately, there is no experimental control, that should consist of two plots supporting the same agricultural management implemented in the treatment plots and differing from them only by irrigation. Therefore, it is highly recommended to try to create these control plots or, as a second option, to identify farms in the closest vicinity totally comparable to the experimental site in soil and management and only differing from treatment plots by irrigation. In the absence of controls, soil monitoring will only inform on the physical and chemical evolution of soil under the proposed rotation when reused water is provided.



At each of the two experimental plots (Zone 1 & Zone 2) soil will be sampled with the 15 cm depth soil borer described in the "equipment" section. At each plot, six soil samples will be taken at 6 points randomly distributed in the central part of the plots (avoid sampling plot edges). The six samples of each field will be pooled in pairs into three plastic zip bags (per zone) duly labelled with the date and the name of the field (Zone 1/Zone 2). The resulting 6 soil samples will be sent to an expert lab for analysis as soon as possible. The soil lab must have been previously consulted for instructions about the preparation of the samples before shipping.

Sampling calendar

The two fields will be sampled in the proposed dates every two years for 10 years (5 times, Two rotation cycles).

Equipment

Samples will be extracted from soil with soil borers of known and constant (the same for all samples at each sampling campaign) depth and diameter. The borer should be 15 cm long and the recommended diameter is 5 cm. Some providers of these soil samplers are: https://www.ams-samplers.com/soilaugers/; https://www.vanwalt.com/equipment/telescoping-augers/. Any other equivalent sampler of these dimensions is acceptable (but try to respect the 15 cm depth). Some small field materials, such as zip bags.

External subcontracting

Yes. A trustable lab delivering soil fertility analyses must be hired.

References

- Al-Hamaiedeh, H., Bino, M. (2010). Effect of treated grey water reuse in irrigation on soil and plants. *Desalination*, 256(1-3), 115-119.
- Boudjabi, S., Chenchouni, H. (2022). Soil fertility indicators and soil stoichiometry in semi-arid steppe rangelands. *Catena*, 210, 105910.
- O'connor, G. A., Elliott, H. A., Bastian, R. K. (2008). Degraded water reuse: An overview. *Journal of Environmental Quality*, 37(S5), S-157.
- Velemis, D., Almaliotis, D., Bladenopoulou, S., Karapetsas, N. (2002). Yield of maize in relation to soil fertility parameters at Vegoritis area in northern Greece. In *International Meeting on Soil with Mediterranean Type of Climate* (pp. 227-233).
- For soil fertility in crops: https://www.agromatica.es/referencia-de-un-analisis-de-suelo/; https://www.fbn.com/community/blog/how-to-read-a-soil-analysis-report; https://pubs.nmsu.edu/_circulars/CR676/
- For soil fertility in gardens: https://extension.umaine.edu/gardening/manual/soils/interpretingsoil-tests/

3.1.1.2 Hydrological Regulation

- **Code:** Sardinia_Soil02
- **Environmental Sector**: Soil Hydrological Regulation / Penetration resistance
- **Units:** Mpa

Meaning and importance of the indicator

The penetration resistance is a soil attribute that indicates areas with restriction due to compaction, which results in mechanical impedance for water and air permeability which in turn enhances runoff erosion and crop yield losses. Thus, compaction is one of the major problems of modern agriculture and reflects the overuse of machinery, intensive cropping and organic matter depletion. Soil penetration is a physical property of the soil and depends on soil characteristics and management. Soil proprieties such as texture, bulk density, aggregation, organic matter content, lithology and water content influence penetration resistance.

Expected evolution of the indicator

Optimal value range is very controversial because it depends on soil texture and type of crop. However, we will expect a decrease in soil penetration resistance under appropriate soil management, parallel to an increasing of soil organic matter and porosity which favors soil-plant system quality.

Possible relationship with other soil analyses

Soil bulk density, water holding capacity, soil organic matter, crop production

Data obtention

Required data:

- To be analysed at each soil sampling campaign: soil water content

Sampling plan:

Field measurement. The same for the fertility and the other biodiversity analysis.

Sampling calendar

This indicator will be produced every two years for a total of 10 years, coinciding with the evaluation of soil physical and chemical fertility (See Sardinia_Soil01).

Equipment

Soil dynamic penetrometer.

References

- Klonowski, J.; Lisowski, A.; Dąbrowska, M.; Chlebowski, J.; Sypuła, M.; Zychowicz, W. The Usefulness of Soil Penetration Resistance Measurements for Improving the Efficiency of Cultivation Technologies. Sustainability 2024, 16, 6962. https://doi.org/10.3390/su16166962

3.1.1.3 Soil Organic Carbon Content

- **Code**: Sardinia_Soil03
- **Environmental Sector**: Soil / Soil Health
- **Units:** %C

Meaning and importance of the indicator

Soil organic carbon (SOC) constitutes about 58% of soil organic matter that is a chief indicator of soil health. SOC enters the soil through the decomposition of plant and animal residues, root exudates and living and dead soil biota (including microorganisms). Plant carbon comes from the C that plants remove from the atmosphere (photosynthesis), and animals obtain C from plant ingestion; therefore, the final origin of SOC is atmospheric CO_2. The stable fraction of SOC (the soil fraction that stays in soil for longtime periods and resists microbial attack) is considered "sequestered carbon" and contributes to climate change mitigation.

Expected evolution of the indicator

Increasing %C in the soil of the irrigated plots. If external control plots are identified for monitoring (see Sardinia_Soil01), increasing positive difference between %C in the soil of the irrigated and the control plots is expected to occur.

Data obtention

Sampling plan:

Soil organic carbon analysis is included in the analyses of soil physical and chemical fertility (Sardinia_Soil01).

Sampling calendar

This indicator will be produced every two years for a total of 10 years, coinciding with the evaluation of soil physical and chemical fertility (Sardinia_Soil01).

Equipment

See (Sardinia_Soil01).

External subcontracting

Yes. A trustable lab delivering soil fertility analyses must be hired.

References

- Blanco-Canqui, H., Shapiro, C. A., Wortmann, C. S., Drijber, R. A., et al. (2013). Soil organic carbon: The value to soil properties. *Journal of Soil and Water Conservation*, 68(5), 129A-134A.
- Bot, A., Benites, J. (2005). The importance of soil organic matter: Key to drought-resistant soil and sustained food production (No. 80). Food & Agriculture Org.

3.1.1.4 Water Holding Capacity

- **Code:** Sardinia_Soil04
- **Environmental Sector**: Soil / Soil Health
- **Units:** %

Meaning and importance of the indicator

The water holding capacity (WHC) is an important agronomic characteristic. The WHC of a soil is the maximum amount of water a soil can hold under standard conditions. Water holding capacity is affected by soil texture (sand, silt, and clay proportion) and soil structure (pore size, porosity, pores connectivity distribution and characteristics are essential determinants). A soil with a limited WHC reaches sooner the saturation than a soil with a higher WHC, especially between sandy soils as they tend to have low water storage capacity.

Expected evolution of the indicator

Soil structure can be improved by adding organic matter content to stimulate the soil porosity, which increases the water holding capacity. Also, a better water holding capacity of the soil can be accomplished by increasing soil organic carbon. However, deforestation and farming activities may decrease soil water holding capacity.

Data obtention

Required data:

It needs to be analysed the first time and every two years for 10 years (5 times) (See Sardinia_Soil01).

Sampling plan:

Field sampling followed by lab analyses Field sampling followed by lab analyses (See Sardinia_Soil01).

Collect the sample using a soil core, air dry it, break the aggregates and pass through a 2.0 mm sieve. Place the core containing soil in a water tray for saturation overnight and then place the sample in an oven at 105º C for 24-48 h. Finally, weight the core sample.

For further instructions go to the Practical manual on measurement of soil physical properties, on page 34.

Sampling calendar

This indicator will be produced every two years for a total of 10 years, coinciding with the evaluation of soil physical and chemical fertility (See Sardinia_Soil01).

Required equipment

Additional field materials: A soil cylinder /core, a tray, filter papers, a spatula, a sieve, water try, a balance and a drying oven (See Sardinia_Soil01).

External subcontracting

If a reliable scale and an oven are available, WHC can be obtained very simply without the need of an expert lab. If not, a trustable lab delivering soil fertility analyses must be hired (See Sardinia_Soil01).

Calculation formula

WHC%= (Vw/Vt) * 100, while Vw is volume of water and Vt, is total volume of saturated soil.

References

- Honghong, L., Xingwu, D., Yifan, D., Ronghua, Z., Li, R. & Jiangcheng, H. (2023). Responses of soil water-holding capacity to environmental changes in alpine ecosystems across the southern Tibetan Plateau in the past 35–40 years. *Catena*, 222,106840. https://doi.org/10.1016/j.catena.2022.106840**.**
- Soil Quality Test Kit Guide. USDA Natural Resources Conservation Service. 1999. https://efotg.sc.egov.usda.gov/references/public/WI/Soil_Quality_Test_Kit_Guide.pdf
- Role of Soil Physical Properties in Soil Health Management and Crop Productivity in Rainfed Systems-II Management Technologies and Crop Productivity ManualonPracticalsoilphysics.pdf
- https://www.nature.com/scitable/knowledge/library/soil-water-dynamics-103089121/
- Zhang, Y. & Wang, K. & Wang, J. & Changhai L. & Shangguan, Z. (2021). Changes in soil water holding capacity and water availability following vegetation restoration on the Chinese Loess Plateau. Scientific Reports. 11.10.1038/s41598-021-88914-0.

3.1.1.5 Soil Biodiversity

- **Code:** Sardinia_Soil05
- **Environmental Sector**: Soil Biodiversity/ Microbial DNA Biodiversity
- **Units:** Diversity Indexes, Unitless

Meaning and importance of the indicator

Soil harbours a quarter of the world's biodiversity. By far the most important group of organisms of soil biodiversity are soil microorganisms. Soil microbial communities play a pivotal role in terrestrial ecosystems by regulating carbon dynamics, nutrient cycles and regulating plant growth and the quality of atmosphere and the hydrosphere. Hence, the evaluation and monitoring of soil microbial biodiversity is crucial to estimate the ability of soil ecosystems to face stressful environmental conditions, and to assess its resilience, resistance and sustainability. Metagenomics analysis is a remarkable tool for studying microbiomes. *Shotgun Metagenome Sequencing* provides information in taxonomic and functional profile. Both kinds of information should be obtained in order to define soil quality and health. Moreover, this technique allows the detection of potential pathogens in our studied system.

Expected evolution of the indicator

There is not an optimal value for this indicator, given that it is more relevant to obtain information on its trends in time. Then, a decrease in soil microbial diversity (both functionally and taxonomically) can lead to a loss in soil functions and health. These changes will be related to changes in more stressed environmental condition, or/and changes in management strategies.

Possible relationship with other soil analyses

Soil fertility analysis and other soil biodiversity indicators

Data obtention

Required data:

- To be analyzed at each soil sampling campaign: gravimetric soil water content

Sampling plan:

Field sampling followed by lab analyses. The same for the fertility and the other biodiversity analysis (See Sardinia_Soil01).

Sampling calendar

The two fields will be sampled in the proposed dates every two years for 10 years (See Sardinia_Soil01).

Equipment

Samples, around 10 grams of soil, are an aliquot of the sample for other biodiversity analysis, and must be keep retriggered at the field, and then frozen at -20º C at the laboratory. The borer should be 15 cm long and the recommended diameter is 5 cm. Some providers of these soil samplers are: https://www.ams-samplers.com/soil-augers/; https://www.vanwalt.com/equipment/telescopingaugers/. Any other equivalent sampler of these dimensions is acceptable (but try to respect the 15 cm depth). Some small field materials, such as zip bags and cooler bags.

External subcontracting

Yes. A trustable lab delivering metagenomics analysis must be hired.

Data sources

Yes

Calculation formula

Alpha diversity index calculations

References

- Abraham, B.S., Caglayan, D., Carrillo, N.V. et al. Shotgun metagenomic analysis of microbial communities from the Loxahatchee nature preserve in the Florida Everglades. Environmental Microbiome 15, 2 (2020). https://doi.org/10.1186/s40793-019-0352-4
- Frey B, Varliero G, Qi W, Stierli B, Walthert L, Brunner I. Shotgun Metagenomics of Deep Forest Soil Layers Show evidence of altered Microbial Genetic potential for Biogeochemical Cycling. Front Microbiol. Frontiers Media S.A. 2022;13:828977.

3.1.2 Water Indicators

3.1.2.1 Water Monitoring Plan

Sampling points

Optimising Crop Productivity and Water Quality and Safety Through combined NBS

Sampling point	Location	Purpose
SP-01	Inlet of the tank of the tertiary and quaternary treatment	Monitor potential recoverable material from the treatment process
SP-02	Outlet of the tank of the tertiary and quaternary treatment	Monitor wastewater, reclaimed water, amount of material recovered after the treatment
SP-03	Inlet of the constructed wetland	Monitor constructed wetland efficiency
SP-04	Outlet of the constructed wetland (before discharge in the river)	Monitor constructed wetland efficiency
SP-05	Inlet of the aquaculture	Monitor aquaculture efficiency

SP-06	Outlet of the aquaculture	Monitor aquaculture efficiency
SP-07	Inlet of the riparian buffer	Monitor riparian buffer efficiency
SP-08	Outlet of the riparian buffer (before discharge in the river)	Monitor riparian buffer efficiency

Parameters to be analyzed

Parameter	Applicable Sampling point	Related indicator/s	Type
Volume of treated wastewater (WW)	SP-02	RWP; WA	flow water measurements [volume/time]
Volume of reclaimed water produced	SP-02	RWnpU, RWP WA; AWW; WFP (WFN and ISO)	flow water measurements [volume/time]
Volume of reclaimed water used for irrigation	SP-03	RWnpU, WSC; CtotalRW	flow water measurements [volume/time]
Water withdrawal for irrigation (tap water, surface water, groundwater, etc.)	SP-02	AWW; WFP (WFN and ISO)	flow water measurements [volume/time]
Water quality parameters: Nitrogen content (TN, NO3 or NH3) depending on the fertilizer it would replace and its N content. -Total phosphorus (TP) content	SP-01, SP-02, SP-04, SP-08	WR; WFP (WFN and ISO)	water parameters quality
Water quality parameters: Conductivity, COD, BOD5, TSS, TN, TP, TOC, Temperature, turbidity, E. coli	SP-01, SP-02, SP-04, SP-08	CtotalRW; EPR; WFP (WFN and ISO)	water parameters quality

Sampling method

Water flow measurements:

Direct measurement of volume provided during a time period or water flow with flow meters and/or water level sensors.

a) Automatic method

Automatic flow meters can be installed at the recommended sampling points (SP). For the automatization process, it is recommended to register the measurements with a datalogger/digital control system in the DEMO. It is recommended to measure the flow at the recommended sampling points (SP).

Data should be stored in a datalogger/digital control system and then be able to be exported in a spreadsheet to calculate the associated indicators. When this is not possible, manual readings of the flow meters can be done instead.

b) Manual method

This could be applied as the last option if there is no possibility to apply the automatic method.

- Periodic manual measurements
- If no devices are available to measure, correct and reliable estimates must be made to assess the indicator.
- Measure the volume at the point of reuse or approximate the value based on the amount of water demand met by agroforestry for reuse.

Water quality parameters:

Automatic measurement methods (a) or manual sampling campaigns (water sampling + laboratory analysis) (b) can be employed, with specific requirements for different types of pollutants. a) Automatic method

Advanced sensors of water quality can be installed in the recommended sampling points (SP) to continuously monitor and measure various water quality parameters, such as temperature, pH, turbidity, dissolved oxygen, NO_3, etc. These sensors collect data in real-time, providing continuous and accurate information about water quality. The data is often transmitted wirelessly to a central database, or sensors can be also connected to a datalogger. The data is often transmitted wirelessly to a central database, or sensors can be also connected to a datalogger.

b) Manual method

As the DEMO is already implemented, mature and operating, sampling campaigns will be carried out periodically to control the operation and performance of the treatment system. Samples will be collected at the recommended sampling points (SP).

Two types of water quality analysis have been defined: **basic** and **complete**. Different sampling and analysis periodicities will be suggested during the start-up phase, stabilization phase and mature operation.

Basic analysis will include all water quality parameters that are required to be monitored by legislation for reclaimed water reuse for irrigation: turbidity, BOD_5, E. coli, TSS (other if required by legislation).

Complete analysis includes other water quality parameters for general monitoring and indicators' assessment: conductivity, TN, TP, TOC, temperature, NO_3 and/or NH_3.

Samples can be obtained manually or using automatic sampling equipment. An automatic sampler is a device that can be refrigerated or non-refrigerated and include automatic sampling pumps and upward stage samplers. The process involves collecting water samples intended for laboratory analysis of water quality parameters. However, there are limitations associated with automatic sampling, such as intermediate sampling containers, sampling from a fixed point, and sample storage and preservation, which must be considered and documented. Personnel using these methods should have training and prior experience in the use and calibration of automatic sampling equipment.

The laboratory analysis is done following current ISO laboratory protocols for each different parameter.

Water depth variation:

The variation in the water content of the wetlands and the soil can be done manually or through automatic methods.

a) Automatic method

For the constructed NBS: Water level sensors, weather stations, remote sensing through hydrological models.

For the agriculture soil: weather stations, sensors, remote sensing through hydrological models. b) Manual method

For the constructed wetlands: direct water level measurements in a period of time. Measure water depth

of the wetland at the initial time and after a period of time (e.g. minutes, hours, 1 day, etc.) For the agriculture soil: field direct measurements using lysimeters or scintillometers.

Sampling Calendar

Water flow measurements and water depth variation:

Data should be collected frequently for a relevant time period (e.g., daily, weekly, monthly) to allow for accumulation over the entire reporting period (yearly). This high frequency is also relevant to study seasonal variations.

Water quality parameters:

As the DEMO has not been implemented yet, different sampling and analysis periodicities will be suggested during the start-up phase, stabilization phase and mature operation:

- Start-up phase: the first 3 months of operation of the DEMO it is recommended to increase the frequency of the analysis to 2 basic analysis per week and 1 complete analysis per week.
- Stabilization phase: from month 4 to month 12 of operation it is recommended to do 1 basic analysis per week and 2-3 complete analysis per month.
- Mature operation: from month 13, the recommended frequency of water quality analysis is 1 basic analysis per week and 1 complete analysis per month.

Equipment

a) Water flow measurements:

Water flow meters are essential tools for monitoring and assessing the efficiency of these systems, as they provide real-time data on water movement and usage through the treatment processes and the different pipes, helping to determine the volume of water at those particular locations. Some indicative providers of these water flow meters are:

- Endress+Hauser - Systec Controls
- Aobo instrument

Any equivalent water flow meter is acceptable, these are given as examples.

b) Water quality parameters:

The automatic sampling method requires simple or multiparametric sensors for water quality and data loggers or digital control systems for data recording. It also requires personnel for data collection and treatment.

The manual sampling campaign requires laboratory and field personnel for manual sampling and analysis and also reagents and laboratory material depending on the current ISO laboratory protocols for each parameter.

Some indicative providers for water quality parameters are:

- ANISE sensor (NH_4 and NO_3) - Hach

- Conductivity meter - METTLER TOLEDO
- pH meter - METTLER TOLEDO
- Multi-parameter water quality analyzer (temperature, pH, conductivity, DO, turbidity, BOD, COD, ammonia nitrogen, NO_3, colour, chloride, depth, etc.) - BOQU instruments Any equivalent water level sensor is acceptable, this is given as an example.

c) Water depth variation:

Some indicative providers are:

- Lysimeter - Royal Eijkelkamp ; MundoRiego
- Sensor - LI-COR
- Scintillometer - SCINTEC
- Water level sensor - ATMI

External subcontracting

Yes. A trustable laboratory delivering water quality analyses must be hired if not available internally.

3.1.2.2 Agricultural Water Withdrawal (AWW)

- **Code**: Sardinia_Water01
- **Environmental Sector:** Water / Water Consumption
- **Units:** %

Meaning and importance of the indicator

The Agricultural Water Withdrawal (AWW) indicator assesses the volume of freshwater or groundwater withdrawn and used by the agricultural sector as a percentage of the total water withdrawn for all purposes (agricultural, municipal, industrial, etc.). This indicator helps to understand the water-food relationship within the food-energy-water nexus, as agriculture is a major consumer of water resources. It provides insights into the sustainability of agricultural practices and helps identify trends in water use that could impact food security and water availability, particularly in arid and semi-arid regions. The AWW indicator is essential for evaluating the pressure exerted on water resources by agricultural activities and for guiding policies aimed at improving water use efficiency in agriculture.

Expected evolution of the indicator

Ideally, the percentage of water withdrawal for agriculture should decrease or stabilize as more efficient irrigation practices are adopted, and alternative water sources (e.g., reclaimed water) are utilized. If it's taken into account the possibility of using reclaimed water for irrigation, the 0% corresponds to the best expected value, since a decrease or zero consumption of freshwater and groundwater (i.e. drinking water) for agriculture would be the ideal case.

Possible relationship with other indicators

Water footprint.

Data obtention

Sampling plan:

- Agricultural water withdrawal (m^3/year): Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total water withdrawal for all sectors (agricultural, municipal, industrial, etc.) (m^3/year). Total water demand for all water uses in a year. This is a context value that can be obtained from water management authorities or companies, municipal reports, etc.

Calculation formula

$$AWW = \frac{Agricultural\ water\ withdrawal}{Total\ water\ withdrawal} \cdot 100$$

Where:

- AWW: Agricultural Water Withdrawal ratio (%),
- Agricultural water withdrawal: The total volume of water extracted and used for irrigation and other agricultural activities (m^3/year),

- Total water withdrawal: The sum of total water withdrawn for different uses, including agricultural, municipal, industrial, etc. (m^3/year).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- Nature4Cities project (2016). Nature Based Solutions for Re-naturing Cities: knowledge diffusion and decision support platform through new collaborative models. European Union's Horizon 2020 Research and Innovation programme. https://docs.wixstatic.com/ugd/55d29d_3b17947e40034c168796bfc9a9117109.pdf
- European Commission, Directorate-General for Research and Innovation (2021). Evaluating the impact of nature-based solutions: A handbook for practitioners. Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577

3.1.2.3 Compliant Reclaimed Water (CtotalRW)

- **Code**: Sardinia_Water02
- **Environmental Sector:** Water / Safe and secure fit-for-purpose water provision
- **Units:** %

Meaning and importance of the indicator

This indicator represents the percentage of reclaimed water that adheres to the required quality standards at the specified compliance location, ensuring it meets the necessary criteria. 'Reclaimed water' means urban wastewater that has been treated in compliance with the requirements set out in Directive 91/271/EEC (Urban Wastewater Treatment Directive), and which results from further treatment in a reclamation facility; in accordance with Section 2 of Annex I to this Regulation: 'Point of compliance' means the point where a reclamation facility operator or alternative water supplier delivers reclaimed and/or non-potable water to the next actor in the chain. 'Non-compliance with reclaimed water quality standards per type of use' is defined in accordance with the agreements under EU or national legislation, such as Regulation (EU) 2020/741 of the European Parliament and of the Council on minimum requirements for water reuse for agriculture uses.

Expected evolution of the indicator

The optimal target for the CtotalRW indicator is 100%, indicating that all reclaimed water produced meets the required quality standards at the point of compliance. The target could be assessed based on local policies and directives that establish the water quality limits depending on its use. One example for reclaimed water for uses of A quality reuse (Water Directive 2020/741) would be: *E. coli* ≤ 10 CFU/100 mL, BOD (Biochemical Oxygen Demand) ≤ 10 mg/l, TSS (Total Suspended Solids) ≤ 10 mg/L ,Turbidity ≤ 5 NTU, *legionella* current country legislation and bacteriophages <1000 UFC/100mL, contaminants according to the environmental quality standards.

Possible relationship with other water indicators

Reclaimed water production, Environmental flow requirement compliance rate, Safe drinking water, Effluent pollutant removal, Water quality compliance: biological, physical, and chemical parameters.

Data obtention

Sampling plan:

Total number of samples with exceedance (i.e. sum of samples with microbial, chemical or indicator parameter exceedance); total number of samples analyzed in assessment period.

Calculation formula

$ne_{totalRW}$

$$CtotalRW = \left(1 - \frac{ne_{totalRW}}{n_{totalRW}}\right) \cdot 100$$

Where:

- $C_{totalRW}$: = Percentage of total compliance for safe reclaimed water (%),
- $ne_{totalRW}$: Total number of samples of reclaimed water with exceedance, i.e., sum of samples with microbial, chemical or indicator parameter exceedance (No./year),
    - $ne_{totalRW} = \sum_{i=A} (nMi + nCi + nIi)$, with
    - nM = number of samples with microbial exceedance ○ nC= number of samples with chemical exceedance ○ nI= number of samples with indicator exceedance ○ i = Class A, B, C, D
- $n_{totalRW}$: Total number of reclaimed water samples analyzed in assessment period (No./year).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- EU regulation 2020/741 of the European Parliament and of the Council of 25 May 2020 on minimum requirements for water reuse. Official Journal of the European. https://eurlex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020R0741&from=EN
- Boletín Oficial del Estado (2020). Reglamento (UE) 2020/741 del parlamento europeo y del consejo de 25 de mayo de 2020 relativo a los requisitos mínimos para la reutilización del agua. https://www.boe.es/doue/2020/177/L00032-00055.pdf
- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/resultsdownloads/water-smartness-assessment-framework/

3.1.2.4 Effluent Pollutant Removal (EPR)

- **Code**: Sardinia_Water03
- **Environmental Sector:** Water / Water treatment / Water quality
- **Units:** %

Meaning and importance of the indicator

The indicator measures the average removal ratio between incoming and outgoing pollution load of the NBS. It can be evaluated for any pollutant. It is used to assess the effectiveness of water treatment processes in reducing pollution before discharge into the environment or wastewater treatment plant or its reuse.

*If there are additional water treatments in combination with the NBS, we recommend sampling before and after each treatment to have a better understanding of the role of each one in the treatment process.

Expected evolution of the indicator

The target can be determined based on design requirements (e.g., why the NBS is necessary, which pollutant needs to be addressed, and the desired removal efficiency) or according to local regulations and guidelines that define water quality standards depending on its intended use (such as for consumption, discharge, or reuse). For reclaimed water (as per Water Directive 2020/741), the goals would be: 95% removal of microbiological and emerging contaminants, 60-95% removal of nutrient pollutants, and 95% removal of physico-chemical parameters (such as turbidity). For treated wastewater (under RD 509/1996 and RD 11/1995), the objectives would include 70-80% reduction of nutrient pollutants and 90% removal of physico-chemical parameters (such as turbidity). For drinking water (in line with RD 3/2023), the goals would involve: 99-100% elimination of microbiological contaminants, 80-99% reduction of chemical pollutants, and 95% removal of physico-chemical parameters (such as turbidity) and nutrients.

Possible relationship with other water indicators

Reclaimed water production, Environmental flow requirement compliance rate, Safe drinking water, Water quality compliance: biological, physical and chemical parameters.

Data obtention

Sampling plan:

- Average influent concentration (mg/L).
- Average effluent concentration (mg/L).

Water quality parameters:

- Physical-chemical properties data:
  - - pH (unitless) ○ - Temperature (ºC)
  - - Electrical Conductivity (EC) (µS/cm) ○ - Turbidity (NTU)
  - - TSS (Total Suspended Solids) (mg/L)
- Biological data:
  - - DO (Dissolved Oxygen) (mg/L O_2) ○ - BOD (Biochemical Oxygen Demand) (mg/L O_2) ○ - COD (Chemical Oxygen Demand) (mg/L O_2)
  - - TOC (Total Organic Carbon) (mg/L O_2)
- Chemical pollutant data: ○ - Heavy metals (µg/L)
  - Total hydrocarbons (µg/L)
  - Total pesticides (µg/L)

- Nutrients data:
  - ○ - TN (Total Nitrogen) (mg/L N) ○ - NO_3 (Nitrates) (mg/L) ○ - TP (Total Phosphorus) (mg/L P) ○ - PO_4 (Phosphates) (mg/L)
- Microbiological data:
  - ○ - E. Coli (CFU/100 mL)
- Other specific pollutants data:
  - ○ - Contaminants of emerging concern ○ - Pollutants from industrial effluents will be added if necessary.

Calculation formula

$$\%Re = \frac{(Ci - Ce)}{Ci} \cdot 100$$

Where:

- %Re: average effluent pollutant removal (%),
- Ci: average influent concentration (mg/L), • Ce: average effluent concentration (mg/L).

*To be evaluated for each pollutant.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: A handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577
- Boletín Oficial del Estado (2023). Real Decreto 3/2023, de 10 de enero, por el que se establecen los criterios técnico-sanitarios de la calidad del agua de consumo, su control y suministro. https://www.boe.es/buscar/pdf/2023/BOE-A-2023-628-consolidado.pdf
- Boletín Oficial del Estado (1998). Real Decreto 2116/1998, de 2 de octubre, por el que se modifica el Real Decreto 509/1996, de 15 de marzo, de desarrollo del Real Decreto-ley 11/1995, de 28 de diciembre, por el que se establecen las normas aplicables al tratamiento de las aguas residuales urbanas. https://www.boe.es/eli/es/rd/1998/10/02/2116/dof/spa/pdf
- Boletín Oficial del Estado (1996). Real Decreto 509/1996, de 15 de marzo, de desarrollo del Real Decreto-ley 11/1995, de 28 de diciembre, por el que se establecen las normas aplicables al tratamiento de las aguas residuales urbanas. https://www.boe.es/buscar/pdf/1996/BOE-A-19967159-consolidado.pdf
- Boletín Oficial del Estado (2020). Reglamento (UE) 2020/741 del parlamento europeo y del consejo de 25 de mayo de 2020 relativo a los requisitos mínimos para la reutilización del agua. https://www.boe.es/doue/2020/177/L00032-00055.pdf
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- Environmental Protection Water (2018). Water quality sampling using automated sampling equipment. https://environment.desi.qld.gov.au/__data/assets/pdf_file/0032/90779/physical-andchemical-assesssment-water-quality-sampling-using-automated-sampling-equipment.pdf
- Nature4Cities project (2016). Nature Based Solutions for Re-naturing Cities: knowledge diffusion and decision support platform through new collaborative models. European Union's Horizon 2020 Research and Innovation programme. https://docs.wixstatic.com/ugd/55d29d_3b17947e40034c168796bfc9a9117109.pdf

3.1.2.5 Reclaimed Water in Non-Potable Uses (RWnpU)

- **Code**: Sardinia_Water04
- **Environmental Sector:** Water / Water resource recovery and use
- **Units:** %

Meaning and importance of the indicator

The indicator measures the proportion of reclaimed water (from treated wastewater, rainwater, urban runoff, etc.) used in non-potable applications where previously drinking or freshwater was used. It is related to the total volume of water used for those purposes. This indicator provides valuable insight into the sustainable use of water resources by quantifying the extent to which reclaimed water is used for non-potable purposes.

Expected evolution of the indicator

The optimal value for the RWnpU indicator is as close to 100% as possible, indicating that the majority of non-potable water needs are met with reclaimed water, minimizing the demand for freshwater.

Possible relationship with other water indicators

Compliant reclaimed water, Water availability, Reclaimed water production, Water provision by the ecosystem.

Data obtention

Sampling plan:

- Volume of reclaimed water used for non-potable uses (e.g., irrigation, street cleaning, groundwater recharge) (m^3/year)

  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.

- Total volume of water used for non-potable uses, from all sources, including freshwater and reclaimed water (m^3/year)

  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.

Calculation formula

$$RWnpU = \frac{RW}{npW} \cdot 100$$

Where:

- RWnpU: Reclaimed Water in non-potable Uses (%),
- RW: Volume of reclaimed water used for non-potable uses (e.g., irrigation, street cleaning, groundwater recharge) (m^3/year),
- npW: Total volume of water used for non-potable uses, from all sources, including freshwater and reclaimed water (m^3/year).

Note: “used” may be “supplied” or “consumed” but must be consistent in RW and npW.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/resultsdownloads/water-smartness-assessment-framework/

3.1.2.6 Reclaimed Water Production (RWP)

- **Code**: Sardinia_Water05
- **Environmental Sector:** Water / Water resource recovery and use
- **Units:** %

Meaning and importance of the indicator

The indicator measures the volume of reclaimed water produced, either for internal use or transfer to third parties, as a percentage of the total volume of treated wastewater, etc. This indicator aims to assess the level of environmental sustainability of the service in terms of circularity and the resources recovery, regarding the production of reclaimed water, obtained from the wastewater treatment. Reclaimed water means urban wastewater that has been treated in compliance with the requirements set out in Directive 91/271/EEC and which results from further treatment in a reclamation facility (EU Regulation 2020/741). However, based on further assessments, the approach to reclaimed water may need adjustment, particularly if the indicator for reclaimed water also includes treated rainwater or water from other sources. So, in this context, reclaimed water can also be considered treated water from other sources (i.e. rainwater/stormwater, greywater, etc.) which is suitable for its reuse.

Expected evolution of the indicator

The optimal value for the RWP indicator is as high as possible, ideally close to 100%, which would indicate that almost all treated wastewater (or other treated water sources) is further processed to produce reclaimed water. This contributes to more sustainable water management practices and to reduce the dependency on freshwater sources.

Possible relationship with other water indicators

Compliant reclaimed water, Water availability, Reclaimed water in non-potable uses, Effluent pollutant removal, Water footprint.

Data obtention

Sampling plan:

- Volume of reclaimed water produced under the responsibility of the utility, and which is transferred to other entities for use or for its own uses (exclude the recirculation or recycling of water, when it occurs in a closed circuit within one or more processes) (m^3/year).
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
  Only data that complies with reclaimed water suitable for its reuse will be selected.
- Volume of wastewater treated or treated water from other sources (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.

Calculation formula

$$RWP = \frac{V_{reclaimed}}{TWW} \cdot 100$$

Where:

- RWP: Reclaimed Water Production (%),

- $V_{reclaimed}$: Volume of reclaimed water produced under the responsibility of the utility, and which is transferred to other entities for use or for its own uses (exclude the recirculation or recycling of water, when it occurs in a closed circuit within one or more processes) (m^3/year),
- TWW: Volume of wastewater treated or treated water from other sources (m^3/year).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/resultsdownloads/water-smartness-assessment-framework/

3.1.2.7 Water Availability (WA)

- **Code**: Sardinia_Water06
- **Environmental Sector:** Water / Freshwater supply / Resource efficiency
- **Units:** m^3/year

Meaning and importance of the indicator

The indicator refers to the volume of water available provided by the DEMO for its reuse in various applications (e.g. aquifer recharge, ecosystem restoration, on site reuse, irrigation, industrial activities, etc.). The water available should comply with quality standards required for different reuses as per current legislation.

Expected evolution of the indicator

The baseline for this indicator is the initial water availability capacity, which may start at 0 m^3/year. It is expected to increase over time once the DEMO is operating and optimized, reflecting an improvement in water availability for reuse and ecosystem services. Ensure that 100% of the water provided by the DEMO is available for reuse.

Possible relationship with other water indicators

Water footprint, Water provision by the ecosystem.

Data obtention

Sampling plan:

- Direct annual flow of the effluent or annual volume provided by the DEMO for specific purposes (e.g., aquifer recharge, ecosystem restoration, etc.) (m^3/year).

  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total volume water available in the DEMO (WA) (m^3/year).

Calculation formula

$$WA = Water\ inflows\ (WI) - Water\ losses\ (WL)$$

Where:

- WI: Total water entering the DEMO system (e.g., precipitation, surface water, groundwater recharge, recycled water) (m^3)
- WL: Total water lost (due to evaporation (m^3))

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/resultsdownloads/water-smartness-assessment-framework/

- United Nations Conference on Trade and Development (2023). Environmental indicators: Module B Core SDG Indicators for Entity Reporting Training Manual. https://unctad.org/system/files/information-document/UNCTAD_GCI_MANUAL_ENVIRONMENTAL-FINAL.pdf
- URBAN GreenUP (2019). D5. 3: City diagnosis and monitoring procedures. https://www.urbangreenup.eu/kdocs/1912498/urban_greenup_d5_3_city_diagnosis_and_monitoring_procedures.pdf
- U.S. Environmental Protection Agency (2024). Basic information about water reuse. https://www.epa.gov/waterreuse/basic-information-about-water-reuse

3.1.2.8 Water Footprint (ISO)

- **Code:** Sardinia_Water07
- **Environmental Sector:** Water / Water resource efficiency
- **Units:** m^3/ m^3

Meaning and importance of the indicator

The Water Footprint (WF), as defined by the ISO 14046 standard, is an indicator that quantifies the potential environmental impacts associated with the water use of a product, process, or organization. This standard adopts a Life Cycle Assessment (LCA) approach to evaluate both direct and indirect water use. Key aspects of water footprint according to ISO 14046 include:

- Consumptive use: Refers to freshwater that is abstracted and either evaporates, is incorporated into products, or is returned to a different watershed or the sea after use.
- Degradative use: Involves the deterioration in water quality when the water is returned to the same basin from which it was abstracted.

The water footprint methodology evaluates the impact of water use both in terms of quantity (consumed or contaminated) and quality (degradation or restoration). It considers all inputs and outputs of water throughout the life cycle of the product, process, or organization.

Additionally, water footprint studies must consider direct water use, which refers to the amount of water used during production or treatment (e.g., drinking water, wastewater treatment), and indirect water use, which includes the water required for the production of resources (e.g., energy, chemicals, equipment) utilized in the process. Overall, the ISO 14046 standard provides a detailed framework for assessing both the quantity and the quality impacts of water use in a more comprehensive manner than traditional water footprint methodologies.

Expected evolution of the indicator

The focus will be on minimizing both consumptive and degradative water use, with an emphasis on sustainable water management and reducing the overall environmental impact. This evolution will ensure that the WF indicator becomes increasingly effective in guiding resource efficiency and mitigating water-related environmental impacts.

Possible relationship with other water indicators

Water Footprint (WFN), Water quality compliance: biological, physical and chemical parameters.

Data obtention

Sampling plan:

To assess the water footprint according to ISO 14046, the following data should be collected:

Drinking Water Production:

1. Direct water usage: The total water consumed directly by the utility for producing 1 m^3 of drinking water. This includes:
    - Water used in the entire treatment process
    - Water used for network operation (e.g., pumping)
    - Water lost through leakages in the drinking water network
2. Indirect water usage: Water required for producing the resources and materials used in drinking water production. This includes:
    - Energy consumption: Electricity and energy used in treatment and distribution processes

- Chemicals: Used in water treatment processes
- Infrastructure and equipment: Pipes, pumps, valves, and other treatment and distribution systems used in water production

Wastewater Treatment and Reclamation:

1. Direct water usage: The total water used for the collection, treatment, and reclamation of 1 m^3 of wastewater. This includes:
    - Water used in the treatment and reclamation facilities
    - Water used for network operations, including leakages in the reclaimed water network
2. Indirect water usage: Water used in the production of resources necessary for wastewater treatment and reclamation, such as:
    - Energy consumption: Electricity for treatment and distribution networks
    - Chemicals: Used in the wastewater treatment process
    - Equipment and infrastructure: Pipes, pumps, valves, and other materials involved in wastewater collection and treatment

Additional Environmental Impact Data:

- Raw materials and their origin; Conductivity, COD, TSS, TN, TP
- Temp; consumables (e.g. caustic soda, disinfectant, etc.)
- Energy consumption (GoO or not)
- Volume wastewater treated or reclaimed.

Calculation formula

$$WFPdw = \frac{WFdw}{DWP} \; or \; WFPww = \frac{WFww}{TWW}$$

Where:

- WFdw (Water footprint in the drinking water system) and WFWW (Water footprint in the wastewater system): should be collected for every process and product that is being used in the system (this includes water used in the whole of the treatment plant, water used for operation of the network, and water which is lost through leakages in the drinking water network) through a period of time (e.g., year) (m^3/year),
- DWP: Annual drinking water production; used for drinking water systems (m^3/year),
- TWW: Volume of wastewater treated; used for wastewater systems (m^3/year).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- ISO 14046:2014(en). Environmental management — Water footprint — Principles, requirements and guidelines.
- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/resultsdownloads/water-smartness-assessment-framework/

3.1.2.9 Water-Related Materials' Recovery (WR)

- **Code**: Sardinia_Water08
- **Environmental Sector:** Water / Water resource recovery and use
- **Units:** %

Meaning and importance of the indicator

The indicator is defined as the percentage of a by-product* material or waste that is recovered and suitable for reuse after a treatment process or activity* to improve other activities within the same DEMO or other external sites (i.e. drinking water plant, wastewater treatment plant, industry, agroforestry, etc). **By-product*: a secondary product produced in the manufacturing, treatment or synthesis of something else. Some examples may be: nitrogen and phosphorus recovery for its reuse as biofertilizer, sludge recovery from wastewater as compost, harvested microalgal biomass as fertilizer, organic biomass from aquaculture as fertilizer and saturated filter media or adsorption materials for water filtration, purification of aqueous or gaseous mediums, retention of contaminants.

Treatment process or activity: the main infrastructure or technology where the DEMO or an external organization performs its main activities.

If more than one waste stream is recovered, a weighting factor can be applied to obtain a single total indicator.

Expected evolution of the indicator

The optimal value is ideally close to 100%. A higher percentage indicates that more materials are being recovered, which suggests greater resource efficiency and reduced environmental impact.

Possible relationship with other water indicators

Reclaimed water production, Water footprint.

Data obtention

Sampling plan:

- Material recovered from the treatment process or activity and considered suitable for reuse (kg/year) Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total potential recoverable material entering the treatment process or activity (kg/year) Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.

Calculation formula

$W_{i,re}$

$$WR = \frac{W_{i,re}}{W_{i,in}} \cdot 100$$

Where:

- WR: Water-related materials' Recovery (%),
- $W_{i,re}$: Material recovered from the treatment process or activity and considered suitable for reuse (kg/year),
- $W_{i,in}$: Total potential recoverable material entering the treatment process or activity (including materials that are added and recovered during the process) (kg/year).

Note: some examples of recoverable material are: nitrogen and phosphorus for its reuse as biofertilizer, sludge from wastewater as compost, harvested microalgal biomass as fertilizer, organic biomass from aquaculture as fertilizer.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/resultsdownloads/water-smartness-assessment-framework/
- European Union (2022). PLATFORM ON SUSTAINABLE FINANCE: TECHNICAL WORKING GROUP: PART B – Annex: Technical Screening Criteria. PLATFORM ON SUSTAINABLE FINANCE. https://finance.ec.europa.eu/system/files/2022-03/220330-sustainable-finance-platformfinance-report-remaining-environmental-objectives-taxonomy-annex_en.pdf
- OECD. The OECD Inventory of Circular Economy indicators, Retrieved September 13, 2024, from https://www.oecd.org/cfe/cities/InventoryCircularEconomyIndicators.pdf

3.1.3 Energy indicators

3.1.3.1 Energy Recovered/Saved

- **Code**: Sardinia_Energy01
- **Environmental Sector**: Energy
- **Units**: kWh

Meaning and importance of the indicator

"Energy recovered/saved" measures the amount of energy that is either recovered through various processes or saved by efficiency improvements within the wastewater treatment (WWT), agricultural production, runoff treatment, and aquaculture systems. This indicator is critical for assessing energy efficiency in each subsystem and identifying areas where energy recovery or savings are achieved through optimized processes, such as harnessing waste heat, integrating efficient equipment, or reducing the energy intensity of each component.

Expected evolution of the indicator

The expected evolution of the indicator "Energy recovered/saved" is towards an increasing trend, reflecting growing efforts to enhance energy efficiency and maximize energy recovery in various systems and operations.

Data obtention

Required data: Direct measurement where possible from dedicated energy meters on recovery equipment, or calculated based on reductions in energy use from previous periods, recorded for each subsystem (WWT, agriculture, runoff treatment, and aquaculture).

Frequency

Monthly direct measurements where available, otherwise quarterly estimates.

3.1.3.2 Reduction of the Energy Footprint Per Unit of Water

- **Code**: Sardinia_Energy02
- **Environmental Sector**: Energy
- **Units**: kWh/m^3 irrigation water

Meaning and importance of the indicator

"Reduction of the energy footprint per unit of water" measures the decrease in the amount of energy required to treat, distribute, and manage one unit of water over time. This indicator is crucial for assessing the efficiency and sustainability of water management practices. Reducing the energy footprint per unit of water signifies improved energy efficiency, leading to lower operational costs and reduced greenhouse gas emissions. This is essential for mitigating climate change and conserving energy resources. Monitoring this indicator helps identify opportunities for implementing advanced technologies, optimizing processes, and integrating renewable energy sources in water management systems. Ultimately, reducing the energy footprint per unit of water supports broader environmental and economic sustainability goals by ensuring that water services are provided in a more energy-efficient and environmentally friendly manner.

Expected evolution of the indicator

The expected evolution of the indicator "Reduction of the energy footprint per unit of water" is towards a continuous decrease, driven by advancements in technology, improved efficiency measures, and stronger regulatory and policy frameworks promoting sustainability.

Data obtention

Required data: Direct measurement from energy meters or fuel logs for equipment used in water treatment. Where direct measurement is unavailable, estimates are based on equipment capacities and operating hours.

Frequency

Monthly if direct measurements are available; quarterly for estimated assessments.

3.1.3.3 Energy / CO_2 Footprint of Irrigation Systems

- **Code**: Sardinia_Energy03
- **Environmental Sector:** Energy
- **Units**: kWh or kg CO_2 eq./ m^3 irrigation water

Meaning and importance of the indicator

The indicator "Energy/CO_2 footprint of irrigation systems" measures the amount of energy consumed and the corresponding carbon dioxide emissions generated by irrigation practices in agriculture. This indicator is vital for evaluating the sustainability and environmental impact of irrigation systems. High energy and CO_2 footprints indicate inefficient water use and significant contributions to greenhouse gas emissions, which can exacerbate climate change and increase operational costs. Conversely, reducing these footprints through the adoption of energy-efficient technologies, renewable energy sources, and optimized irrigation practices can lead to significant environmental and economic benefits. Monitoring this indicator helps identify areas for improvement, promote sustainable water management, and support broader goals of reducing carbon emissions and conserving energy resources in agricultural practices. Ultimately, it contributes to the development of more sustainable and resilient agricultural systems.

Expected evolution of the indicator

The expected evolution of the indicator "Energy/CO_2 footprint of irrigation systems" is towards a decrease, driven by technological advancements, improved irrigation practices, and regulatory measures aimed at sustainability.

Data obtention

Required data: Energy meter readings for irrigation equipment, distinguishing between grid-supplied energy and solar energy (KPI 3.3.6). CO_2 footprint will be calculated by WP5 partners using the life cycle assessment method based on total energy consumption data.

Frequency

Annual calculation, with monthly measurements where possible.

3.1.3.4 Water-Energy-Food-Carbon Footprint of the Integrated System

- **Code**: Sardinia_Energy04
- **Environmental Sector**: Energy
- **Units**: The footprints (kg CO_2 eq., or m^3, or kWh per system's function)

Meaning and importance of the indicator

"Water-Energy-Food-Carbon footprint of the integrated system" measures the combined impact of energy consumption, carbon emissions, and resource use across the wastewater treatment, agricultural, aquaculture, and runoff treatment components. This comprehensive indicator is crucial for assessing the sustainability and efficiency of resource use across these interdependent sectors. By quantifying the footprints together, it highlights the synergies and trade-offs between water use, energy consumption, food production, and carbon emissions, offering a holistic view of their cumulative impact. Monitoring this indicator is important because it enables policymakers, businesses, and stakeholders to identify inefficiencies, implement integrated resource management practices, and develop strategies that minimize environmental impacts. Ultimately, reducing the Water-Energy-FoodCarbon footprint supports broader sustainability goals, including climate change mitigation, resource conservation, and the promotion of resilient and sustainable systems that can meet the needs of present and future generations.

Expected evolution of the indicator

The expected evolution of the indicator "Water-Energy-Food-Carbon footprint of the integrated system" is towards a reduction in overall footprints, reflecting improvements in sustainability and efficiency across these interconnected sectors.

Data obtention

Required data: Collected through surveys and energy data from partners across the system components. Total footprints are calculated via life cycle assessment based on measured and estimated energy consumption.

Frequency

Calculated at the end of each cycle of the experimental campaign.

3.1.3.5 Energy Saving from Rainwater Removed from Combined Sewer and Not Treated in Centralized Wastewater Treatment Plant

- **Code:** Sardinia_Energy05
- **Environmental Sector:** Energy
- **Units:** kWh

Meaning and importance of the indicator

"Energy saving from rainwater removed from combined sewer and not treated in centralized wastewater treatment plant" measures the amount of energy conserved by diverting rainwater from combined sewer systems, preventing it from entering centralized wastewater treatment facilities. This indicator is significant because treating rainwater in wastewater plants requires substantial energy for processes like pumping, aeration, and filtration. By diverting rainwater, municipalities can reduce the load on these plants, leading to significant energy savings and lower operational costs. Additionally, this practice mitigates the risk of sewer overflows during heavy rainfall, improving the efficiency and resilience of urban water management systems. Monitoring this indicator helps identify the effectiveness of sustainable urban drainage systems and green infrastructure solutions like rain gardens and permeable pavements. Ultimately, it supports broader sustainability goals by promoting energy efficiency, reducing greenhouse gas emissions, and enhancing the overall environmental performance of urban water management.

Expected evolution of the indicator

The expected evolution of the indicator "Energy saving from rainwater removed from combined sewer and not treated in centralized wastewater treatment plant" is towards an increase, driven by the growing adoption of sustainable urban drainage systems and green infrastructure.

Data obtention

Required data: Field measurement or assessment based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

3.1.3.6 Renewable Energy Sources (RES) Units Integrated and Capacity

- **Code**: Sardinia_Energy06
- **Environmental Sector:** Energy
- **Units**: kWh RES

Meaning and importance of the indicator

"RES units integrated and capacity" measures the number of renewable energy source (RES) units, such as solar panels, wind turbines, hydroelectric generators, and biomass facilities, that have been integrated into the energy system, along with the actual energy produced by these units and their total generating capacity. This indicator is crucial for assessing the progress and effectiveness of transitioning to sustainable energy systems. It highlights the extent to which renewable energy technologies are being adopted and utilized to meet energy demands. Specifically, the energy produced by the solar panels will be tracked to quantify the renewable energy directly contributing to the system's energy needs. Monitoring this indicator is important because it reflects the contribution of renewable energy to reducing greenhouse gas emissions, enhancing energy security, and decreasing reliance on fossil fuels. Additionally, it helps policymakers and stakeholders evaluate the success of policies and investments aimed at promoting renewable energy, guiding future decisions to further accelerate the deployment of clean energy technologies. Ultimately, increasing the integration and capacity of RES units supports global sustainability goals and the fight against climate change.

Expected evolution of the indicator

The expected evolution of the indicator "RES units integrated and capacity" (Renewable Energy Sources units integrated and their capacity) is towards a significant increase, reflecting global efforts to transition to sustainable energy systems.

Data obtention method

Direct measurements from energy meters or inverters attached to solar panels for energy production data, combined with a desk calculation of total RES capacity installed and operational.

Frequency

Monthly for solar energy production data; capacity assessed annually.

3.1.3.7 Gross Renewable Consumption Relative to Total Gross Final Consumption

- **Code**: Sardinia_Energy07
- **Environmental Sector:** Energy
- **Units**: kWh RE/kWh total

Meaning and importance of the indicator

"Gross Renewable Consumption Relative to Total Gross Final Consumption" measures the proportion of energy consumed from renewable sources compared to the total energy consumption across all sectors, including residential, industrial, and transportation. This indicator is crucial for assessing the progress of a region or country in transitioning to a sustainable energy system. A higher proportion indicates a greater reliance on renewable energy, which is essential for reducing greenhouse gas emissions, mitigating climate change, and decreasing dependence on fossil fuels. Monitoring this indicator helps policymakers and stakeholders evaluate the effectiveness of energy policies, identify areas for improvement, and set targets for increasing the share of renewable energy. Ultimately, increasing the percentage of gross renewable consumption supports environmental sustainability, enhances energy security, and contributes to achieving global climate goals.

Expected evolution of the indicator

The expected evolution of the indicator "Gross Renewable Consumption Relative to Total Gross Final Consumption" is towards a significant increase, reflecting global efforts to transition to cleaner energy sources and reduce carbon emissions.

Data obtention

Required data: Field measurement or assessment based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

3.1.3.8 Increase in Renewable Energy Use in the Area

- **Code**: Sardinia_Energy08
- **Environmental Sector:** Energy
- **Units**: kWh RE/kWh total

Meaning and importance of the indicator

"Increase in renewable energy use in the area" measures the growth in the consumption and integration of renewable energy sources, such as solar, wind, hydro, and biomass, within a specific region over a defined period. This indicator is crucial for evaluating the progress and effectiveness of policies and initiatives aimed at transitioning to sustainable energy systems. An increase in renewable energy use signifies a reduction in reliance on fossil fuels, leading to lower greenhouse gas emissions and improved air quality. It also reflects advancements in energy technology, economic investments in green infrastructure, and societal shifts towards sustainability. Monitoring this indicator helps stakeholders identify successful strategies, allocate resources efficiently, and set future targets for renewable energy adoption. Ultimately, increasing renewable energy use supports global efforts to combat climate change, enhance energy security, and promote sustainable development, contributing to a cleaner and more resilient energy future.

Expected evolution of the indicator

The expected evolution of the indicator "Increase in renewable energy use in the area" is towards a substantial and continuous rise, driven by various factors including technological advancements, economic benefits, and regulatory support.

Data obtention

Required data: Field measurement or assessment based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

3.1.3.9 Sustainable Energy Practices

- **Code**: Sardinia_Energy09
- **Environmental Sector:** Energy
- **Units**: kWh

Meaning and importance of the indicator

"Sustainable Energy Practices" measures the adoption and implementation of energy-related actions and strategies that promote long-term environmental, economic, and social sustainability. This encompasses a wide range of activities, including the use of renewable energy sources, energy efficiency improvements, reducing carbon emissions, and implementing energy-saving technologies and practices. The importance of this indicator lies in its ability to provide a comprehensive view of how effectively a region, organization, or sector is progressing towards sustainable energy goals. Monitoring sustainable energy practices helps identify best practices, guide policy decisions, and foster innovation in energy management. It supports the transition to a low-carbon economy, enhances energy security, and mitigates the impacts of climate change. Ultimately, the widespread adoption of sustainable energy practices contributes to the overall health and resilience of the environment and society, ensuring a sustainable future for generations to come.

Expected evolution of the indicator

The expected evolution of the indicator "Sustainable Energy Practices" is towards a significant and continuous increase, reflecting the global shift towards more environmentally, economically, and socially sustainable energy systems.

Data obtention

Required data: Field measurement or assessment based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

3.1.3.10 Energy Consumption for Wastewater Treatment

- **Code**: Sardinia_Energy10
- **Environmental Sector:** Energy
- **Units**: kWh/m^3 wastewater

Meaning and importance of the indicator

"Energy Consumption for Wastewater Treatment" measures the amount of energy (mainly electricity) used in the processes involved in treating wastewater to make it safe for discharge or reuse. This indicator is crucial for evaluating the sustainability and efficiency of wastewater treatment facilities. High energy consumption can indicate inefficiencies and result in increased operational costs and higher carbon emissions, which are detrimental to both economic and environmental goals. Conversely, optimizing energy use in wastewater treatment can lead to significant cost savings, lower greenhouse gas emissions, and a reduced environmental footprint. Monitoring this indicator helps in identifying opportunities for implementing energy-saving technologies and practices, such as using more efficient equipment, improving process controls, and integrating renewable energy sources. Ultimately, reducing energy consumption in wastewater treatment supports broader sustainability objectives by minimizing resource use and contributing to climate change mitigation.

Expected evolution of the indicator

The expected evolution of the indicator "Energy Consumption for Wastewater Treatment" is towards decreasing energy use per unit of treated wastewater, reflecting improvements in efficiency and sustainability of treatment processes. This evolution is driven by technological advancements, better operational practices, and increased regulatory and policy pressures to reduce environmental impact.

Data obtention

Required data: Field measurement or assessment based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

3.1.3.11 Energy Footprint Per Kg of Food

- **Code**: Sardinia_Energy11
- **Environmental Sector**: Energy
- **Units**: kWh/kg food

Meaning and importance of the indicator

"Energy footprint per kg of food" measures the total amount of energy consumed throughout the entire lifecycle of producing one kilogram of food, including energy used in farming, processing, transportation, and storage. This indicator is vital for assessing the environmental and economic sustainability of food production systems. A high energy footprint suggests inefficiencies and greater environmental impact, contributing to increased greenhouse gas emissions and higher production costs. Conversely, a lower energy footprint indicates more efficient and sustainable practices, reducing the overall environmental burden and conserving energy resources. By monitoring this indicator, stakeholders can identify areas for improvement, adopt energy-saving technologies, and implement best practices to enhance the sustainability of food production. Ultimately, reducing the energy footprint per kg of food supports global efforts towards sustainable agriculture, climate change mitigation, and resource conservation.

Expected evolution of the indicator

The expected evolution of the indicator "Energy footprint per kg of food" is towards a decreasing trend, reflecting improvements in the efficiency and sustainability of food production systems.

Data obtention method

Field measurement or based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

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ANNEX D: DEMO4

DEMO4: Sicily

DEMO4.1: Catania	Sector	Code
Avoided Floods (AF)	Water	Catania_Water01
Captured Runoff (Vrunoff)	Water	Catania_Water02
Effective Stormwater Treatment (SWTeff)	Water	Catania_Water03
Effluent Pollutant Removal (EPR)	Water	Catania_Water04
Flood-Excess Volume (FEV)	Water	Catania_Water05
Rainfall Interception of NBS (RI)	Water	Catania_Water06
Water Availability (WA)	Water	Catania_Water07
Water Quality Compliance (WQC): Biological, Physical and Chemical Parameters	Water	Catania_Water08
Flying Insect Sampling	Biodiversity	Catania_Bio01
Electricity consumption during construction stage (in terms of working hours)	Energy	Catania_Energy01
Electricity consumption during urgent irrigation purposes	Energy	Catania_Energy02
DEMO4.2: Ferla		
Compliant Reclaimed Water (CtotalRW)	Water	Ferla_Water01
Effective Wastewater Treatment (WWTeff)	Water	Ferla_Water02
Effluent Pollutant Removal (EPR)	Water	Ferla_Water03
Rate of Evapotranspiration (ETrate)	Water	Ferla_Water04
Reclaimed Water in Non-Potable Uses (RWnpU)	Water	Ferla_Water05
Water Availability (WA)	Water	Ferla_Water06
Water Quality Compliance (WQC)	Water	Ferla_Water07
Flying Insect Sampling	Biodiversity	Ferla_Bio01
New Fauna Habitat Area	Biodiversity	Ferla_Bio02
Air Temperature At 2 Meters (Daytime and Night-Time)	Human Well-being	Ferla_Well01
Daily Temperature Range (Difference Between the Daily Maximum and Daily Minimum Temperature)	Human Well-being	Ferla_Well02
Heatwave Risks (Number of Combined Tropical Nights (>20°c) And Hot Days (>35°c))	Human Well-being	Ferla_Well03
Days With Temperature >90th Percentile (TX90p)	Human Well-being	Ferla_Well04
Mean Or Peak Daytime Local Temperatures (°C)	Human Well-being	Ferla_Well05
Monthly Mean Value of Daily Maximum Temperature (TXx)	Human Well-being	Ferla_Well06
Monthly Mean Value of Daily Minimum Temperature (TNn)	Human Well-being	Ferla_Well07
KPI1 - Energy Consumption Of NBS, Compared with Equivalent Conventional Infrastructure (% Decrease)	Energy	Ferla_Energy01
KPI10 - Decrease in Urban Heat Island (UHI) Effect (In Terms of Surface Temperatures)	Energy	Ferla_Energy02
Energy Consumption for Wastewater Treatment	Energy	Ferla_Energy03
Building Temperature Behavior	Energy	Ferla_Energy04
Energy Performance of Building (Energy Bills of the School)	Energy	Ferla_Energy05

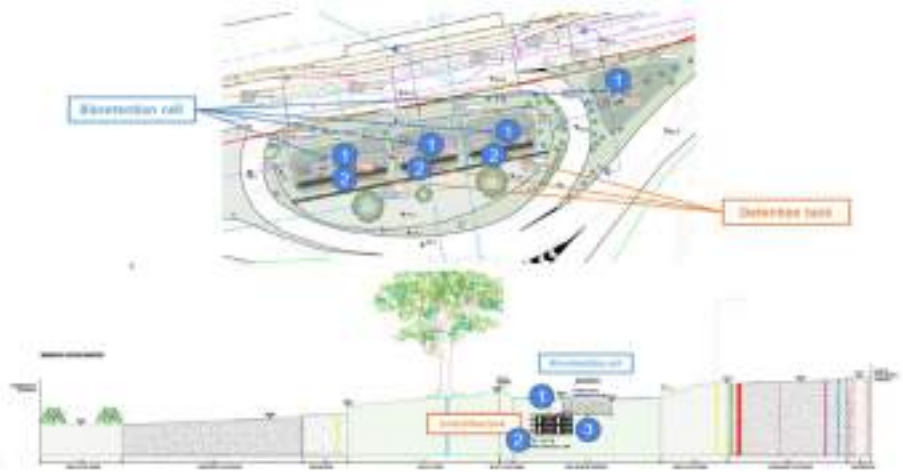
DEMO4.1: Catania

To reduce the risk of urban flood peaks, a nature-based solution is being developed in Andrea Doria, Catania (Italy). The main objective is to capture the water runoff from Alessandro Doria Avenue and Via del Bosco, during the storms thus decreasing flood risks in the city. This is achieved with the implementation of staggered filters made of soil and other materials, that can remove pollutants and help to improve water infiltration. This NbS will be complemented by adding a rain garden with local plants, reducing urban flood peaks. The system will also store the purified water and make it usable for irrigation purposes.

4.1.1 Water Indicators

4.1.1.1 Water Monitoring Plan

Sampling points



SuDS Retrofitting for Improved Stormwater Management-

Sampling point	Location	Purpose
SP-01	In the bioretention cells	Monitor the rainfall interception, rainwater to be treated (efficiency of the whole treatment), and captured runoff
SP-02	Inlet of the detention tanks	Monitor the water quality and the total water available (volume)
SP-03	Underside of the bioretention cell	Monitor the water quality and the efficiency of the bioretention cell

Parameters to be analyzed

Parameter	Applicable Sampling point	Related indicator/s	Type
Volume of rainwater treated	SP-01, SP-02	SWTeff; RWP; WA; Vrunoff; RI; FEV	water flow measurements [volume/time]
Volume of rainfall/runoff captured by the NBS	SP-01, SP-02	RI; Vrunoff	water flow measurements [volume/time]

Rainwater/stormwater events	SP-01, SP-02	AF; FEV	rainwater/stormwater data
Water quality parameters: Conductivity, pH,TSS, COD, TN, TP, temperature	SP-01, SP-02, SP-03	EPR; WFP	water quality parameters

Sampling method

Water flow measurements:

Direct measurement of volume provided during a time period or water flow with flow meters and/or water level sensors.

a) Automatic method

Automatic flow meters can be installed at the recommended sampling points (SP). For the automatization process, it is recommended to register the measurements with a datalogger/digital control system in the DEMO. It is recommended to measure the flow at the recommended sampling points (SP).

Data should be stored in a datalogger/digital control system and then be able to be exported in a spreadsheet to calculate the associated indicators. When this is not possible, manual readings of the flow meters can be done instead.

b) Manual method

This could be applied as the last option if there is no possibility to apply the automatic method.

- Periodic manual measurements
- If no devices are available to measure, correct and reliable estimates must be made to assess the indicator.
- Measure the volume at the point of reuse or approximate the value based on the amount of water demand met by agroforestry for reuse.

Water quality parameters:

Automatic measurement methods (a) or manual sampling campaigns (water sampling + laboratory analysis) (b) can be employed, with specific requirements for different types of pollutants.

a) Automatic method

Advanced sensors of water quality can be installed in the recommended sampling points (SP) to continuously monitor and measure various water quality parameters, such as temperature, pH, TSS, COD, TN, TP, etc. These sensors collect data in real-time, providing continuous and accurate information about water quality. The data is often transmitted wirelessly to a central database, or sensors can be also connected to a datalogger. The data is often transmitted wirelessly to a central database, or sensors can be also connected to a datalogger.

b) Manual method

As the DEMO is already implemented, mature and operating, sampling campaigns will be carried out periodically to control the operation and performance of the treatment system. Samples will be collected at the recommended sampling points (SP).

Two types of water quality analysis have been defined: **basic** and **complete**. Basic analysis will include all water quality parameters that are required to be monitored by legislation for reclaimed water reuse TSS, TN, TP.

Complete analysis includes other water quality parameters for general monitoring and indicators' assessment: conductivity, COD, TN, TP, TSS.

Samples can be obtained manually or using automatic sampling equipment. An automatic sampler is a device that can be refrigerated or non-refrigerated and include automatic sampling pumps and upward stage samplers. The process involves collecting water samples intended for laboratory analysis of water quality parameters. However, there are limitations associated with automatic sampling, such as intermediate sampling containers, sampling from a fixed point, and sample storage and preservation, which must be considered and documented. Personnel using these methods should have training and prior experience in the use and calibration of automatic sampling equipment.
The laboratory analysis is done following current ISO laboratory protocols for each different parameter.

Sampling calendar

Water flow measurements and water depth variation:
Data should be collected frequently for a relevant time period (e.g., daily, weekly, monthly) to allow for accumulation over the entire reporting period (yearly). This high frequency is also relevant to study seasonal variations.

Water quality parameters:
As the DEMO has not been implemented yet, different sampling and analysis periodicities will be suggested during the start-up phase, stabilization phase and mature operation:

- Start-up phase: the first 3 months of operation of the DEMO it is recommended to increase the frequency of the analysis to 2 basic analysis per week and 1 complete analysis per week.
- Stabilization phase: from month 4 to month 12 of operation it is recommended to do 1 basic analysis per week and 2-3 complete analysis per month.
- Mature operation: from month 13, the recommended frequency of water quality analysis is 1 basic analysis per week and 1 complete analysis per month.

Rainwater/stormwater data:
Data should be collected every time there is a rain event.

Equipment

a) Water flow measurements:

Water flow meters are essential tools for monitoring and assessing the efficiency of these systems, as they provide real-time data on water movement and usage through the treatment processes and the different pipes, helping to determine the volume of water at those particular locations.
Some indicative providers of these water flow meters are:

- Endress+Hauser
- Systec Controls
- Aobo instrument

Any equivalent water flow meter is acceptable, these are given as examples.

b) Water quality parameters:

The automatic sampling method requires simple or multiparametric sensors for water quality and data loggers or digital control systems for data recording. It also requires personnel for data collection and treatment.
The manual sampling campaign requires laboratory and field personnel for manual sampling and analysis and also reagents and laboratory material depending on the current ISO laboratory protocols for each parameter.

Some indicative providers for water quality parameters are:

- ANISE sensor (NH_4 and NO_3) - Hach
- Conductivity meter - METTLER TOLEDO
- pH meter - METTLER TOLEDO
- Multi-parameter water quality analyzer (temperature, pH, conductivity, DO, turbidity, BOD, COD, ammonia nitrogen, NO_3, colour, chloride, depth, etc.) - BOQU instruments

Any equivalent water level sensor is acceptable, this is given as an example.

c) Rainwater/stormwater data:

In this DEMO, the main water flow measurements would be rainwater/stormwater, so there are different rain gauges that can be used for it.
Some indicative providers of are:

- OMEGA
- Amazon

Any equivalent water level sensor is acceptable, this is given as an example.

External subcontracting

Yes. A trustable laboratory delivering water quality analyses must be hired if not available internally.

4.1.1.2 Avoided Floods (AF)

- **Code**: Catania_Water01
- **Environmental Sector:** Water / Rainwater management and flood protection
- **Units:** %/year

Meaning and importance of the indicator

The indicator measures the effectiveness of NBS in reducing the occurrence of flood events. It is expressed as the percentage of flood events that have been avoided due to the implementation of NBS, compared to the number of floods that would have occurred in the absence of these interventions. This indicator is applicable to NBS that are designed to retain and/or store a certain volume of stormwater/runoff. NBS retention capacity: the maximum volume of stormwater/runoff that the NBS is designed to manage. When stormwater/runoff volume exceeds the NBS capacity, it cannot be expected to retain all, and flooding may occur.

Expected evolution of the indicator

The baseline for this indicator is the averaged total number of flood events per year (minimum of 5 years) before the implementation of NBS. Ideally, the indicator should show a decrease in the number of flood events over time, reflecting the effectiveness of the NBS. The optimal value would approach 100%, indicating that all potential floods have been successfully avoided due to the NBS.

Possible relationship with other water indicators

Flood excess volume.

Data obtention

Sampling plan:

- The number of floods that did not occur due to the presence of NBS,
- The actual number of flood events observed during the period after the implementation of NBS.

Calculation formula

$$Nf = \frac{100 \cdot Nf_o}{Nf_t}$$

Where:

- Nf: Number of avoided Flood (%/year),
- Nf_t: Number of avoided flood events (n/year),
- Nf_o: Observed number of flood events (n/year).

*Only events under the capacity of the infrastructure are considered, annually.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- Barraud S., Moura P., Cherqui F. (2008). Rapport sur les indicateurs et sur les méthodes de constructions des indicateurs de performances des ouvrages d'infiltration. Agence Nationale de la Recherche, Programme PRECODD-Ecopluies. https://www.graie.org/ecopluies/delivrables/D-D2-v1.pdf

4.1.1.3 Captured Runoff (Vrunoff)

- **Code**: Catania_Water02
- **Environmental Sector:** Water / Rainwater management and flood protection
- **Units:** %/year

Meaning and importance of the indicator

This indicator provides the volume of stormwater runoff captured by the NBS, based on the NBS design capacity. This is essential for assessing the effectiveness of NBS in managing stormwater, preventing floods, and improving water quality. Capturing runoff effectively helps to mitigate the risk of flooding, reduce the burden on conventional drainage systems, and enhance the sustainability of water resources by promoting infiltration and storage of rainwater.

Expected evolution of the indicator

The ideal value for this indicator is 100%, indicating that the NBS is capturing runoff efficiently, in line with its design capacity. Over time, the indicator should approach or maintain a value close to 100%, reflecting the successful management of runoff by the NBS.

Possible relationship with other water indicators

Avoided floods, Flood excess volume.

Data obtention

Sampling plan:

- Annual volume of runoff captured by NBS over a year (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total number of runoff events per year (nº)
  See more information at the individual DEMO Monitoring Plan.
- NBS capture capacity (m^3)
  The total volume of the NBS that is able to receive runoff. The total volume of the NBS that is able to receive runoff, rainwater, stormwater, or any other water flow with runoff potential. It should be a constant value. But maybe some clogging may occur during the operation of the NBS and the capacity can decrease over time, so it should be measured periodically.

Calculation formula

$$Vrunoff = \left(\frac{V_C}{V_S \cdot N}\right)$$

Where:

- Vrunoff: Captured runoff (%/year),
- V_c: Annual runoff captured by NBS (m^3/year),
- N: Number of runoff events per year (n),
- V_s: NBS capture capacity (m^3).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- Barraud S., Moura P., Cherqui F. (2008). Rapport sur les indicateurs et sur les méthodes de constructions des indicateurs de performances des ouvrages d'infiltration. Agence Nationale de la Recherche, Programme PRECODD-Ecopluies. https://www.graie.org/ecopluies/delivrables/D-D2-v1.pdf

4.1.1.4 Effective Stormwater Treatment (SWTeff)

- **Code**: Catania_Water03
- **Environmental Sector:** Water / Safeguarded water ecosystems
- **Units:** %

Meaning and importance of the indicator

The SWTeff indicator measures the percentage of stormwater that is treated in compliance with legal requirements before being discharged into natural water bodies, such as lakes, rivers, seas, or groundwater or being reused. This metric provides critical insight into the extent to which polluted stormwater generated in a given area is directly released into the environment without adequate treatment. The untreated polluted stormwater will have a negative impact on ecosystems in all kinds of water bodies, and the share of polluted stormwater that is treated is therefore a measure of the level of protection of water bodies.

Expected evolution of the indicator

The range is from 0 to 100%, the optimal value for the SWTeff indicator is ideally 100%, indicating that all polluted stormwater in the assessed area is treated to meet or exceed legal standards before discharge. Achieving this would mean no untreated stormwater is released into the environment, thus ensuring maximum protection for water bodies.

Possible relationship with other water indicators

Water quality compliance: biological, physical and chemical parameters, Compliant reclaimed water, Effluent pollutant removal, Avoided floods.

Data obtention

Sampling plan:

- Identified potential stormwater pollution areas where suitable treatment is implemented (m^2 or ha). Only data that corresponds to areas where suitable treatment has been implemented in the DEMO will be selected. Total potential stormwater pollution area identified (m^2 or ha).

Field area measuring and/or geographic information systems (GIS).

In order to have data on this indicator it is necessary to have three categories of data:

4. It is necessary to have an overview of all the installed and built local stormwater treatment systems, through an inventory and evaluation of the infrastructure.
5. In case of combined wastewater systems (where both stormwater and sewer are sent to treatment plants for treatment), it is necessary to have an overview of areas where stormwater is not effectively connected to the combined system, and where the stormwater instead is discharged (untreated).
6. GIS modelling procedures. It is necessary to know the areas where solutions described under point 1 and/or 2 are implemented. GIS can be used to assess the size of these areas and thus also the size of the areas not having in place a system for stormwater treatment. This way the share of the area of a city/municipality that has treatment systems in place can be estimated.

Calculation formula

$$SWTeff = \frac{A_{Treatment}}{A_{Total}} \cdot 100$$

Where:

- SWTeff: Effective stormwater treatment (%),
- $A_{Treatment}$: Identified potential stormwater pollution areas where suitable treatment is implemented (m^2 or ha),
- A_{Total}: Total potential stormwater pollution area identified (m^2 or ha).

Note: both $A_{Treatment}$ and A_{Total} must be consistent and select the same units.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- Indicator adapted from Effective Wastewater treatment (WWTeff). B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

4.1.1.5 Effluent Pollutant Removal (EPR)

- **Code**: Catania_Water04
- **Environmental Sector:** Water / Water treatment / Water quality
- **Units:** %

Meaning and importance of the indicator

The indicator measures the average removal ratio between incoming and outgoing pollution load of the NBS. It can be evaluated for any pollutant. It is used to assess the effectiveness of water treatment processes in reducing pollution before discharge into the environment or wastewater treatment plant or its reuse.

*If there are additional water treatments in combination with the NBS, we recommend sampling before and after each treatment to have a better understanding of the role of each one in the treatment process.

Expected evolution of the indicator

The target can be determined based on design requirements (e.g., why the NBS is necessary, which pollutant needs to be addressed, and the desired removal efficiency) or according to local regulations and guidelines that define water quality standards depending on its intended use (such as for consumption, discharge, or reuse). For reclaimed water (as per Water Directive 2020/741), the goals would be: 95% removal of microbiological and emerging contaminants, 60-95% removal of nutrient pollutants, and 95% removal of physico-chemical parameters (such as turbidity). For treated wastewater (under RD 509/1996 and RD 11/1995), the objectives would include 70-80% reduction of nutrient pollutants and 90% removal of physico-chemical parameters (such as turbidity). For drinking water (in line with RD 3/2023), the goals would involve: 99-100% elimination of microbiological contaminants, 80-99% reduction of chemical pollutants, and 95% removal of physico-chemical parameters (such as turbidity) and nutrients.

Possible relationship with other water indicators

Reclaimed water production, Environmental flow requirement compliance rate, Safe drinking water, Water quality compliance: biological, physical and chemical parameters.

Data obtention

Sampling plan:

- Average influent concentration (mg/L).
- Average effluent concentration (mg/L).

Water quality parameters:

- Physical-chemical properties data:
  - - pH (unitless)
  - - Temperature (ºC)
  - - Electrical Conductivity (EC) (µS/cm)
  - - Turbidity (NTU)
  - - TSS (Total Suspended Solids) (mg/L)
- Biological data:
  - - DO (Dissolved Oxygen) (mg/L O_2)

- - BOD (Biochemical Oxygen Demand) (mg/L O_2)
- - COD (Chemical Oxygen Demand) (mg/L O_2)
- - TOC (Total Organic Carbon) (mg/L O_2)

- Chemical pollutant data:
  - - Heavy metals (µg/L)

  - Total hydrocarbons (µg/L)
  - Total pesticides (µg/L)
- Nutrients data:
  - - TN (Total Nitrogen) (mg/L N)
  - - NO_3 (Nitrates) (mg/L)
  - - TP (Total Phosphorus) (mg/L P)
  - - PO_4 (Phosphates) (mg/L)
- Microbiological data:
  - - E. Coli (CFU/100 mL)
- Other specific pollutants data:
  - - Contaminants of emerging concern
  - - Pollutants from industrial effluents will be added if necessary.

Calculation formula

$$\%Re = \frac{(Ci - Ce)}{Ci} \cdot 100$$

Where:

- %Re: average effluent pollutant removal (%),
- Ci: average influent concentration (mg/L),
- Ce: average effluent concentration (mg/L).

*To be evaluated for each pollutant.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: A handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577
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4.1.1.6 Flood-Excess Volume (FEV)

- **Code**: Catania_Water05
- **Environmental Sector:** Water / Rainwater management and flood protection
- **Units:** m^3

Meaning and importance of the indicator

The indicator helps to quantify the volume of water that contributes to flooding, and therefore the volume of flood water that should be mitigated (i.e. reduced to zero) by the cumulative effect of various flood mitigation measures (i.e. NBS implementation). This indicator is useful as a complementary way of classifying flood events and evidence-based decision-making for flood-mitigation schemes.

Expected evolution of the indicator

Over time, the FEV should decrease as more effective flood mitigation measures, including NBS, are implemented. The last goal is to reduce the FEV to 0 m^3, indicating that all excess water is managed without causing flooding.

Possible relationship with other water indicators

Avoided floods, Rainfall interception.

Data obtention

Sampling plan:

- Total volume of water potential to cause flood (m^3)
  - Continuous monitoring of runoff and rainwater/stormwater events.
- Capacity of the infrastructure (i.e. NBS, DEMO) to manage water before flooding occurs (m^3)
  - The total volume of the NBS that is able to receive runoff, rainwater, stormwater, or any other water flow with flooding potential. It should be a constant value. But maybe some clogging may occur during the operation of the NBS and the capacity can decrease over time, so it should be measured periodically.

Calculation formula

$$FEV = V_{flood} - V_{capacity}$$

Where:

- FEV: Flood Excess Volume (m^3),
- V_{floodl}: Total volume of water potential to cause flood (m^3),
- $V_{capacity}$: Capacity of the infrastructure (i.e. NBS, DEMO) to manage water before flooding occurs (m^3).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: a handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577
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4.1.1.7 Rainfall Interception of NBS (RI)

- **Code**: Catania_Water06
- **Environmental Sector:** Water / Rainwater management and flood protection
- **Units:** mm/h

Meaning and importance of the indicator

The indicator measures the rate at which rainfall is intercepted by the NBS. This indicator is important for assessing the effectiveness of NBS in managing rainwater, reducing surface runoff, and mitigating flood risks. The interception capacity of NBS directly influences the hydrological balance and contributes to water retention in the ecosystem, thereby playing a vital role in flood prevention and sustainable water management.

Expected evolution of the indicator

Baseline: Initial interception capacity of the NBS.

Target: The optimal value would be a higher rate of rainfall interception compared to the baseline scenario and conventional infrastructure, leading to reduced surface runoff and enhanced groundwater recharge. This should ideally increase over time as the NBS matures and vegetation coverage expands.

Possible relationship with other water indicators

Captured runoff, Flood excess volume, Avoided floods.

Data obtention

Sampling plan:

- Volume of rainfall intercepted by the NBS (mm)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Time duration of the rainfall event (h)

Calculation formula

$$RI = \frac{Vrainfall\ NBS}{t}$$

Where:

- RI: Rainfall Interception Rate (mm/h),
- Vrainfall NBS: The total volume of rainfall intercepted by the NBS during a given time period (mm),
- t: time duration of the rainfall event (h).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: a handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577

4.1.1.8 Water Availability (WA)

- **Code**: Catania_Water07
- **Environmental Sector:** Water / Freshwater supply / Resource efficiency
- **Units:** m^3/year

Meaning and importance of the indicator

The indicator refers to the volume of water available provided by the DEMO for its reuse in various applications (e.g. aquifer recharge, ecosystem restoration, on site reuse, irrigation, industrial activities, etc.). The water available should comply with quality standards required for different reuses as per current legislation.

Expected evolution of the indicator

The baseline for this indicator is the initial water availability capacity, which may start at 0 m^3/year. It is expected to increase over time once the DEMO is operating and optimized, reflecting an improvement in water availability for reuse and ecosystem services. Ensure that 100% of the water provided by the DEMO is available for reuse.

Possible relationship with other water indicators

Water footprint, Water provision by the ecosystem.

Data obtention

Sampling plan:

- Direct annual flow of the effluent or annual volume provided by the DEMO for specific purposes (e.g., aquifer recharge, ecosystem restoration, etc.) (m^3/year).
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total volume water available in the DEMO (WA) (m^3/year).

Calculation formula

$$WA = Water\ inflows\ (WI) - Water\ losses\ (WL)$$

Where:

- WI: Total water entering the DEMO system (e.g., precipitation, surface water, groundwater recharge, recycled water) (m^3)
- WL: Total water lost (due to evaporation (m^3))

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

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- U.S. Environmental Protection Agency (2024). Basic information about water reuse. https://www.epa.gov/waterreuse/basic-information-about-water-reuse

4.1.1.9 Water Quality Compliance (WQC): Biological, Physical and Chemical Parameters

- **Code:** Catania_Water08
- **Environmental Sector:** Water / Water quality
- **Units:** [Compliant with regulatory standards: Yes/No]

Meaning and importance of the indicator

The indicator provides a simplified view of regulatory compliance regarding water quality, taking into account various parameters. It is especially important to validate quality standards required by current regulations. It can be evaluated for each water quality parameter: pH, temperature, DO, BOD, COD, electrical conductivity (EC), total suspended solids (TSS), total dissolved solids (TDS), nitrogen (N), ammonium (NH_4^+), phosphorus (P), metals (Cadmium (Cd) - Copper (Cu) - Lead (Pb) - Mercury (Hg) - Nickel (Ni) - Zinc (Zn), etc.), other ions (Chloride (Cl^-) - Sulphate (SO_4^{2-}) - Sodium (Na) - Potassium (K) - Calcium (Ca) - Magnesium (Mg)), total faecal coliform bacteria, PAH content, total organic carbon (TOC), Organic micropollutants such as pesticides and chemicals (polychlorinated bisphenols (PCBs) - Hexachlorocyclohexane (HCH) group compounds - Polycyclic aromatic hydrocarbons (PAHs)), other depending on legislation and needs.

Expected evolution of the indicator

The indicator should show that all measured parameters meet or exceed regulatory compliance standards over time. Optimal values vary depending on the specific parameter and local environmental regulations but should indicate no exceedance of legal thresholds for water quality. One example is:
The target could be assessed based on local policies and directives that establish the water quality limits depending on its use (water consumption, discharge, reuse, etc.).
For reclaimed water (Water Directive 2020/741), the targets would be: E. coli ≤ 10 CFU/100 m/L, BOD (Biochemical Oxygen Demand) ≤ 10 mg/L, TSS (Total Suspended Solids) ≤ 10 mg/L and Turbidity ≤ 5 NTU.
For treated wastewater (RD 509/1996 and RD 11/1995), the targets would be: TN (Total Nitrogen) 15 mg/L N (from 10,000 to 100,000 h-e) 10 mg/l N (more than 100,000 h-e), TP (Total Phosphorus) 2 mg/L P (from 10,000 to 100,000 h-e) 1 mg/L P (more than 100,000 h-e), BOD (Biochemical Oxygen Demand) 25 mg/L O_2, COD (Chemical Oxygen Demand) 125 mg/L O_2, TSS (Total Suspended Solids) 35 mg/L.
For drinking water (RD 3/2023), the targets would be: E. coli 0 CFU/100 mL, pH 6.5-9.5, Electrical Conductivity (EC) 2500 µS/cm at 20 ºC, Turbidity 4.0 NTU, Total Organic Carbon (TOC) 5.0 mg/L, Polycyclic Aromatic Hydrocarbons (PAHs) 0.10 µg/L, Arsenic 10 µg/L, Cadmium 5.0 µg/L, Chromium 25 µg/L, Mercury 1.0 µg/L, Nickel 20 µg/L, Lead 5.0 µg/L, Antimony 10 µg/L, Selenium 20 µg/L, Nitrate 50 mg/L, Nitrite 0.50 mg/L and individual pesticide 0.10 µg/L."

Possible relationship with other water indicators

Reclaimed water production, Compliant reclaimed water.

Data obtention

Sampling plan:
The quality parameters required by the current regulations or permits associated:

- Physical Parameters: pH, temperature, EC, TSS, turbidity, alkalinity, etc.

- Chemical Parameters: COD, BOD, nutrients (nitrogen, phosphorus), metals (Cd, Cu, Pb, Hg, Ni, Zn), and other ions (Cl^-, SO_4^{2-}, Na, K, Ca, Mg).
- Biological Parameters: DO, total coliform bacteria, E. coli, Legionella spp., etc.
- Organic Micropollutants: Pesticides, PCBs, polycyclic aromatic hydrocarbons (PAHs), etc.

See more information at the individual DEMO Monitoring Plan.

Calculation formula

Compare Ce to Creg:
If Ce < Creg, then WQC = Yes
If Ce > Creg, then WQC = No

Where:

- Ce: average effluent concentration in pollutant concentration units.
- Creg: regulated pollutant concentration for water use in pollutant concentration units.

*To be evaluated for each pollutant.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- Boletín Oficial del Estado (1995). Real Decreto 11/1995, de 28 de diciembre, por el que se establecen las normas aplicables al tratamiento de las aguas residuales urbanas. Boletín Oficial del Estado, núm. 312, 37517-37519. https://www.boe.es/boe/dias/1995/12/30/pdfs/A37517-37519.pdf
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4.1.2 Biodiversity Indicators

4.1.2.1 Flying Insect Sampling

- **Code:** Catania_Bio01
- **Environmental Sector:** Biodiversity / Fauna
- **Units:** Number of flying insects, Number of species

Meaning and Importance of the Indicator

Urban parks serve as key green spaces that support biodiversity within cities. Insect populations in these parks provide valuable ecosystem services, such as pollination and pest control, while also serving as food for urban wildlife. Yellow sticky traps are a common methodology used to monitor flying insects in urban environments, offering insight into the health of insect populations. These traps attract and capture flying insects drawn to the colour yellow, particularly pest species like aphids, leafhoppers, and flies, as well as pollinators and other beneficial species. Monitoring the diversity and abundance of flying insects in urban parks helps to evaluate the ecological quality of these green spaces and can reveal the impacts of urbanization, pollution, and habitat fragmentation on insect communities.

Expected Evolution of the Indicator

In a healthy urban park, a balanced population of both pest and beneficial insects should be present. Over time, any shifts in insect populations—such as an increase in pests or a decline in pollinators—could indicate environmental stresses, such as excessive pesticide use, air pollution, or habitat degradation. When introducing landscape or vegetation changes to the park it is especially useful to monitor changes in insect populations and can help urban park managers make informed decisions about maintenance practices, plant diversity, and habitat restoration efforts.

Data obtention

Required data:

- Number of flying insects caught on yellow sticky traps, categorized by morphospecies or morphological groups (e.g., aphids, flies, pollinators, beetles).

Sampling Plan

- Bright yellow adhesive-coated traps (dimensions: 10-15 cm x 20-30 cm) will be used to capture flying insects.
- Traps will be placed at various locations within the park, focusing on areas with high insect activity, such as near flowering plants, water features, or shrubs.
- Traps will be mounted vertically on poles or tree branches at approximately 2-3 meters above the ground to capture a wide range of flying insect species, and also to avoid the general public acces to the traps.
- A minimum of 10 traps will be deployed across the park, ensuring that different habitats within the park (e.g., flowerbeds, lawns, and wooded areas) are covered.
- The traps will be left in place for 24-72 hours during each sampling event to allow for sufficient insect capture. After this period, the traps will be collected, and the captured insects will be identified and recorded. If the traps fill too quickly, this time can be adjusted.

- Traps should be placed in open areas with direct sunlight, as yellow is most effective at attracting insects in well-lit locations.
- Traps should be replaced after each sampling event to ensure accurate results. Traps that become too saturated with insects or debris may lose their effectiveness.
- Insects captured on the traps should be identified in the lab or by an expert.

Sampling Calendar

Sampling will be conducted monthly from May to September, covering the active flight periods of most flying insect species in the park. Monitoring will take place annually over the duration of the demo action.

Equipment

- Adhesive-coated yellow traps (10-15 cm x 20-30 cm).
- Poles, stakes, or tree branches to mount the traps at 2-3 meters above the ground.
- Plastic containers or zip bags to transport traps and collected insects for analysis.

External subcontracting

Yes, external subcontracting may be required for detailed taxonomic identification of the insects captured on the yellow sticky traps. While basic identification can be performed in the field (e.g., categorizing into functional groups such as pollinators or pests), species-level identification should be handled by professional entomologists or specialized laboratories.

References

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4.1.3 Energy Indicators

4.1.3.1 Electricity consumption during construction stage (in terms of working hours)

- **Code**: Catania_Energy01
- **Environmental Sector**: Energy
- **Units**: kWh/day

Meaning and importance of the indicator

"Electricity consumption during the construction stage (per working hour)" measures the total electrical energy used on-site for each hour of construction activities. This indicator is essential in understanding the Demo's immediate energy impact, identifying potential inefficiencies, and comparing the energy demands of various construction activities. By measuring energy use per hour, it becomes easier to pinpoint which operations are most energy-intensive, allowing for targeted efficiency improvements. This is particularly significant in terms of cost savings, resource optimization, and environmental sustainability, as reduced energy consumption directly decreases greenhouse gas emissions associated with the construction phase.

Expected evolution of the indicator

Ideally, this indicator should show a downward trend as construction progresses due to improved efficiencies, optimized workflows, and possibly the implementation of energy-saving technologies. The optimal range varies based on project scale and complexity, but the goal is to keep consumption as low as possible without compromising construction progress. Advanced projects might target an optimal range set by industry benchmarks or environmental standards, but even small reductions per hour can accumulate significantly over the full construction period.

Data obtention

Energy consumption assessment will be based on electrical capacities of equipment and total using time.

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

4.1.3.2 Electricity consumption during urgent irrigation purposes

- **Code**: Catania_Energy02
- **Environmental Sector**: Energy
- **Units**: kWh/m^2 land

Meaning and importance of the indicator

"Energy use" measures the amount of energy consumed in irrigation activities. This indicator is crucial for assessing the energy efficiency and environmental impact of irrigation practices. High electricity consumption can indicate inefficiencies, leading to increased operational costs and higher carbon emissions. Conversely, optimizing electricity use enhances sustainability by reducing greenhouse gas emissions and lowering production costs, which is vital for the economic viability of farming. Monitoring this indicator helps identify opportunities for implementing energy-saving technologies and practices, such as precision agriculture, renewable energy integration, and efficient irrigation systems. Ultimately, reducing electricity use supports broader sustainability goals, including resource conservation, climate change mitigation, and the promotion of eco-friendly irrigation practices.

Expected evolution of the indicator

The expected evolution of the indicator "Electricity use in irrigation" is towards greater efficiency and sustainability, driven by technological advancements, economic considerations, and environmental regulations.

Data obtention method

Field measurement or assessment based on amount of irrigated water. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

DEMO4.2: Ferla

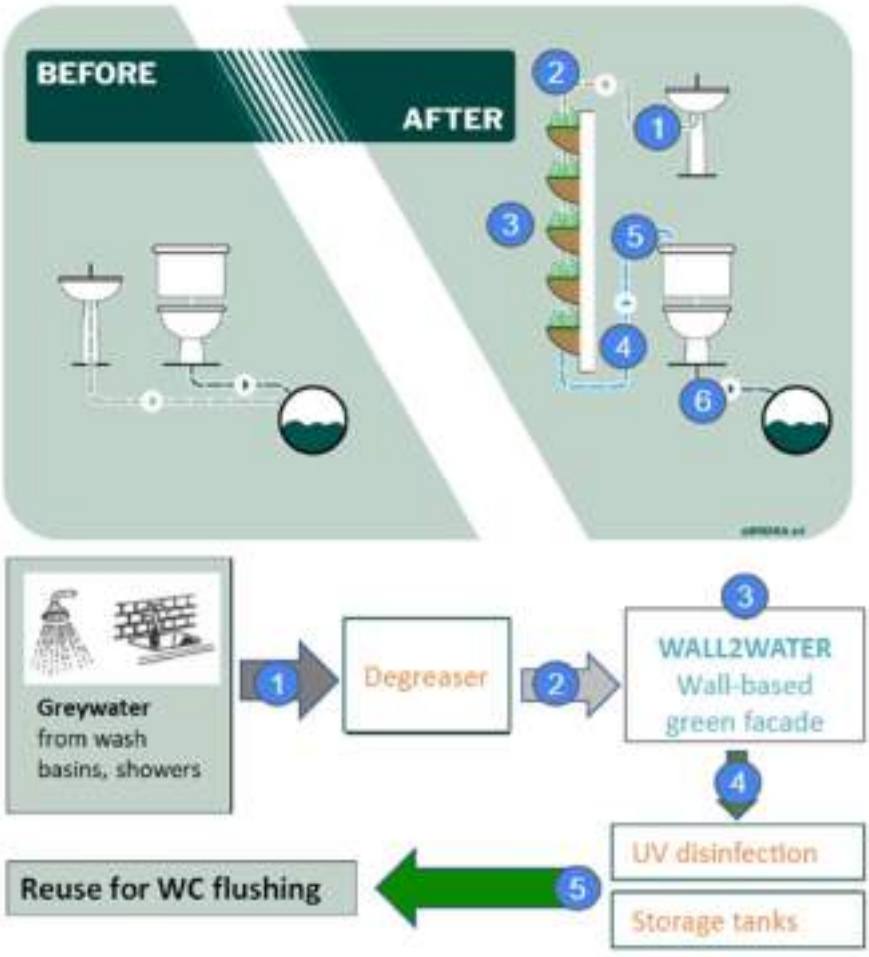
The construction of a green living wall system, a NbS that showed a production of averagely 150-200 l/day of greywater, has been carried out in a schoolyard in Ferla, Sicily (Italia). The system is used to manage the greywater from the hand washing stations of the school, and to reuse it to cultivate and grow vegetation on the wall. After excess water from the living wall is then reused again as treated greywater for toilet flushing. Temperature sensors are installed to provide continuous monitoring on how the green wall helps lower the temperature inside the school building.

4.2.1 Water Indicators

4.2.1.1 Water Monitoring Plan

Sampling points

Beyond Aesthetics: Wall-based green facade for sustainable water management



Sampling point	Location	Purpose

SP-01	Inlet of the degreaser (after the wash, basins, showers,...)	Monitor total volume of water for non-potable uses
SP-02	Outlet of the degreaser treatment	Monitor the reclaimed water
SP-03	Middle of the surface of the wall-based green façade	Monitor evapotranspiration
SP-04	Inlet of the disinfection treatment	Monitor the effectiveness of disinfection treatment
SP-05	Outlet of the disinfection treatment	Monitor the reclaimed water
SP-06	Outlet of the WC (before the discharge)	Monitor the wastewater efficiency treatment

Parameters to be analyzed

Parameter	Applicable Sampling point	Related indicator/s	Type
Volume of treated wastewater (WW)	SP-01, SP-05	WWTeff; RWP; WA	water flow measurements [volume/time]
Volume of reclaimed water produced	SP-02, SP-05	RWnpU; WA;	water flow measurements [volume/time]
Water quality parameters: -Nitrogen content (TN, NO3 or NH3) depending on the fertilizer it would replace and its N content. -Total phosphorus (TP) content	SP-01, SP-6	WQC; WA	water quality parameters
Water quality parameters: Conductivity, COD, BOD5, TSS, TN, TP, TOC, Temperature, turbidity, E. coli	SP-01, SP-6	WQC; CtotalRW; EPR;	water quality parameters
Amount of water that is lost by evapotranspiration over a period	SP-03	ETrate;	water depth variation [mm]

Sampling method

Water flow measurements:

Direct measurement of volume provided during a time period or water flow with flow meters and/or water level sensors.

a) Automatic method

Automatic flow meters can be installed at the recommended sampling points (SP). For the automatization process, it is recommended to register the measurements with a datalogger/digital control system in the DEMO. It is recommended to measure the flow at the recommended sampling points (SP).

Data should be stored in a datalogger/digital control system and then be able to be exported in a spreadsheet to calculate the associated indicators. When this is not possible, manual readings of the flow meters can be done instead.

b) Manual method

This could be applied as the last option if there is no possibility to apply the automatic method.

- Periodic manual measurements
- If no devices are available to measure, correct and reliable estimates must be made to assess the indicator.
- Measure the volume at the point of reuse or approximate the value based on the amount of water demand met by the green facade for reuse.

Water quality parameters:

Automatic measurement methods (a) or manual sampling campaigns (water sampling + laboratory analysis) (b) can be employed, with specific requirements for different types of pollutants.

a) Automatic method

Advanced sensors of water quality can be installed in the recommended sampling points (SP) to continuously monitor and measure various water quality parameters, such as temperature, pH, turbidity, dissolved oxygen, NO_3, etc. These sensors collect data in real-time, providing continuous and accurate information about water quality. The data is often transmitted wirelessly to a central database, or sensors can be also connected to a datalogger. The data is often transmitted wirelessly to a central database, or sensors can be also connected to a datalogger.

b) Manual method

As the DEMO is already implemented, mature and operating, sampling campaigns will be carried out periodically to control the operation and performance of the treatment system. Samples will be collected at the recommended sampling points (SP).

Two types of water quality analysis have been defined: **basic** and **complete**. Basic analysis will include all water quality parameters that are required to be monitored by legislation for reclaimed water reuse for irrigation: turbidity, BOD_5, E.coli, TSS (other if required by legislation).

Complete analysis includes other water quality parameters for general monitoring and indicators' assessment: conductivity, TN, TP, TOC, temperature, NO_3 and/or NH_3.

Samples can be obtained manually or using automatic sampling equipment. An automatic sampler is a device that can be refrigerated or non-refrigerated and include automatic sampling pumps and upward stage samplers. The process involves collecting water samples intended for laboratory analysis of water quality parameters. However, there are limitations associated with automatic sampling, such as intermediate sampling containers, sampling from a fixed point, and sample storage and preservation, which must be considered and documented. Personnel using these methods should have training and prior experience in the use and calibration of automatic sampling equipment.

The laboratory analysis is done following current ISO laboratory protocols for each different parameter.

Water depth variation:

The variation in the water content of the wetlands and the soil can be done manually or through automatic methods.

a) Automatic method

For the constructed wetlands: Water level sensors, weather stations, remote sensing through hydrological models.

For the agroforestry soil: weather stations, sensors, remote sensing through hydrological models.

b) Manual method

For the constructed wetlands: direct water level measurements in a period of time. Measure water depth of the wetland at the initial time and after a period of time (e.g. minutes, hours, 1 day, etc.)

For the agroforestry soil: field direct measurements using lysimeters or scintillometers.

Sampling calendar

Water flow measurements and water depth variation:

Data should be collected frequently for a relevant time period (e.g., daily, weekly, monthly) to allow for accumulation over the entire reporting period (yearly). This high frequency is also relevant to study seasonal variations.

Water quality parameters:

During the operation, the recommended frequency of water quality analysis is 1 basic analysis per week (as reclaimed water is being used in agroforestry) and 1 complete analysis per month.

Equipment

a) Water flow measurements:

Water flow meters are essential tools for monitoring and assessing the efficiency of these systems, as they provide real-time data on water movement and usage through the treatment processes and the different pipes, helping to determine the volume of water at those particular locations.

Some indicative providers of these water flow meters are:

- Endress+Hauser
- Systec Controls
- Aobo instrument

Any equivalent water flow meter is acceptable, these are given as examples.

b) Water quality parameters:

The automatic sampling method requires simple or multiparametric sensors for water quality and data loggers or digital control systems for data recording. It also requires personnel for data collection and treatment.

The manual sampling campaign requires laboratory and field personnel for manual sampling and analysis and also reagents and laboratory material depending on the current ISO laboratory protocols for each parameter.

Some indicative providers for water quality parameters are:

- ANISE sensor (NH_4 and NO_3) - Hach

- Conductivity meter - METTLER TOLEDO
- pH meter - METTLER TOLEDO
- Multi-parameter water quality analyser (temperature, pH, conductivity, DO, turbidity, BOD, COD, ammonia nitrogen, NO_3, colour, chloride, depth, etc.) - BOQU instruments

Any equivalent water level sensor is acceptable, this is given as an example.

c) Water depth variation:

Some indicative providers are:

- Lysimeter - Royal Eijkelkamp ; MundoRiego
- Sensor - LI-COR
- Scintillometer - SCINTEC
- Water level sensor - ATMI

External subcontracting

Not needed if internal technical resources are available.

4.2.1.2 Compliant Reclaimed Water (CtotalRW)

- **Code**: Ferla_Water01
- **Environmental Sector:** Water / Safe and secure fit-for-purpose water provision
- **Units:** %

Meaning and importance of the indicator

This indicator represents the percentage of reclaimed water that adheres to the required quality standards at the specified compliance location, ensuring it meets the necessary criteria. 'Reclaimed water' means urban wastewater that has been treated in compliance with the requirements set out in Directive 91/271/EEC (Urban Wastewater Treatment Directive), and which results from further treatment in a reclamation facility; in accordance with Section 2 of Annex I to this Regulation: 'Point of compliance' means the point where a reclamation facility operator or alternative water supplier delivers reclaimed and/or non-potable water to the next actor in the chain. 'Non-compliance with reclaimed water quality standards per type of use' is defined in accordance with the agreements under EU or national legislation, such as Regulation (EU) 2020/741 of the European Parliament and of the Council on minimum requirements for water reuse for agriculture uses.

Expected evolution of the indicator

The optimal target for the CtotalRW indicator is 100%, indicating that all reclaimed water produced meets the required quality standards at the point of compliance. The target could be assessed based on local policies and directives that establish the water quality limits depending on its use. One example for reclaimed water for uses of A quality reuse (Water Directive 2020/741) would be: *E. coli* ≤ 10 CFU/100 mL, BOD (Biochemical Oxygen Demand) ≤ 10 mg/l, TSS (Total Suspended Solids) ≤ 10 mg/L ,Turbidity ≤ 5 NTU, *legionella* current country legislation and bacteriophages <1000 UFC/100mL, contaminants according to the environmental quality standards.

Possible relationship with other water indicators

Reclaimed water production, Environmental flow requirement compliance rate, Safe drinking water, Effluent pollutant removal, Water quality compliance: biological, physical, and chemical parameters.

Data obtention

Sampling plan:

- Total number of samples with exceedance (i.e. sum of samples with microbial, chemical or indicator parameter exceedance); total number of samples analysed in assessment period.

Calculation formula

$$CtotalRW = \left(1 - \frac{ne_{totalRW}}{n_{totalRW}}\right) \cdot 100$$

Where:

- $C_{totalRW}$: = Percentage of total compliance for safe reclaimed water (%),

- $ne_{totalRW}$: Total number of samples of reclaimed water with exceedance, i.e., sum of samples with microbial, chemical or indicator parameter exceedance (No./year),
    - $ne_{totalRW} = \sum_{i=A} (nMi + nCi + nIi)$, with
        - nM = number of samples with microbial exceedance
        - nC= number of samples with chemical exceedance
        - nI= number of samples with indicator exceedance
        - i = Class A, B, C, D
    - $n_{totalRW}$: Total number of reclaimed water samples analysed in assessment period (No./year).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- EU regulation 2020/741 of the European Parliament and of the Council of 25 May 2020 on minimum requirements for water reuse. Official Journal of the European. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020R0741&from=EN
- Boletín Oficial del Estado (2020). Reglamento (UE) 2020/741 del parlamento europeo y del consejo de 25 de mayo de 2020 relativo a los requisitos mínimos para la reutilización del agua. https://www.boe.es/doue/2020/177/L00032-00055.pdf
- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

4.2.1.3 Effective Wastewater Treatment (WWTeff)

- **Code**: Ferla_Water02
- **Environmental Sector:** Water / Safeguarded water ecosystems
- **Units:** %

Meaning and importance of the indicator

The indicator measures the percentage of wastewater that is treated in compliance with legal and regulatory standards out of the total volume of wastewater treated. Includes the wastewater treatment coverage and volumetric efficiency. The concept is based on having an overview of the share of customers that is connected to the public wastewater system or is having a local legal treatment system in place. Based on population data, the share of total generated wastewater that is being treated can then be estimated. This indicator is used to have an overview of how much wastewater is generated in an area and it's important because untreated wastewater or not complying treated wastewater will have a negative impact on ecosystems in all kinds of water bodies.

Expected evolution of the indicator

The range is from 0 to 100%, the optimal value for the WWTeff indicator is ideally 100%, indicating that all treated wastewater meets or exceeds legal standards. However, achieving and maintaining values above 90-95% is considered very good and indicative of a highly effective wastewater treatment system.

Possible relationship with other indicators

Water quality compliance: biological, physical and chemical parameters, Reclaimed Water in non-potable Uses.

Data obtention

Sampling plan:

- Volume of treated wastewater complying with legal requirements (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO. Only data that complies with legal requirements will be selected.
- Volume of wastewater generated and treated in the DEMO (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.

Calculation formula

$$WWTeff = \frac{V_{Treatment}}{WW} \cdot 100$$

Where:

- WWTeff: Effective wastewater treatment (%),
- $V_{Treatment}$: Volume of treated wastewater complying with legal requirements (m^3/year),
- WW: Volume of treated wastewater (m^3/year).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- European Commission, Directorate-General for Research and Innovation (2021). Evaluating the impact of nature-based solutions: A handbook for practitioners. Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577
- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

4.2.1.4 Effluent Pollutant Removal (EPR)

- **Code**: Ferla_Water03
- **Environmental Sector:** Water / Water treatment / Water quality
- **Units:** %

Meaning and importance of the indicator

The indicator measures the average removal ratio between incoming and outgoing pollution load of the NBS. It can be evaluated for any pollutant. It is used to assess the effectiveness of water treatment processes in reducing pollution before discharge into the environment or wastewater treatment plant or its reuse.

*If there are additional water treatments in combination with the NBS, we recommend sampling before and after each treatment to have a better understanding of the role of each one in the treatment process.

Expected evolution of the indicator

The target can be determined based on design requirements (e.g., why the NBS is necessary, which pollutant needs to be addressed, and the desired removal efficiency) or according to local regulations and guidelines that define water quality standards depending on its intended use (such as for consumption, discharge, or reuse). For reclaimed water (as per Water Directive 2020/741), the goals would be: 95% removal of microbiological and emerging contaminants, 60-95% removal of nutrient pollutants, and 95% removal of physico-chemical parameters (such as turbidity). For treated wastewater (under RD 509/1996 and RD 11/1995), the objectives would include 70-80% reduction of nutrient pollutants and 90% removal of physico-chemical parameters (such as turbidity). For drinking water (in line with RD 3/2023), the goals would involve: 99-100% elimination of microbiological contaminants, 80-99% reduction of chemical pollutants, and 95% removal of physico-chemical parameters (such as turbidity) and nutrients.

Possible relationship with other water indicators

Reclaimed water production, Environmental flow requirement compliance rate, Safe drinking water, Water quality compliance: biological, physical and chemical parameters.

Data obtention

Sampling plan:

- Average influent concentration (mg/L).
- Average effluent concentration (mg/L).

Water quality parameters:

- Physical-chemical properties data:
  - - pH (unitless)
  - - Temperature (ºC)
  - - Electrical Conductivity (EC) (µS/cm)
  - - Turbidity (NTU)
  - - TSS (Total Suspended Solids) (mg/L)
- Biological data:
  - - DO (Dissolved Oxygen) (mg/L O_2)

- - BOD (Biochemical Oxygen Demand) (mg/L O_2)
- - COD (Chemical Oxygen Demand) (mg/L O_2)
- - TOC (Total Organic Carbon) (mg/L O_2)

- Chemical pollutant data:
  - - Heavy metals (µg/L)

  - Total hydrocarbons (µg/L)
  - Total pesticides (µg/L)
- Nutrients data:
  - - TN (Total Nitrogen) (mg/L N)
  - - NO_3 (Nitrates) (mg/L)
  - - TP (Total Phosphorus) (mg/L P)
  - - PO_4 (Phosphates) (mg/L)
- Microbiological data:
  - - E. Coli (CFU/100 mL)
- Other specific pollutants data:
  - - Contaminants of emerging concern
  - - Pollutants from industrial effluents will be added if necessary.

Calculation formula

$$\%Re = \frac{(Ci - Ce)}{Ci} \cdot 100$$

Where:

- %Re: average effluent pollutant removal (%),
- Ci: average influent concentration (mg/L),
- Ce: average effluent concentration (mg/L).

*To be evaluated for each pollutant.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: A handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577
- Boletín Oficial del Estado (2023). Real Decreto 3/2023, de 10 de enero, por el que se establecen los criterios técnico-sanitarios de la calidad del agua de consumo, su control y suministro. https://www.boe.es/buscar/pdf/2023/BOE-A-2023-628-consolidado.pdf
- Boletín Oficial del Estado (1998). Real Decreto 2116/1998, de 2 de octubre, por el que se modifica el Real Decreto 509/1996, de 15 de marzo, de desarrollo del Real Decreto-ley 11/1995, de 28 de diciembre, por el que se establecen las normas aplicables al tratamiento de las aguas residuales urbanas. https://www.boe.es/eli/es/rd/1998/10/02/2116/dof/spa/pdf

- Boletín Oficial del Estado (1996). Real Decreto 509/1996, de 15 de marzo, de desarrollo del Real Decreto-ley 11/1995, de 28 de diciembre, por el que se establecen las normas aplicables al tratamiento de las aguas residuales urbanas. https://www.boe.es/buscar/pdf/1996/BOE-A-1996-7159-consolidado.pdf

- Boletín Oficial del Estado (2020). Reglamento (UE) 2020/741 del parlamento europeo y del consejo de 25 de mayo de 2020 relativo a los requisitos mínimos para la reutilización del agua. https://www.boe.es/doue/2020/177/L00032-00055.pdf
- Dumitru, A., & Wendling, L. (2021). Evaluating the impact of nature-based solutions: Appendix of methods. European Commission. https://doi.org/10.2777/11361
- Environmental Protection Agency (EPA). (2021). Temperature: Water Quality Standards Criteria Summaries. https://www.epa.gov/system/files/documents/2021-07/parameter-factsheet_temperature.pdf
- Environmental Protection Water (2018). Water quality sampling using automated sampling equipment. https://environment.desi.qld.gov.au/__data/assets/pdf_file/0032/90779/physical-and-chemical-assesssment-water-quality-sampling-using-automated-sampling-equipment.pdf
- Nature4Cities project (2016). Nature Based Solutions for Re-naturing Cities: knowledge diffusion and decision support platform through new collaborative models. European Union's Horizon 2020 Research and Innovation programme. https://docs.wixstatic.com/ugd/55d29d_3b17947e40034c168796bfc9a9117109.pdf

4.2.1.5 Rate of Evapotranspiration (ETrate)

- **Code**: Ferla_Water04
- **Environmental Sector:** Water / Water management / Resource efficiency
- **Units:** mm/m^2 day

Meaning and importance of the indicator

The rate of evapotranspiration (ETrate) measures the amount of water vapor released into the atmosphere from both soil and plant surfaces over a given period of time. This indicator helps to understand the water balance within the urban environment and assess the effectiveness of the NBS, crops, forest, soils, etc. in managing water resources. Evapotranspiration plays a significant role in the hydrological cycle, influencing local climate conditions, water availability, and thermal comfort in urban areas. By monitoring the ETrate, the impact of vegetation, green spaces, and other NBS on water conservation, irrigation needs, and heat mitigation can be assessed. This indicator can be assessed, for example, in constructed wetlands, soils, fields, etc.

Expected evolution of the indicator

The ETrate is expected to vary with seasonal changes, vegetation cover, and weather conditions. In urban areas with well-implemented NBS, a higher ETrate is generally desirable during warmer months as it indicates effective cooling through latent heat flux. However, in water-scarce regions, the optimal ETrate would balance cooling needs with water conservation, preventing excessive water loss. The ideal range will depend on the specific urban context, including climate, vegetation type, and water availability. The following table shows the normal good levels of evapotranspiration in mm/year depending on the region or geographical context where it is found in the world.

Region/Context	Good annual levels, mm/year
Arid regions	200-500
Temperate regions	500-700
Humid/tropical regions	800-1500

Note: Allen, R. G. et al. (1998).

For example, urban parks which are considered temperate regions, have good levels of evapotranspiration at the range of 500-800 mm/year. Another example are agricultural fields (e.g., corn), which levels are between 400-700 mm/year.

The table below provides estimates of annual evapotranspiration values (mm/year) in different climate regions, categorized by temperature and humidity conditions. This helps to illustrate how evapotranspiration varies not only by thermal regime but also by region type, whether tropical, subtropical, or temperate:

Region/Temperature	Cold (10ºC), mm/year	Moderate (20ºC), mm/year	Warm (30ºC), mm/year
Humid and sub-humid (tropics/subtropics)	730 - 1095	1095 - 1825	1825 - 2555
Arid and semi-arid (tropics/subtropics)	730 - 1460	1460 - 2190	2190 - 2920
Humid and sub-humid (temperature zone)	365 - 730	730 - 1460	1460 - 2555
Arid and semi-arid (temperature zone)	365 - 1095	1460 - 2555	2190 - 3285

Note: Cherlinka, V. (2023).

Possible relationship with other water indicators

Water footprint, Rainfall interception of NBS, Rainfall storage/absorption capacity of NBS.

Data obtention

Sampling plan:

- Amount of water that is lost by evapotranspiration over the period (mm),
- Area of study or the NBS from the DEMO (m^2),
- Time period for the study (days).

Calculation formula

$$ETrate = \frac{ETt}{A \cdot t}$$

Where:

- ETrate: Rate of evapotranspiration ($mm/m^2 \cdot day$),
- ETt: Total evapotranspiration over the period (mm),
- t: Time period (days),
- A: Area of study or the NBS (m^2).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- Allen, R. G., Pereira, L. S., Raes, D., Smith, M. (1998). Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage paper. Food and Agriculture Organization of the United Nations. Rome https://www.fao.org/4/x0490e/x0490e00.htm

- Cherlinka, V. (2023). Evapotranspiration in agriculture and its measuring methods. EOS Data Analytics. https://eos.com/blog/evapotranspiration/
- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: a handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577
- Nature4Cities project (2016). Nature Based Solutions for Re-naturing Cities: knowledge diffusion and decision support platform through new collaborative models. European Union's Horizon 2020 Research and Innovation programme. https://docs.wixstatic.com/ugd/55d29d_3b17947e40034c168796bfc9a9117109.pdf

4.2.1.6 Reclaimed Water in Non-Potable Uses (RWnpU)

- **Code**: Ferla_Water05
- **Environmental Sector:** Water / Water resource recovery and use
- **Units:** %

Meaning and importance of the indicator

The indicator measures the proportion of reclaimed water (from treated wastewater, rainwater, urban runoff, etc.) used in non-potable applications where previously drinking or freshwater was used. It is related to the total volume of water used for those purposes. This indicator provides valuable insight into the sustainable use of water resources by quantifying the extent to which reclaimed water is used for non-potable purposes.

Expected evolution of the indicator

The optimal value for the RWnpU indicator is as close to 100% as possible, indicating that the majority of non-potable water needs are met with reclaimed water, minimizing the demand for freshwater.

Possible relationship with other water indicators

Compliant reclaimed water, Water availability, Reclaimed water production, Water provision by the ecosystem.

Data obtention

Sampling plan:

- Volume of reclaimed water used for non-potable uses (e.g., irrigation, street cleaning, groundwater recharge) (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total volume of water used for non-potable uses, from all sources, including freshwater and reclaimed water (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.

Calculation formula

$$RWnpU = \frac{RW}{npW} \cdot 100$$

Where:

- RWnpU: Reclaimed Water in non-potable Uses (%),
- RW: Volume of reclaimed water used for non-potable uses (e.g., irrigation, street cleaning, groundwater recharge) (m^3/year),
- npW: Total volume of water used for non-potable uses, from all sources, including freshwater and reclaimed water (m^3/year).

Note: “used” may be “supplied” or “consumed” but must be consistent in RW and npW.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

4.2.1.7 Water Availability (WA)

- **Code**: Ferla_Water06
- **Environmental Sector:** Water / Freshwater supply / Resource efficiency
- **Units:** m^3/year

Meaning and importance of the indicator

The indicator refers to the volume of water available provided by the DEMO for its reuse in various applications (e.g. aquifer recharge, ecosystem restoration, on site reuse, irrigation, industrial activities, etc.). The water available should comply with quality standards required for different reuses as per current legislation.

Expected evolution of the indicator

The baseline for this indicator is the initial water availability capacity, which may start at 0 m^3/year. It is expected to increase over time once the DEMO is operating and optimized, reflecting an improvement in water availability for reuse and ecosystem services. Ensure that 100% of the water provided by the DEMO is available for reuse.

Possible relationship with other water indicators

Water footprint, Water provision by the ecosystem.

Data obtention

Sampling plan:

- Direct annual flow of the effluent or annual volume provided by the DEMO for specific purposes (e.g., aquifer recharge, ecosystem restoration, etc.) (m^3/year).
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total volume water available in the DEMO (WA) (m^3/year).

Calculation formula

$$WA = Water\ inflows\ (WI) - Water\ losses\ (WL)$$

Where:

- WI: Total water entering the DEMO system (e.g., precipitation, surface water, groundwater recharge, recycled water) (m^3)
- WL: Total water lost (due to evaporation (m^3))

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/
- United Nations Conference on Trade and Development (2023). Environmental indicators: Module B Core SDG Indicators for Entity Reporting Training Manual. https://unctad.org/system/files/information-document/UNCTAD_GCI_MANUAL_ENVIRONMENTAL-FINAL.pdf
- URBAN GreenUP (2019). D5. 3: City diagnosis and monitoring procedures. https://www.urbangreenup.eu/kdocs/1912498/urban_greenup_d5_3_city_diagnosis_and_monitoring_procedures.pdf
- U.S. Environmental Protection Agency (2024). Basic information about water reuse. https://www.epa.gov/waterreuse/basic-information-about-water-reuse

4.2.1.8 Water Quality Compliance (WQC): Biological, Physical and Chemical Parameters

- **Code:** Ferla_Water07
- **Environmental Sector:** Water / Water quality
- **Units:** [Compliant with regulatory standards: Yes/No]

Meaning and importance of the indicator

The indicator provides a simplified view of regulatory compliance regarding water quality, taking into account various parameters. It is especially important to validate quality standards required by current regulations. It can be evaluated for each water quality parameter: pH, temperature, DO, BOD, COD, electrical conductivity (EC), total suspended solids (TSS), total dissolved solids (TDS), nitrogen (N), ammonium (NH_4^+), phosphorus (P), metals (Cadmium (Cd) - Copper (Cu) - Lead (Pb) - Mercury (Hg) - Nickel (Ni) - Zinc (Zn), etc.), other ions (Chloride (Cl^-) - Sulphate (SO_4^{2-}) - Sodium (Na) - Potassium (K) - Calcium (Ca) - Magnesium (Mg)), total faecal coliform bacteria, PAH content, total organic carbon (TOC), Organic micropollutants such as pesticides and chemicals (polychlorinated bisphenols (PCBs) - Hexachlorocyclohexane (HCH) group compounds - Polycyclic aromatic hydrocarbons (PAHs)), other depending on legislation and needs.

Expected evolution of the indicator

The indicator should show that all measured parameters meet or exceed regulatory compliance standards over time. Optimal values vary depending on the specific parameter and local environmental regulations but should indicate no exceedance of legal thresholds for water quality. One example is:
The target could be assessed based on local policies and directives that establish the water quality limits depending on its use (water consumption, discharge, reuse, etc.).
For reclaimed water (Water Directive 2020/741), the targets would be: E. coli ≤ 10 CFU/100 m/L, BOD (Biochemical Oxygen Demand) ≤ 10 mg/L, TSS (Total Suspended Solids) ≤ 10 mg/L and Turbidity ≤ 5 NTU.
For treated wastewater (RD 509/1996 and RD 11/1995), the targets would be: TN (Total Nitrogen) 15 mg/L N (from 10,000 to 100,000 h-e) 10 mg/l N (more than 100,000 h-e), TP (Total Phosphorus) 2 mg/L P (from 10,000 to 100,000 h-e) 1 mg/L P (more than 100,000 h-e), BOD (Biochemical Oxygen Demand) 25 mg/L O_2, COD (Chemical Oxygen Demand) 125 mg/L O_2, TSS (Total Suspended Solids) 35 mg/L.
For drinking water (RD 3/2023), the targets would be: E. coli 0 CFU/100 mL, pH 6.5-9.5, Electrical Conductivity (EC) 2500 µS/cm at 20 ºC, Turbidity 4.0 NTU, Total Organic Carbon (TOC) 5.0 mg/L, Polycyclic Aromatic Hydrocarbons (PAHs) 0.10 µg/L, Arsenic 10 µg/L, Cadmium 5.0 µg/L, Chromium 25 µg/L, Mercury 1.0 µg/L, Nickel 20 µg/L, Lead 5.0 µg/L, Antimony 10 µg/L, Selenium 20 µg/L, Nitrate 50 mg/L, Nitrite 0.50 mg/L and individual pesticide 0.10 µg/L."

Possible relationship with other water indicators

Reclaimed water production, Compliant reclaimed water.

Data obtention

Sampling plan:
The quality parameters required by the current regulations or permits associated:

- Physical Parameters: pH, temperature, EC, TSS, turbidity, alkalinity, etc.

- Chemical Parameters: COD, BOD, nutrients (nitrogen, phosphorus), metals (Cd, Cu, Pb, Hg, Ni, Zn), and other ions (Cl^-, SO_4^{2-}, Na, K, Ca, Mg).
- Biological Parameters: DO, total coliform bacteria, E. coli, Legionella spp., etc.
- Organic Micropollutants: Pesticides, PCBs, polycyclic aromatic hydrocarbons (PAHs), etc.

See more information at the individual DEMO Monitoring Plan.

Calculation formula

Compare Ce to Creg:
If Ce < Creg, then WQC = Yes
If Ce > Creg, then WQC = No

Where:

- Ce: average effluent concentration in pollutant concentration units.
- Creg: regulated pollutant concentration for water uses in pollutant concentration units.

*To be evaluated for each pollutant.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- Boletín Oficial del Estado (1995). Real Decreto 11/1995, de 28 de diciembre, por el que se establecen las normas aplicables al tratamiento de las aguas residuales urbanas. Boletín Oficial del Estado, núm. 312, 37517-37519. https://www.boe.es/boe/dias/1995/12/30/pdfs/A37517-37519.pdf
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4.2.2 Biodiversity Indicators

4.2.2.1 Flying Insect Sampling

- **Code:** Ferla_Bio01
- **Environmental Sector:** Biodiversity / Fauna
- **Units:** Number of flying insects, Number of species

Meaning and Importance of the Indicator

Urban parks serve as key green spaces that support biodiversity within cities. Insect populations in these parks provide valuable ecosystem services, such as pollination and pest control, while also serving as food for urban wildlife. Yellow sticky traps are a common methodology used to monitor flying insects in urban environments, offering insight into the health of insect populations. These traps attract and capture flying insects drawn to the colour yellow, particularly pest species like aphids, leafhoppers, and flies, as well as pollinators and other beneficial species. Monitoring the diversity and abundance of flying insects in urban parks helps to evaluate the ecological quality of these green spaces and can reveal the impacts of urbanization, pollution, and habitat fragmentation on insect communities.

Expected Evolution of the Indicator

In a healthy urban park, a balanced population of both pest and beneficial insects should be present. Over time, any shifts in insect populations—such as an increase in pests or a decline in pollinators—could indicate environmental stresses, such as excessive pesticide use, air pollution, or habitat degradation. When introducing landscape or vegetation changes to the park it is specially useful to monitor changes in insect populations and can help urban park managers make informed decisions about maintenance practices, plant diversity, and habitat restoration efforts.

Data obtention

Required data:

- Number of flying insects caught on yellow sticky traps, categorized by morphospecies or morphological groups (e.g., aphids, flies, pollinators, beetles).

Sampling Plan

- Bright yellow adhesive-coated traps (dimensions: 10-15 cm x 10-30 cm) will be used to capture flying insects.
- Traps will be placed at various locations within the area, focusing on areas with high insect activity, such as near flowering plants, water features, or shrubs.
- Traps will be mounted vertically on poles or tree branches at approximately 2-3 meters above the ground to capture a wide range of flying insect species, and also to avoid the general public access to the traps.
- A minimum of 10 traps will be deployed across the park, ensuring that different habitats within the park (e.g., flowerbeds, lawns, and wooded areas) are covered.
- The traps will be left in place for 24-72 hours during each sampling event to allow for sufficient insect capture. After this period, the traps will be collected, and the captured insects will be identified and recorded. If the traps fill too quickly, this time can be adjusted.

- Traps should be placed in open areas with direct sunlight, as yellow is most effective at attracting insects in well-lit locations.
- Traps should be replaced after each sampling event to ensure accurate results. Traps that become too saturated with insects or debris may lose their effectiveness.
- Insects captured on the traps should be identified in the lab or by an expert.

Sampling calendar

Sampling will be conducted monthly from May to September, covering the active flight periods of most flying insect species in the park. Monitoring will take place annually over the duration of the demo action.

Equipment

- Adhesive-coated yellow traps (10-15 cm x 20-30 cm).
- Poles, stakes, or tree branches to mount the traps at 2-3 meters above the ground.
- Plastic containers or zip bags to transport traps and collected insects for analysis.

External Subcontracting

Yes, external subcontracting may be required for detailed taxonomic identification of the insects captured on the yellow sticky traps. While basic identification can be performed in the field (e.g., categorizing into functional groups such as pollinators or pests), species-level identification should be handled by professional entomologists or specialized laboratories.

References

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4.2.2.2 New Fauna Habitat Area

- **Code**: Ferla_Bio02
- **Environmental Sector**: Fauna habitats
- **Units:** Square meters (m^2)

Meaning and importance of the indicator

This indicator measures the establishment of new functional habitats for fauna (particularly invertebrates and birds), created by the green wall. This metric is critical for understanding the ecological value of the green wall in supporting biodiversity, especially in urban environments where such structures can provide essential refuge for species that contribute to ecosystem services, such as pollination or seed dispersal, serving as a key indicator of the green wall's ecological performance.

Expected evolution of the indicator

The total cover of new functional habitat is expected increase, until reaching the optimal scenario where the entirety of the green wall serves as functional habitat for fauna, implying that all available vertical and horizonal surface area contributes effectively to biodiversity enhancement and habitat provision.

Possible relationship with other analyses

Habitat quality may depend on the substrate quality in the pots, including nutrient content, drainage and moisture retention capacity, the irrigation water quality and specially the plant species planted play a crucial role on the overall habitat's ability to support fauna.

Data obtention

Required data:

Total coverage of new fauna functional habitat created (m^2).

Data obtention method

The required data should be obtained through field sampling. For obtaining the total cover of functional habitats for fauna, both vertical and horizontal components should be measured:

- Horizontal Area Measurement (Pots or Containers): Measurement of the surface area of each pot or container where the plants are located. This includes the top surface area (length × width) where the plants grow.
- Vertical Area Measurement (Wall Surface): Measure the vertical surface area of the green wall covered by the plants (height × width). If plants grow downwards or spread horizontally beyond the pots, include this as part of the vertical habitat.

Calculate the total habitat area by combining both, horizontal surface area and vertical surface area. The measurements need to avoid double counting the same space, so the vertical area should exclude any overlap with the horizontal area already accounted for by the pots.

Sampling plan

The measures should be done during the spring month (May or early June) to capture the plant cover at its peak development stage.

Sampling calendar

This indicator will be produced every year for a total of 10 years.

Equipment

Tape measure for manual measurements and sheet for noting the results, including the date, environmental conditions and observer's name.

Calculation formula

New functional Habitat Area (A) = Horizontal area + vertical area

References

- European Commission. 2021. Evaluating the Impact of Nature-based Solutions: A Handbook for Practitioners. Luxembourg. *Indicator 10.2 Area of habitats restored* doi:10.2777/244577
- Fundación Biodiversidad. 2022. Guía para la medición y seguimiento de indicadores. Convocatoria de subvenciones de la Fundación Biodiversidad F.S.P., para el fomento de actuaciones dirigidas a la renaturalización y resiliencia en ciudades españolas, correspondiente al año 2022, en el marco del Plan de Recuperación, Transformación y Resiliencia. *Indicator SUP-001*. https://fundacion-biodiversidad.es/wp-content/uploads/2022/10/guia_indicadores_renaturb_2022_0.pdf

4.2.3 Human Well-being

4.2.3.1 Air Temperature At 2 Meters (Daytime and Night-Time)

- **Code:** Ferla_Well01
- **Environmental Sector**: Air Temperature Comfort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for people.

Expected evolution of the indicator

The temperature indicator is expected to show a gradual decrease as vegetation matures and green infrastructure becomes more established. The tendency should reflect a cooling effect, particularly during warmer months, as plants provide shade, increase evapotranspiration, and mitigate heat absorption from hard surfaces. The optimal value range will vary depending on the local climate, but ideally, temperatures in greened areas should be noticeably lower than in non-greened parts of the campus, contributing to a more comfortable and cooler environment.

Possible relationship with other air temperature analyses

Ferla_Well 02 to 07.

Data obtention

Required data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors at the campus at 2 meters (sensor 1: will take data before the nature based solution application and will be in charge of taking measurements after the transformation and thus in the vertical garden; Sensor 2: outside the vertical garden in a place where there is high sun exposure (not transformed) Sensor 3: : outside the vertical garden in a place where there is low sun exposure (not transformed)

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

Calculation formula

Collect temperature data at 15-minute intervals throughout the 24-hour period.
Segregate the data into daytime and nighttime intervals (from sunrise to sunset for daytime and from sunset to sunrise for nighttime). Calculate the average temperature for both periods using the formulas

$$T_{day} = \frac{1}{n_{day}} \sum_{i=1}^{n_{day}} T_i$$

Where:

- Ti is the temperature recorded at the i-th 15-minute interval during the daytime
- nday is the number of 15-minute intervals during daytime

$$T_{night} = \frac{1}{n_{night}} \sum_{j=1}^{n_{night}} T_j$$

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

4.2.3.2 Daily Temperature Range (Difference Between the Daily Maximum and Daily Minimum Temperature)

- **Code:** Ferla_Well02
- **Environmental Sector:** Air Temperature Comfort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for people.
In particular, this indicator shows how much the temperature fluctuates throughout the day, often used to assess climate variability and the effect of green infrastructure on stabilizing temperature extremes.

Expected evolution of the indicator

Tendency: As green infrastructure, such as tree planting and vegetation, matures, the daily temperature range is expected to narrow. Vegetation helps moderate both daytime highs and nighttime lows by providing shade during the day and trapping heat during the night.
Optimal value range: A moderate daily temperature range (DTR) is often considered optimal, with smaller fluctuations typically indicating a healthier microclimate. The exact value range depends on the local climate, but in urban areas, a reduction in DTR could indicate improved thermal regulation due to greening projects.

Possible relationship with other air temperature analyses

Ferla_Well01 and from 02 to 07.

Data obtention

Required Data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors at the campus at 2 meters (sensor 1: will take data before the nature based solution application and will be in charge of taking measurements after the transformation and thus in the vertical garden; Sensor 2: outside the vertical garden in a place where there is high sun exposure (not transformed) Sensor 3: : outside the vertical garden in a place where there is low sun exposure (not transformed)

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

External subcontracting

Yes, the sensor provider.

Calculation formula

$$Daily\ Temperature\ Range = Tmax - Tmin$$

Where:

- Tmax is the daily maximum temperature (from sunrise to sunset)
- Tmin is the daily minimum temperature (from sunset to sunrise)

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

4.2.3.3 Heatwave Risks (Number of Combined Tropical Nights (>20ºc) And Hot Days (>35ºc))

- **Code:** Ferla_Well04
- **Environmental Sector**: Air Temperature Comfort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for people. This indicator counts the number of nights where the temperature does not fall below 20ºC (tropical nights) combined with days where the temperature exceeds 35ºC (hot days) to assess potential risks related to human health and infrastructure due to heat stress during heatwaves.

Expected evolution of the indicator

Tendency: In urban areas, the risks of tropical nights and hot days are expected to increase over time due to global warming. However, greening projects can mitigate some of these effects by lowering both daytime and nighttime temperatures, reducing the frequency of tropical nights (>20ºC) and hot days (>35ºC). Optimal value range: Ideally, the number of tropical nights and hot days should be minimized, as both pose significant risks to human health. The optimal value would be near zero for tropical nights and hot days during most of the year, particularly in regions not typically exposed to extreme heat.

Possible relationship with other air temperature analyses

Ferla_Well01 to 03 and 05 to 07.

Data obtention

Required data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors at the campus at 2 meters (sensor 1: will take data before the nature based solution application and will be in charge of taking measurements after the transformation and thus in the vertical garden; Sensor 2: outside the vertical garden in a place where there is high sun exposure (not transformed) Sensor 3 : outside the vertical garden in a place where there is low sun exposure (not transformed)

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

Calculation formula

Tropical nights: Count of nights for a given year where Tmin >20°C
Hot days: Count of days for a given year where Tmax>35°C

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
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4.2.3.4 Days With Temperature >90th Percentile (TX90p)

- **Code:** Ferla_Well03
- **Environmental Sector**: Air Temperature Comfort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for people.

TX90p is the number of days where the maximum daily temperature exceeds the 90th percentile of the long-term reference period. This indicator is often used to assess heatwave frequency and climate change impacts.

Expected evolution of the indicator

Tendency: Without intervention, the number of days with temperatures above the 90th percentile is likely to increase due to climate change, especially in urban areas. However, the implementation of nature-based solutions (such as urban greening) can slow or reduce this trend by cooling the environment.

Optimal value range: Ideally, the number of days exceeding the 90th percentile should remain low. While occasional days above this threshold are normal, a high or increasing trend could indicate vulnerability to heat stress.

Possible relationship with other air temperature analyses

Ferla_Well01 to 02 and 04 to 07.

Data obtention

Required data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors at the campus at 2 meters (sensor 1: will take data before the nature based solution application and will be in charge of taking measurements after the transformation and thus in the vertical garden; Sensor 2: outside the vertical garden in a place where there is high sun exposure (not transformed) Sensor 3: outside the vertical garden in a place where there is low sun exposure (not transformed).

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

Calculation formula

First, calculate the 90th percentile of maximum temperatures for a reference period (e.g. 30 years), then count how many days in a specific time period (e.g. every year of sampling) exceed this value.

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
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4.2.3.5 Mean Or Peak Daytime Local Temperatures (°C)

- **Code**: Ferla_Well05
- **Environmental Sector:** Air Temperature Comfort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for people. The mean or peak daytime local temperatures (°C) is the highest temperature recorded during the daytime hours (from sunrise to sunset) which helps assess local heat conditions and the effectiveness of green infrastructure in cooling the environment.

Expected evolution of the indicator

Tendency: Mean and peak daytime temperatures are expected to decrease with the maturation of green infrastructure. Vegetation provides shade and promotes evapotranspiration, leading to a cooling effect, especially during the hottest parts of the day. Optimal value range: Ideally, peak daytime temperatures would stay below heat stress thresholds (often around 30–35ºC, depending on local climate conditions).

Possible relationship with other air temperature analyses

Ferla_Well01 to 04 and 06 to 07.

Data obtention

Required data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors at the campus at 2 meters (sensor 1: will take data before the nature based solution application and will be in charge of taking measurements after the transformation and thus in the vertical garden; Sensor 2: outside the vertical garden in a place where there is high sun exposure (not transformed) Sensor 3: : outside the vertical garden in a place where there is low sun exposure (not transformed).

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

Calculation formula

Obtention of the highest temperature every day of the year.
Mean of the highest temperatures during the year.

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

4.2.3.6 Monthly Mean Value of Daily Maximum Temperature (TXx)

- **Code:** Ferla_Well06
- **Environmental Sector:** Air Temperature Confort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for people. This indicator calculates the monthly average of the daily maximum temperatures over a given month which helps assess local heat conditions and the effectiveness of green infrastructure in cooling the environment.

Expected evolution of the indicator

Tendency: The monthly mean of daily maximum temperatures is expected to decrease with effective greening interventions, particularly during the hottest months. Green infrastructure mitigates extreme heat by providing shade and cooling the air through transpiration. Optimal value range: The optimal value depends on the region's climate. Generally, a lower mean daily maximum temperature during summer months is desirable to avoid heat stress.

Possible relationship with other air temperature analyses

Ferla_Well01 to 05 and 07.

Data obtention

Required data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors at the campus at 2 meters (sensor 1: will take data before the nature based solution application and will be in charge of taking measurements after the transformation and thus in the vertical garden; Sensor 2: outside the vertical garden in a place where there is high sun exposure (not transformed) Sensor 3: : outside the vertical garden in a place where there is low sun exposure (not transformed).

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

External subcontracting required

Yes, the sensor provider.

Calculation formula

$$TXx = \frac{1}{n}\sum_{i=1}^{n} T_{max,i}$$

Where*:*

- *Tmax*,is the daily maximum temperature for day *i*
- *n* is the number of days in the month

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

4.2.3.7 Monthly Mean Value of Daily Minimum Temperature (TNn)

- **Code:** Ferla_Well07
- **Environmental Sector**: Air Temperature Comfort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for people.

This indicator measures the monthly average of the daily minimum temperatures over a given month which helps assess local heat conditions and the effectiveness of green infrastructure in cooling the environment.

Expected evolution of the indicator

Tendency: The monthly mean of daily minimum temperatures could decrease slightly with increased greening, as vegetation helps release heat more gradually at night, reducing the "urban heat island" effect. However, the change in nighttime temperatures may be less pronounced than daytime changes.

Optimal value range: The optimal value would be moderately low but above a threshold that ensures comfort during nighttime. In warm regions, values closer to 15–20ºC are often desirable to avoid discomfort during tropical nights.

Possible relationship with other air temperature analyses

Ferla_Well01 to 06 and 08.

Data obtention

Required data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors at the campus at 2 meters (sensor 1: will take data before the nature based solution application and will be in charge of taking measurements after the transformation and thus in the vertical garden; Sensor 2: outside the vertical garden in a place where there is high sun exposure (not transformed) Sensor 3: : outside the vertical garden in a place where there is low sun exposure (not transformed)

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

External subcontracting required

Yes, the sensor provider.

Calculation formula

$$TNn = \frac{1}{n}\sum_{i=1}^{n} T_{min,i}$$

Where:

- *Tmin* is the daily minimum temperature for day *i*
- *n* is the number of days in the month

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

4.2.4 Energy Indicators

4.2.4.1 Energy Consumption Of NBS, Compared With Equivalent Conventional Infrastructure (% Decrease)

- **Code**: Ferla_Energy01
- **Environmental Sector**: Energy
- **Units**: kWh/m^3 wastewater

Meaning and importance of the indicator

"Energy consumption of Nature-Based Solutions (NBS), compared with equivalent conventional infrastructure (% decrease)" measures the percentage reduction in energy use achieved by implementing NBS instead of traditional infrastructure solutions. This indicator is crucial for evaluating the efficiency and sustainability of NBS, such as green roofs, wetlands, and urban forests, which are designed to provide similar functions to conventional infrastructure but with lower energy requirements. By comparing the energy consumption of NBS to that of traditional methods, this indicator highlights the potential for significant energy savings and reduced environmental impact. Monitoring this indicator helps policymakers, urban planners, and engineers understand the benefits of adopting NBS, guiding decisions towards more sustainable and energy-efficient infrastructure development. Ultimately, reducing energy consumption through NBS supports broader goals of mitigating climate change, conserving resources, and enhancing the resilience and sustainability of urban environments.

Expected evolution of the indicator

The expected evolution of the indicator "Energy consumption of Nature-Based Solutions (NBS), compared with equivalent conventional infrastructure (% decrease)" is towards a significant and continuous decrease, indicating the growing efficiency and sustainability of NBS relative to traditional infrastructure.

Data obtention

Sampling plan:

Field measurement or assessment based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time. For the conventional infrastructure literature data will be collected from official governmental sources.

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

4.2.4.2 Decrease In Urban Heat Island (UHI) Effect (In Terms Of Surface Temperatures)

- **Code**: Ferla_Energy02
- **Environmental Sector**: Energy
- **Units**: °C

Meaning and importance of the indicator

"Decrease in urban heat island (UHI) effect (in terms of surface temperatures)" measures the reduction in surface temperatures in urban areas achieved through various mitigation strategies. The urban heat island effect refers to the phenomenon where urban regions experience higher temperatures than their rural surroundings due to human activities, dense infrastructure, and reduced vegetation. This indicator is important because it reflects the effectiveness of interventions such as increased green spaces, reflective roofing materials, and improved urban planning in mitigating UHI. Reducing the UHI effect is crucial for enhancing urban liveability, lowering energy consumption for cooling, and improving public health by decreasing heat-related illnesses. Monitoring this indicator helps policymakers and urban planners assess the success of their strategies, promote sustainable urban development, and contribute to climate resilience by making cities more comfortable and environmentally friendly.

Expected evolution of the indicator

The expected evolution of the indicator "Decrease in urban heat island (UHI) effect (in terms of surface temperatures)" is towards a noticeable reduction in urban surface temperatures as more cities adopt and implement effective mitigation strategies.

Data obtention

Sampling plan:

Field measurement, collection of baseline surface temperature data using remote sensing tools such as satellite imagery (e.g., Landsat, MODIS) and ground-based temperature sensors.

Frequency

Once per month with field measurements or use of remote sensing tools.

4.2.4.3 Energy Consumption for Wastewater Treatment

- **Code**: Ferla_Energy03
- **Environmental Sector**: Energy
- **Units**: kWh/m^3 wastewater

Meaning and importance of the indicator

"Energy Consumption for Wastewater Treatment" measures the amount of energy (mainly electricity) used in the processes involved in treating wastewater to make it safe for discharge or reuse. This indicator is crucial for evaluating the sustainability and efficiency of wastewater treatment facilities. High energy consumption can indicate inefficiencies and result in increased operational costs and higher carbon emissions, which are detrimental to both economic and environmental goals. Conversely, optimizing energy use in wastewater treatment can lead to significant cost savings, lower greenhouse gas emissions, and a reduced environmental footprint. Monitoring this indicator helps in identifying opportunities for implementing energy-saving technologies and practices, such as using more efficient equipment, improving process controls, and integrating renewable energy sources. Ultimately, reducing energy consumption in wastewater treatment supports broader sustainability objectives by minimizing resource use and contributing to climate change mitigation.

Expected evolution of the indicator

The expected evolution of the indicator "Energy Consumption for Wastewater Treatment" is towards decreasing energy use per unit of treated wastewater, reflecting improvements in efficiency and sustainability of treatment processes. This evolution is driven by technological advancements, better operational practices, and increased regulatory and policy pressures to reduce environmental impact.

Data obtention

Sampling plan:

Field measurement or assessment based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

4.2.4.4 Building Temperature Behavior

- **Code**: Ferla_Energy04
- **Environmental Sector**: Energy
- **Units**: °C/hour

Meaning and importance of the indicator

"Building Temperature Behavior" measures the thermal performance and stability of a building's internal environment in response to external temperature fluctuations. This indicator is crucial for assessing the energy efficiency and comfort levels within buildings. Effective temperature behavior indicates that a building maintains a stable internal temperature with minimal reliance on heating, ventilation, and air conditioning (HVAC) systems, thereby reducing energy consumption and operational costs. Monitoring this indicator helps identify areas where building design, insulation, and materials can be improved to enhance energy efficiency and occupant comfort. It also supports sustainable building practices by promoting designs that adapt to and mitigate external temperature changes, ultimately contributing to lower greenhouse gas emissions and more resilient built environments.

Expected evolution of the indicator

The expected evolution of the indicator "Building Temperature Behavior" is towards improved thermal performance and stability, driven by advancements in building design, materials, and technologies.

Data obtention

Sampling plan:

Field measurement. Calculate the average internal temperature, range of fluctuation, and standard deviation. Compare these metrics against external temperature data to evaluate thermal performance.

Frequency

Continuous with field measurements.

4.2.4.5 Energy Performance of Building (Energy Bills of the School)

- **Code**: Ferla_Energy05
- **Environmental Sector**: Energy
- **Units**: kWh/year

Meaning and importance of the indicator

"Energy performance of building (energy bills of the school)" measures the total energy consumption of a school building by analyzing its energy bills over a specific period, typically expressed in kilowatt-hours (kWh) and monetary costs. This indicator is crucial for assessing the efficiency with which a school uses energy for heating, cooling, lighting, and other operational needs. By evaluating energy bills, stakeholders can identify patterns of high energy use, inefficiencies, and opportunities for improvement. Monitoring this indicator helps in setting benchmarks, implementing energy-saving measures, and tracking the effectiveness of interventions aimed at reducing energy consumption and costs. Ultimately, improving the energy performance of school buildings supports environmental sustainability goals, reduces operational expenses, and creates a more comfortable learning environment for students and staff.

Expected evolution of the indicator

The expected evolution of the indicator "Energy performance of building (energy bills of the school)" is towards a significant reduction in energy consumption and costs, reflecting improvements in energy efficiency and sustainable practices.

Data obtention

Sampling plan:

Desk study based on energy bills.

Frequency

None due to desk study.

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ANNEX E: DEMO5

DEMO5: Marseille

DEMO5.1: St. Jerome	Sector	Code
Soil Physical and Chemical Fertility	Soil	Jerome_Soil01
Soil Sealing	Soil	Jerome_Soil02
Water Holding Capacity	Soil	Jerome_Soil03
Soil Organic Carbon Content	Soil	Jerome_Soil04
Soil Bulk Density (ρ)	Soil	Jerome_Soil05
Water Availability (WA)	Water	Jerome_Water01
Water Storage Capacity (WSC)	Water	Jerome_Water02
Rainfall Interception of NBS (RI)	Water	Jerome_Water03
Infiltration Rate (IR)	Water	Jerome_Water04
Air Temperature at 2 Meters (Daytime and Night-Time)	Human Well-being	Jerome_Well01
Daily Temperature Range (Difference Between the Daily Maximum and Daily Minimum Temperature	Human Well-being	Jerome_Well02
Days With Temperature >90th Percentile (TX90p)	Human Well-being	Jerome_Well03
Heatwave Risks (Number of Combined Tropical Nights (>20°C) and Hot days (>35°C))	Human Well-being	Jerome_Well04
Mean Or Peak Daytime Local Temperatures (°C)	Human Well-being	Jerome_Well05
Monthly Mean Value of Daily Maximum Temperature (TXx)	Human Well-being	Jerome_Well06
Monthly Mean Value of Daily Minimum Temperature (TNn)	Human Well-being	Jerome_Well07
Relative Humidity (%)	Human Well-being	Jerome_Well08
PM10	Human Well-being	Jerome_Well09
PM2.5	Human Well-being	Jerome_Well10
Recreational Opportunities Provided by Green Infrastructure	Human Well-being	Jerome_Well11
Self-Reported Well-Being/ Good Moods	Human Well-being	Jerome_Well12
Normalised Difference Vegetation Index (NDVI)	Human Well-being	Jerome_Well13
Number of trees	Human Well-being	Jerome_Well14
Air temperature reduction in case study areas	Energy	Jerome_Energy01
Electricity use for irrigation purposes	Energy	Jerome_Energy02
Plant Mortality Rate	Biodiversity	Jerome_Bio01
Canopy Cover Growth Rate	Biodiversity	Jerome_Bio02
Edible Fruits Produced by Planted Plants	Biodiversity	Jerome_Bio03
Species Richness (Trees, Shrubs and Herbaceous Plants), Jaccard Index (Inter-Annual Similarity)	Biodiversity	Jerome_Bio04
Number of Planted Trees and Shrubs	Biodiversity	Jerome_Bio05
Mosquito Bites	Biodiversity	Jerome_Bio06
DEMO5.2 St. Charles		
Soil Physical and Chemical Fertility	Soil	Charles_Soil01
Soil Organic Carbon Content	Soil	Charles_Soil02
Soil Bulk Density (ρ)	Soil	Charles_Soil03
Water Holding Capacity	Soil	Charles_Soil04
Soil Sealing	Soil	Charles_Soil05
Water Availability (WA)	Water	Charles_Water01
Water Storage Capacity (WSC)	Water	Charles_Water02
Rainfall Interception of NBS (RI)	Water	Charles_Water03
Infiltration Rate (IR)	Water	Charles_Water04
Air temperature at 2 meters (daytime and night-time)	Human Well-being	Charles_Well01
Daily Temperature Range (Difference Between the Daily Maximum and Daily Minimum Temperature)	Human Well-being	Charles_Well02
Days With Temperature >90th Percentile (TX90p)	Human Well-being	Charles_Well03
Heatwave Risks (Number of Combined Tropical Nights (>20°c) and Hotdays (>35°c))	Human Well-being	Charles_Well04
Mean Or Peak Daytime Local Temperatures	Human Well-being	Charles_Well05
Monthly Mean Value of Daily Maximum Temperature (Txx)	Human Well-being	Charles_Well06
Monthly Mean Value of Daily Minimum Temperature (Tnn)	Human Well-being	Charles_Well07
Relative humidity	Human Well-being	Charles_Well08
PM10	Human Well-being	Charles_Well09
PM2.5	Human Well-being	Charles_Well10
Recreational opportunities provided by green infrastructure	Human Well-being	Charles_Well11
Self-reported well-being/ Good Moods	Human Well-being	Charles_Well12
Normalised Difference Vegetation Index (NDVI)	Human Well-being	Charles_Well13
Number of Tree	Human Well-being	Charles_Well14
Air temperature reduction in case study areas	Energy	Charles_Energy01
Plant Mortality Rate	Biodiversity	Charles_Bio01

Canopy Cover Growth Rate	Biodiversity	Charles_Bio02
Edible Fruits Produced by Planted Plants	Biodiversity	Charles_Bio03
Species Richness (Trees, Shrubs and Herbaceous Plants), Jaccard Index (Inter-Annual Similarity)	Biodiversity	Charles_Bio04
Number of Planted Trees and Shrubs	Biodiversity	Charles_Bio05
Mosquito Bites	Biodiversity	Charles_Bio06

DEMO5.1: St. Saint Jérôme

The main activity of the NBS consists of the unsealing 0,55 ha of paved soils around the Saint- Jerôme campus. This approach aims to achieve two primary objectives: (a) enhancing campus quality of life by mitigating heatwave intensity and improving air quality, and (b) reducing the pollutant load reaching the marine environment as a result of rain and stormwater runoff. After the unsealing, the areas will be renaturalized with local trees and shrubs to increase shading areas and biodiversity benefits.

5.1.1 Soil Indicators

5.1.1.1 Soil Physical and Chemical Fertility

- **Code:** Jerome_Soil01
- **Environmental Sector**: Soil / Soil Health
- **Units:** A Multi-Component Indicator. Diverse Units for Specific Components

Meaning and importance of the indicator

Soil fertility, its capacity to sustain plant growth, depends on complex interactions between biological, chemical and physical properties. Achieving and maintaining appropriate levels of physical and chemical fertility is of paramount importance to support urban green. In natural soils, nutrients come from minerals, water, atmospheric deposition, and recycling of plant and animal residues but their availability to plants is significantly affected by soil acidity (pH), and nutrient presence in the soil solution is highly dependent on soil texture and soil cation exchange capacity. Water retention in soils and progressive release to plants is notably improved by soil organic matter, which is particularly important in Mediterranean regions under increasing aridity. Urban soils are highly heterogeneous and are frequently called “technosoils”. Soils are made of human-transported substrates, or are native soils highly transformed by anthropization. Urban soils are very often compacted and polluted, but they perform multiple unvaluable ecosystem services when returned to health, particularly in water and carbon cycles, and play a pivotal role in human wellbeing trough supporting healthy vegetation. Soil analysis is the basic tool to evaluate soil fertility and to guide city managers towards sustainable soil management.

Expected evolution of the indicator

There are recommended ranges and critical values for most of the soil properties to be analyzed. For urban gardens, together with the results of soil analyses agricultural laboratories provide an evaluation of the level of each analyzed parameter (deficient – correct – excessive or similar). The value of each parameter should evolve towards these reference values and will guide gardeners in designing

fertilization or any other correction. You will find some values for vegetated soils in Mediterranean cities in Dondini et al. (2024)

Data obtention

Required data:

To be analysed only the first time: soil texture (% sand; % clay; % silt); textural class.

To be analysed at each soil sampling campaign: pH; Electrical conductivity (CEC); Total organic carbon (%, dry soil basis); Carbonates; Total nitrogen (Kjeldahl); Available phosphorus (Olsen); Cation exchange capacity; Interchangeable bases (Ca, Mg, Na and K); Micronutrients (Fe, Zn, Mn).

Sampling plan:

Field sampling followed by lab analyses. Soil will always be sampled at the same moment of the year (set a fixed spring month), preferably avoiding temporal proximity to gardening interventions (or any other type of actions affecting soil (tree pruning, plantation, grass sowing, fertilization, etc.)

In homogeneous landscapes, two samples per hectare may be a standard sampling density, but the 10.000 m^2 unsealed in St. Jerôme and Saint Charles are not homogeneous and are distributed in islands of unknown size and quality. Let's sample the four biggest islands created at each site.

At each island, take two soil samples from two points randomly selected. The two samples will be mixed into a unique plastic zip bag duly labelled with the date and the identification of the garden island. Soil must be sampled at 15 cm depth with soil samplers similar to those described in the "equipment" section.

The resulting eight soil samples (4 from St Charles and 4 from St Jerôme) will be sent to an expert lab for analysis as soon as possible. The soil lab must have been previously consulted for instructions about the preparation of the samples before shipping.

Sampling calendar

The gardens will be sampled in the proposed season every 2 years for 10 years (5 times).

Equipment

Samples will be extracted from soil with soil borers of similar and known (the same for all samples at each sampling campaign) depth and diameter. The borer should be 15 cm long and the recommended diameter is 5 cm.

Some providers of these soil samplers are: https://www.ams-samplers.com/soil-augers/; https://www.vanwalt.com/equipment/telescoping-augers/. Any other equivalent sampler of these dimensions is acceptable (but try to respect the 15 cm depth)

Some small field materials, such as zip bags.

External subcontracting

Yes. A trustable lab delivering soil fertility analyses must be hired.

References

- Dondini, C., Úbeda, X., Certini, G., Francos, M. (2024). Soil quality in the urban gardens of Barcelona (Spain). *Journal of Soils and Sediments*, 1-13.

- Kortleve, A. J., Mogollón, J. M., Heimovaara, T. J., Gebert, J. (2023). Topsoil carbon stocks in urban greenspaces of The Hague, the Netherlands. *Urban Ecosystems*, *26*(3), 725-742.
- For soil fertility in gardens: https://extension.umaine.edu/gardening/manual/soils/interpreting-soil-tests/

5.1.1.2 Soil Sealing

- **Code:** Jerome_Soil02
- **Environmental Sector** : Soil / Soil Health
- **Units:** % Area (As an Indicator Is Usually Calculated as Percentage (Sealed Area Per Total Area) Or as Sealed Area Per Capita For A Given Region or Country).

Meaning and importance of the indicator

Soil sealing represents one of the major threats of our decade from soil degradation, one of the main environmental issues. Impacts of soil sealing affects ecosystems and furthermore, carbon sequestration, degradation and pollution mitigation. As the main biodiversity is in soil, soil sealing affects both below and above the ground biodiversity, which entails a considerable loss due to topsoil is removed. Soil sealing also increases the risk of flooding and reduces the total and microbial content of carbon and nitrogen, and soil respiration. Soil sealing as an indicator corresponds to an irreversible loss of soil and its biological functions and loss of biodiversity.

Expected evolution of the indicator

The current methods to measure soil sealing are satellite methods, computation based on land use data from cadastres or aerial pictures. Measures to reduce soil sealing inside urban areas are promoted. Sealing rates are usually low in peri-urban areas with on average 10 % and very high in core cities, with on average 36 %.

Data obtention

Required data:

To be analysed only the first time (See Jerome_Soil01).

Sampling plan:

Field sampling followed by lab analyses (See Jerome_Soil01).

Sampling calendar

This indicator will be produced every two years for a total of 10 years, coinciding with the evaluation of soil physical and chemical fertility (See Jerome_Soil01).

Equipment

See Jerome_Soil01.

External subcontracting

Yes. A trustable lab delivering must be hired (See Jerome_Soil01).

References

- Behnisch, M., Poglitsch, H. and Krüger, T. 2016. Soil Sealing and the Complex Bundle of Influential Factors: Germany as a Case Study. *International Journal of Geo-Information*. 5(8): 132. https://doi.org/10.3390/ijgi5080132.

- Peroni, F., Pappalardo, S., Facchinelli, F., Crescini, E., Mufano, M., Hodgson, M.E. & De Marchi, M. 2022. How to map soil sealing, land take and impervious surfaces? A systematic review. *Environmental Research Letters*. 17, 053005. 10.1088/1748-9326/ac6887
- Tobias, S., Conen, F., Duss, A., Wenzel, L.M., Buser, C. & Alewell, C. 2018. Soil sealing and unsealing: State of the art and examples. Land Degradation and Development 29 (99). https://doi.org/10.1002/ldr.2919
- https://esdac.jrc.ec.europa.eu/themes/soil-sealing
- https://recare-hub.eu/soil-threats/sealing
- https://www.eea.europa.eu/publications/soil-monitoring-in-europe

5.1.1.3 Water Holding Capacity

- **Code:** Jerome_Soil03
- **Environmental Sector**: Soil / Soil Health
- **Units:** %

Meaning and importance of the indicator

The water holding capacity (WHC) is an important agronomic characteristic. The WHC of a soil is the maximum amount of water a soil can hold under standard conditions. Water holding capacity is affected by soil texture (sand, silt, and clay proportion) and soil structure (pore size, porosity, pores connectivity distribution and characteristics are essential determinants).

A soil with a limited WHC reaches sooner the saturation than a soil with a higher WHC, especially between sandy soils as they tend to have low water storage capacity.

Expected evolution of the indicator

Soil structure can be improved by adding organic matter content to stimulate the soil porosity, which increases the water holding capacity. Also, a better water holding capacity of the soil can be accomplished by increasing soil organic carbon. However, deforestation and farming activities may decrease soil water holding capacity.

Data obtention

Required data:

It needs to be analysed the first time and every two years for 10 years (5 times) (See Jerome_Soil01).

Sampling plan:

Field sampling followed by lab analyses Field sampling followed by lab analyses (See Jerome_Soil01).

Collect the sample using a soil core, air dry it, break the aggregates and pass through a 2.0 mm sieve. Place the core containing soil in a water tray for saturation overnight and then place the sample in an oven at 105º C for 24-48 h. Finally, weight the core sample.

For further instructions go to the Practical manual on measurement of soil physical properties, on the page 34.

Sampling calendar

This indicator will be produced every two years for a total of 10 years, coinciding with the evaluation of soil physical and chemical fertility (See Jerome_Soil01).

Equipment

Additional field materials: A soil cylinder /core, a tray, filter papers, a spatula, a sieve, water try, a balance and a drying oven (See Jerome_Soil01).

External subcontracting

If a reliable scale and an oven are available, WHC can be obtained very simply without the need of an expert lab. If not, a trustable lab delivering soil fertility analyses must be hired (See Jerome_Soil01).

Calculation formula

$$WHC\% = (Vw/Vt) * 100,$$

Where:

- Vw is volume of water and Vt, is total volume of saturated soil.

5.1.1.4 Soil Organic Carbon Content

- **Code:** Jerome_Soil04
- **Environmental Sector**: Soil / Soil Health
- **Units:** %C

Meaning and importance of the indicator

Soil organic carbon (SOC) constitutes about 58% of soil organic matter (SOM) that is a chief indicator of soil health. SOC enters the soil through the decomposition of plant and animal residues, root exudates and living and dead soil biota (including microorganisms). Plant carbon comes from the C that plants remove from the atmosphere (photosynthesis), and animals obtain C from plant ingestion; therefore, the final origin of SOC is atmospheric CO_2. The stable fraction of SOC (the soil fraction that stays in soil for longtime periods and resists microbial attack) is considered "sequestered carbon" and contributes to climate change mitigation

Expected evolution of the indicator

%C should increase over time. As a reference, organic carbon content in the vegetated areas of the city of Barcelona (Spain) ranges from 0.33% to 4.5%

Data obtention

Sampling plan:

Soil organic carbon analysis is included in the analyses of soil physical and chemical fertility (Jerome_Soil01).

Sampling calendar

This indicator will be produced every two years for a total of 10 years, coinciding with the evaluation of soil physical and chemical fertility (Jerome_Soil01).

Equipment

See Jerome_Soil01.

External subcontracting

Yes. A trustable lab delivering soil fertility analyses must be hired.

References

- Dondini, C., Úbeda, X., Certini, G., Francos, M. (2024). Soil quality in the urban gardens of Barcelona (Spain). *Journal of Soils and Sediments*, 1-13.
- Kortleve, A. J., Mogollón, J. M., Heimovaara, T. J., Gebert, J. (2023). Topsoil carbon stocks in urban greenspaces of The Hague, the Netherlands. *Urban Ecosystems*, *26*(3), 725-742.
- Langemeyer, J., Latkowska, M. J., Gómez-Baggethun, E. N., Voigt, A. et al. (2016). Ecosystem services from urban gardens. In *Urban allotment gardens in Europe* (pp. 115-141). Routledge.
- Scharenbroch, B. C., Lloyd, J. E., Johnson-Maynard, J. L. (2005). Distinguishing urban soils with physical, chemical, and biological properties. *Pedobiologia*, *49*(4), 283-296

5.1.1.5 Soil Bulk Density (ρ)

- **Code:** Jerome_Soil05
- **Environmental Sector** : Soil / Soil Health
- **Units:** G Cm^{-3}

Meaning and importance of the indicator

Bulk density indicates the degree of soil compaction. Bulk density is inversely related to soil porosity which allows air and water to move through the soil and facilitates plant root penetration through the soil. Compaction is the main feature of urban soils, very specially when they have been sealed, since sealing most often is preceded by removal of topsoil horizons and mechanic compaction that induces heavy alteration of the soil pore space and architecture. Compaction is among the main features of physical degradation of urban soils and is accompanied by low water holding capacity, low biological activity and low chemical quality and capacity to sustain healthy plants.

Expected evolution of the indicator

Bulk density is affected by soil texture (sand, silt, and clay proportion) and organic matter content. Fine-textured soils (such as silt and clay loams) with good structure have lower bulk density compared to sandy soils. According to data from the EU Joint Research Centre, mean European values for soil bulk density are 1.26 g cm^{-3} for arable lands, 1.23 g cm^{-3} for permanent crops, and 1.14 for heterogeneous agricultural areas. In highly disturbed urban soils, bulk density can range from 1.5 g cm^3 in lawns to densities that approach those of concrete in heavily trodden paths of sport yards (2.2 g cm^3). Bulk density should decrease as soil recovers its structure and gains organic matter.

Data obtention

Sampling plan:

Field sampling followed by a very simple analysis. Soil will always be sampled for density at the same moment of the year (make it match the soil fertility sampling date), preferably avoiding temporal proximity to gardening interventions (or any other type of action implying soil trampling or compaction)

At each sampling date, you will take two independent samples for soil density assessment from each the four biggest islands created in St. Jerôme and Sait Charles, in the vicinity of the points where you have already sampled soils for fertility (8 points in St Jerôme and 8 points in Saint Charles).

A detailed explanation of the sampling method is provided in the USDA Soil Quality Test Kit Guide (1999), pg.9 (see references).

In short for each sample, drive the metal cylinder all the way into the ground until its upper edge is level with the surface of the ground (using a mallet and a block of wood). Remove the ring taking great care not to lose soil. To do so, dig around the ring and with a trowel underneath it, carefully lift it out. Remove excess soil from the sample with a flat-bladed knife. The top and bottom of the soil sample should be flat and even with the edges of the ring. Using the flat-bladed knife, push out the entire soil sample into a plastic zip bag. Label the bag correctly.

Take the samples to the lab (or any other place where there is a scale - with two decimal places of accuracy- and a drying oven). Transfer each sample individually from the plastic bag to a foil or paper tray duly labelled. Put the soil samples to dry at 100 degrees until constant weight (usually 4 days is enough). Weight the dry soil (in g) and register it in your soil data worksheet. If a drying oven is not

available, you can use a microwave (see the method in the USDA Soil Quality Test Kit Guide (in references).

Sampling calendar

Bulk density will be measured together with soil fertility (Charles_Soil01), every two years for ten years.

Equipment

Bulk density is the ratio between soil dry weight and soil volume. Therefore, soil samples will be taken with a stainless-steel cylinder of perfectly know volume. The recommended dimensions for this case are 10 cm deep and 8 cm in diameter.
Additional field materials: a mallet, a block of wood, a trowel, a knife and zip-bags.

External subcontracting

If a reliable scale and a microwave are available, bulk density can be obtained very simply without the need of an expert lab.

Calculation formula

$$\rho = M / V$$

Where:

- ρ is estimated as g cm^{-3}; M is the **dry** weight of the sample in g, and V the volume of the soil cylinder (in cm^3).

For each garden island, calculate the average of the two estimates of density

References

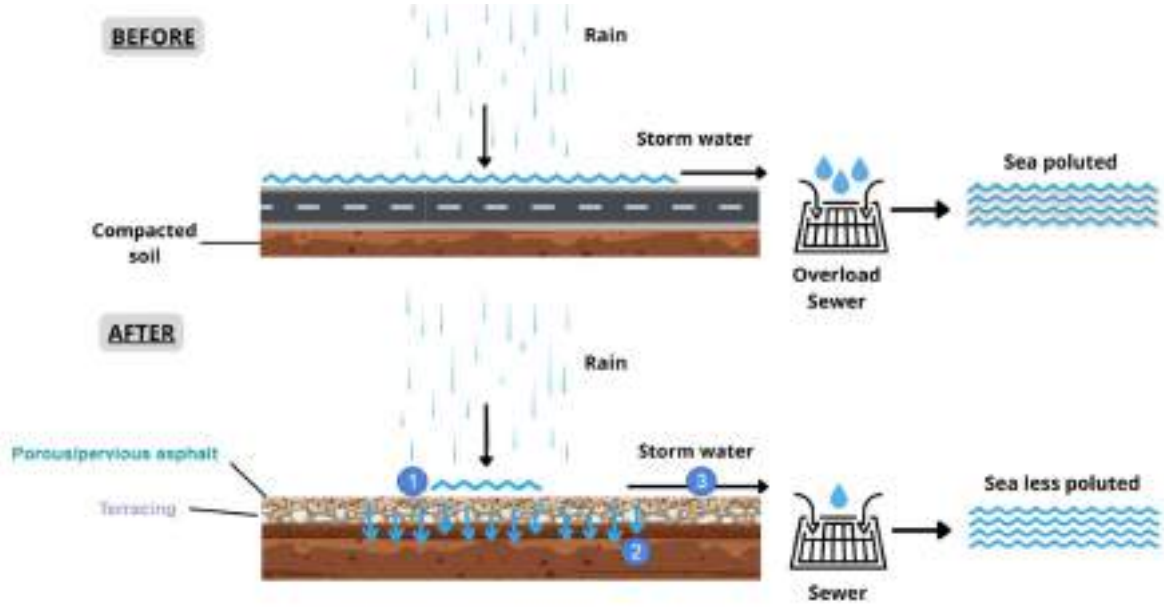
- Can Urban Soil Compaction Be Reversed? Technical Note #108 from Watershed Protection Techniques. 1(4): 666-66. https://owl.cwp.org/mdocs-posts/elc_pwp37/
- Effect of Urban Soil Compaction on Infiltration Rate https://owl.cwp.org/mdocs-posts/effect-of-urban-soil-compaction-on-infiltration-rate/
- O'Riordan, R., Davies, J., Stevens, C., Quinton, J. N. (2021). The effects of sealing on urban soil carbon and nutrients. *Soil*, *7*(2), 661-675.
- Paradelo, R., Herbón, C., Barral, M. T. (2024). Physical properties of the urban soils of Santiago de Compostela (Spain). *Journal of Soils and Sediments*, 1-10.
- Soil Quality Indicators. Bulk Density. USDA Natural Resources Conservation Service https://www.nrcs.usda.gov/sites/default/files/2022-10/nrcs142p2_051591.pdf
- Soil Quality Test Kit Guide. USDA Natural Resources Conservation Service. 1999. https://efotg.sc.egov.usda.gov/references/public/WI/Soil_Quality_Test_Kit_Guide.pdf
- The Compaction of Urban Soils. Technical Note #107 from Watershed Protection Techniques. 3(2): 661-665. https://owl.cwp.org/mdocs-posts/elc_pwp36/

5.1.2 Water Indicators

5.1.2.1 Water Monitoring Plan

Sampling points

From Concrete to green: A Natural-Driven Journey Towards Sustainability.



Sampling points

Sampling point	Location	Purpose
SP-01	Inlet of the porous/pervious asphalt	Monitor the rainfall/stormwater (volume)
SP-02	Outlet of the porous/pervious asphalt	Monitor the infiltration rate
SP-03	Inlet of the sewer	Monitor the rainfall/stormwater availability and storage (volume)

Parameters to be analyzed

Parameter	Applicable Sampling point	Related indicators	Type
Volume of rainfall over the NBS	SP-01	WA; RI	water flow measurements [volume/time]

Water infiltration velocity through the soil	SP-02	IR	water flow measurements [volume/time]
Volume of water availability	SP-03	WSC; WA	water flow measurements [volume/time] and infiltration rate

Sampling method

Water flow measurements:

Direct measurement of volume provided during a time period or water flow with flow meters and/or water level sensors.

a) Automatic method

Automatic flow meters can be installed at the recommended sampling points (SP). For the automatisation process, it is recommended to register the measurements with a datalogger/digital control system in the DEMO. It is recommended to measure the flow at the recommended sampling points (SP).

Data should be stored in a datalogger/digital control system and then be able to be exported in a spreadsheet to calculate the associated indicators. When this is not possible, manual readings of the flow meters can be done instead.

b) Manual method

This could be applied as the last option if there is no possibility to apply the automatic method.

- Periodic manual measurements.
- If no devices are available to measure, correct and reliable estimates must be made to assess the indicator.

Rainwater/stormwater data:

For the registration of rainwater or stormwater data, it is more recommended to apply online and automatic methods.

a) Automatic method

Drone-derived orthophotos or satellite data can be used to measure the rainfall/stormwater. Also information from nearby meteorological/weather stations.

b) Manual method

Manual simple measurements using rain gauges could be used as the last option. These methods can give less accurate data.

Infiltration rate:

The infiltration rate is a type of water flow measurement, very related to the soil. Also, as other indicators, there are automatic and manual methods:

a) Automatic method

To measure infiltration rate automatically in the NBS, a tensiometer-based system or automated infiltrometer can be employed. These systems consist of soil moisture sensors or pressure transducers installed in the ground at various depths to continuously measure changes in soil moisture content or water pressure. The automated system periodically adds a controlled amount of water to the surface,

imitating rainfall or irrigation. The sensors monitor how quickly the water infiltrates and how the moisture levels change over time. Data is collected in real-time and transmitted to a central data logger or computer for analysis, calculating the infiltration rate without manual intervention.

b) Manual method

To manually sample the infiltration rate, it's needed to use a ring infiltrometer. An example of this process is the following. First, hammer a 30 cm diameter ring about 15 cm into the soil, and place a measuring rod inside. Then, hammer a 60 cm diameter ring around the first one (or build an earthen bund) to prevent lateral water movement. Pour water into both rings to a depth of 70-100 mm, and record the time. Measure the drop in water level at regular intervals, adding water to maintain the initial level. Continue until the water drop rate stabilizes, which represents the basic infiltration rate. Repeat the test at least twice for accuracy.

Sampling calendar

Water flow measurements and infiltration rate:

Data should be collected frequently for a relevant time period (e.g., daily, weekly, monthly) to allow for accumulation over the entire reporting period (yearly). This high frequency is also relevant to study seasonal variations.

Rainwater/stormwater data:

Data should be collected every time there is a rain event.

Equipment

a) Water flow measurements:

Water flow meters are essential tools for monitoring and assessing the efficiency of these systems, as they provide real-time data. In this DEMO, the main water flow measurement is about rainwater, so there are different rain gauges that can be used for it.

Some indicative providers of these are:

- OMEGA
- Amazon

Also, for water availability water flow meters can be used. Some providers are:

- Endress+Hauser
- Systec Controls
- Aobo instrument

Any equivalent water flow meter is acceptable, these are given as examples.

b) Rainwater/stormwater data:

In this DEMO, the main water flow measurements would be rainwater/stormwater, so there are different rain gauges that can be used for it.

Some indicative providers of are:

- OMEGA
- Amazon

Any equivalent water level sensor is acceptable, this is given as an example.

Infiltration rate:

Some indicative providers are:

- Manual infiltrometer - Eijkelkamp
- Manual infiltrometer - ELE International

- Automated infiltrometer - SATURO

*For manual infiltrometers, take into account that you may need a hammer, a watch or clock, a bucket, a timber, or any other instrument to work together.
Any equivalent water flow meter is acceptable, these are given as examples.

External subcontracting

Yes. A trustable laboratory delivering water quality analyses must be hired if not available internally.

5.1.2.2 Water Availability (WA)

- **Code**: Jerome_Water01
- **Environmental Sector:** Water / Freshwater supply / Resource efficiency
- **Units:** m^3/year

Meaning and importance of the indicator

The indicator refers to the volume of water available provided by the DEMO for its reuse in various applications (e.g. aquifer recharge, ecosystem restoration, on site reuse, irrigation, industrial activities, etc.). The water available should comply with quality standards required for different reuses as per current legislation.

Expected evolution of the indicator

The baseline for this indicator is the initial water availability capacity, which may start at 0 m^3/year. It is expected to increase over time once the DEMO is operating and optimized, reflecting an improvement in water availability for reuse and ecosystem services. Ensure that 100% of the water provided by the DEMO is available for reuse.

Possible relationship with other water indicators

Water footprint, Water provision by the ecosystem.

Data obtention

Sampling plan:

- Direct annual flow of the effluent or annual volume provided by the DEMO for specific purposes (e.g., aquifer recharge, ecosystem restoration, etc.) (m^3/year).
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total volume water available in the DEMO (WA) (m^3/year).

Calculation formula

$$WA = Water\ inflows\ (WI) - Water\ losses\ (WL)$$

Where:

- WI: Total water entering the DEMO system (e.g., precipitation, surface water, groundwater recharge, recycled water) (m^3)
- WL: Total water lost (due to evaporation (m^3))

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/
- United Nations Conference on Trade and Development (2023). Environmental indicators: Module B Core SDG Indicators for Entity Reporting Training Manual. https://unctad.org/system/files/information-document/UNCTAD_GCI_MANUAL_ENVIRONMENTAL-FINAL.pdf
- URBAN GreenUP (2019). D5. 3: City diagnosis and monitoring procedures. https://www.urbangreenup.eu/kdocs/1912498/urban_greenup_d5_3_city_diagnosis_and_monitoring_procedures.pdf
- U.S. Environmental Protection Agency (2024). Basic information about water reuse. https://www.epa.gov/waterreuse/basic-information-about-water-reuse

5.1.2.3 Water Storage Capacity (WSC)

- **Code:** Jerome_Water02
- **Environmental Sector:** Water / Effectiveness of the adaptive change towards resilient infrastructure
- **Units:** Days

Meaning and importance of the indicator

The indicator assesses the resilience and efficiency of water supply systems. It is defined as the ratio between the total volume of available storage (e.g., water supply tanks, reservoirs for rainwater harvesting, and reclaimed water storage) and the average flow rate either provided to or demanded by the system. This flow rate encompasses all demands associated with distribution systems, rainwater harvesting infrastructure, and treatment facilities. The indicator provides insightful information about the number of days that the system can handle relying on the potential stored volume of water, not on the actual volume of stored water.

Expected evolution of the indicator

The WSC indicator will vary by region, depending on local water availability, climate conditions, and demand patterns in the DEMO. The optimal value is context-specific, but generally, a higher WSC indicates a more resilient water supply system capable of withstanding longer periods without external water inputs. However, as water supply systems integrate more non-conventional water sources (e.g., rainwater harvesting, reclaimed water, etc.), the WSC is expected to increase, improving the system's sustainability and resilience.

Possible relationship with other water indicators

Water availability, Captured runoff.

Data obtention

Sampling plan:

- Total operational volume of storage capacity, such as supply tanks, reservoirs, and reclaimed water storage (m^3)
  Fixed value of the operational volume of the storage capacity.
- Daily average inflow entering or being demanded to the DEMO system (m^3/day)
  The average can be done from data obtained from sampling at the DEMO.

Calculation formula

$$WSC = \frac{V_t}{Q_S}$$

Where:

- WSC: Water Storage Capacity (days),
- V_t: Total operational volume of storage capacity (m^3),
- Q_s: Daily average inflow entering or being demanded to the system (m^3/day).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/
- Carollo, M., Butera, I., & Revelli, R. (2022). Water savings and urban stormwater management: Evaluation of the potentiality of rainwater harvesting systems from the building to the city scale. PLOS ONE, 17(11), e0278107. https://doi.org/10.1371/journal.pone.0278107
- Donatello S., Doddtf N. & Cordella M. (2021). Level(s) indicator 3.1: Use stage water consumption user manual: introductory briefing, instructions and guidance (Publication version 1.1). JRC, European Commission.

5.1.2.4 Rainfall Interception of NBS (RI)

- **Code**: Jerome_Water03
- **Environmental Sector:** Water / Rainwater management and flood protection
- **Units:** mm/h

Meaning and importance of the indicator

The indicator measures the rate at which rainfall is intercepted by the NBS. This indicator is important for assessing the effectiveness of NBS in managing rainwater, reducing surface runoff, and mitigating flood risks. The interception capacity of NBS directly influences the hydrological balance and contributes to water retention in the ecosystem, thereby playing a vital role in flood prevention and sustainable water management.

Expected evolution of the indicator

Baseline: Initial interception capacity of the NBS.

Target: The optimal value would be a higher rate of rainfall interception compared to the baseline scenario and conventional infrastructure, leading to reduced surface runoff and enhanced groundwater recharge. This should ideally increase over time as the NBS matures and vegetation coverage expands.

Possible relationship with other water indicators

Captured runoff, Flood excess volume, Avoided floods.

Data obtention

Sampling plan:

- Volume of rainfall intercepted by the NBS (mm)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Time duration of the rainfall event (h)

Calculation formula

$$RI = \frac{Vrainfall\ NBS}{t}$$

Where:

- RI: Rainfall Interception Rate (mm/h),
- Vrainfall NBS: The total volume of rainfall intercepted by the NBS during a given time period (mm),
- t: time duration of the rainfall event (h).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: a handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577

5.1.2.5 Infiltration Rate (IR)

- **Code**: Jerome_Water04
- **Environmental Sector:** Water / Water management
- **Units:** m/d or mm/h

Meaning and importance of the indicator

The indicator reflects the speed at which water penetrates the soil or a porous surface, typically measured in units of depth per time (e.g., m/d or mm/h). It is influenced by factors such as soil texture, moisture content, and the presence of vegetation or surface structures.

Expected evolution of the indicator

Baseline: Initial recharge capacity based on the natural soil or site specifications. An increase in infiltration rate is expected over time with DEMO implementation, leading to higher recharge volumes compared to areas without the solution. Dependent on the specific NBS and local soil conditions; typically, higher infiltration rates indicate more effective water management, although very high rates could lead to groundwater contamination if not managed properly. The following table shows the basic infiltration rate for various soil types:

Soil type	Basic infiltration rate (mm/hour)
sand	less than 30
sandy loam	20 - 30
loam	10 - 20
clay loam	5 - 10
clay	1 - 5

Note: FAO (n.d.)

Possible relationship with other water indicators

Increased groundwater recharge.

Data obtention

Sampling plan:

- Infiltration rate: Direct measurement of the amount of water that penetrates the ground surface over time (m/d or mm/h).
- Cumulative values during a period will be needed, measuring in terms of time, such as days or hours. If this is not possible, average values can be obtained. The average can be done from daily average data obtained from sampling at the DEMO.
- Area of the infiltration surface (m^2).
- Darcy velocity: Hydraulic conductivity of the material, infiltration area, and difference in water level between the inlet and outlet points.

Calculation formula

$$q_{boundary} = \frac{Q_{out}}{S_b}$$

$$Q_{out} = -K \cdot \frac{dh}{dl} \cdot A$$

or

$$q = \frac{K \cdot A \cdot \Delta h}{L}$$

Where:

- $q_{boundary}$ and q: is the infiltration rate (in units of volume per area and time, such as $m^3/s \cdot m^2$ or m/d or mm/h),
- Q_{out} is the total infiltrated flow (m^3/s), calculated as the integration of the Darcy velocity over the entire infiltration surface,
- K is the hydraulic conductivity of the material (m/s), which depends on the properties of the porous medium,
- A is the infiltration area, which in this case is the cross-sectional area of the material through which the water flows (m^2),
- Δh is the hydraulic head difference (or difference in water level) between the inlet and outlet points (m),
- L is the length of the water flow path through the porous medium (m),
- Sb is the area of the infiltration surface (m^2).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- Bouwer, H. (2017). Water infiltration in an aquifer recharge basin affected by temperature and air entrapment. ResearchGate. https://www.researchgate.net/publication/318655137_Water_infiltration_in_an_aquifer_recharge_basin_affected_by_temperature_and_air_entrapment
- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: a handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577
- European Commission. (2021). *EU biodiversity strategy for 2030: Bringing nature back into our lives*. Publications Office of the European Union. https://doi.org/10.2779/677548
- Food and Agriculture Organization (FAO) of the United Nations. (n. d.). Infiltration rate. https://www.fao.org/4/S8684E/s8684e0a.htm
- Taguas, E. V., Burguet, M., & Ayuso, J. L. (2017). Infiltration in a Mediterranean vineyard with high soil erosion: Temporal variation and its influence on the water balance. Water, 9(2), 119. https://doi.org/10.3390/w9020119

5.1.3 Human Well-being Indicators

5.1.3.1 Air Temperature at 2 Meters (Daytime and Night-Time)

- **Code:** Jerome_Well01
- **Environmental Sector**: Air Temperature Comfort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for people.

Expected evolution of the indicator

The temperature indicator is expected to show a gradual decrease as vegetation matures and green infrastructure becomes more established. The tendency should reflect a cooling effect, particularly during warmer months, as plants provide shade, increase evapotranspiration, and mitigate heat absorption from hard surfaces. The optimal value range will vary depending on the local climate, but ideally, temperatures in greened areas should be noticeably lower than in non-greened parts of the campus, contributing to a more comfortable and cooler environment.

Possible relationship with other air temperature analyses

Jerome_Well from 02 to 07.

Data obtention

Required data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors in each campus at 2 meters (sensor 1: will take data before the nature-based solution application and will be in charge of taking measurements after the transformation; Sensor 2: without vegetation and greater exposure to the sun (not transformed) Sensor 3: below a tree or a vegetation (not transformed).

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH)

External subcontracting

Yes, the sensor provider.

Calculation formula

Collect temperature data at 15-minute intervals throughout the 24-hour period.
Segregate the data into daytime and nighttime intervals (from sunrise to sunset for daytime and from sunset to sunrise for nighttime).
Calculate the average temperature for both periods using the formulas

$$T_{day} = \frac{1}{n_{day}} \sum_{i=1}^{n_{day}} T_i$$

Where:

- Ti is the temperature recorded at the i-th 15-minute interval during the daytime
- nday is the number of 15-minute intervals during daytime

$$T_{night} = \frac{1}{n_{night}} \sum_{j=1}^{n_{night}} T_j$$

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

5.1.3.2 Daily Temperature Range

- **Code:** Jerome_Well02
- **Environmental Sector:** Air Temperature Comfort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for people.
In particular, this indicator shows how much the temperature fluctuates throughout the day, often used to assess climate variability and the effect of green infrastructure on stabilizing temperature extremes.

Expected evolution of the indicator

Tendency: As green infrastructure, such as tree planting and vegetation, matures, the daily temperature range is expected to narrow. Vegetation helps moderate both daytime highs and nighttime lows by providing shade during the day and trapping heat during the night.
Optimal value range: A moderate daily temperature range (DTR) is often considered optimal, with smaller fluctuations typically indicating a healthier microclimate. The exact value range depends on the local climate, but in urban areas, a reduction in DTR could indicate improved thermal regulation due to greening projects.

Possible relationship with other air temperature analyses

Jerome_Well01 and from 02 to 07.

Data obtention

Required Data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors in each campus at 2 meters (sensor 1: will take data before the nature-based solution application and will be in charge of taking measurements after the transformation; Sensor 2: without vegetation and greater exposure to the sun (not transformed) Sensor 3: below a tree or a vegetation (not transformed).

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

External subcontracting

Yes, the sensor provider

Calculation formula

$$Daily\ Temperature\ Range = Tmax - Tmin$$

Where:

- Tmax is the daily maximum temperature (from sunrise to sunset)
- Tmin is the daily minimum temperature (from sunset to sunrise)

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

5.1.3.3 Days With Temperature >90th Percentile (TX90p)

Code: Jerome_Well03

- **Environmental Sector**: Air Temperature Comfort
- **Units**: ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for people.

TX90p is the number of days where the maximum daily temperature exceeds the 90th percentile of the long-term reference period. This indicator is often used to assess heatwave frequency and climate change impacts.

Expected evolution of the indicator

Tendency: Without intervention, the number of days with temperatures above the 90th percentile is likely to increase due to climate change, especially in urban areas. However, the implementation of nature-based solutions (such as urban greening) can slow or reduce this trend by cooling the environment.

Optimal value range: Ideally, the number of days exceeding the 90th percentile should remain low. While occasional days above this threshold are normal, a high or increasing trend could indicate vulnerability to heat stress.

Possible relationship with other air temperature analyses

Jerome_Well01 to 02 and 04 to 07.

Data obtention

Required data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Place three sensors at the campus, each at a height of 2 meters, with the following configurations: Sensor 1: Positioned within the area that will be transformed by the nature-based solution. This sensor will collect baseline data before the installation and continue to take measurements after the transformation. Sensor 2: Positioned outside the NBS in a location with high sun exposure, serving as a control site in an area that is not transformed. Sensor 3: Positioned outside the NBS in a location with low sun exposure, also serving as a control site in an area that is not transformed.

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

External subcontracting

Yes, the sensor provider.

Calculation formula

First, calculate the 90th percentile of maximum temperatures for a reference period (e.g. 30 years), then count how many days in a specific time period (e.g. every year of sampling) exceed this value.

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

5.1.3.4 Heatwave Risks (Number of Combined Tropical Nights (>20ºC) and Hotdays (>35ºC))

- **Code:** Jerome_Well04
- **Environmental Sector**: Air Temperature Comfort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for people.

This indicator counts the number of nights where the temperature does not fall below 20ºC (tropical nights) combined with days where the temperature exceeds 35ºC (hot days) to assess potential risks related to human health and infrastructure due to heat stress during heatwaves.

Expected evolution of the indicator

Tendency: In urban areas, the risks of tropical nights and hot days are expected to increase over time due to global warming. However, greening projects can mitigate some of these effects by lowering both daytime and nighttime temperatures, reducing the frequency of tropical nights (>20ºC) and hot days (>35ºC).

Optimal value range: Ideally, the number of tropical nights and hot days should be minimized, as both pose significant risks to human health. The optimal value would be near zero for tropical nights and hot days during most of the year, particularly in regions not typically exposed to extreme heat.

Possible relationship with other air temperature analyses

Jerome_Well01 to 03 and 05 to 07.

Data obtention

Required data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors in each campus at 2 meters (sensor 1: will take data before the nature-based solution application and will be in charge of taking measurements after the transformation; Sensor 2: without vegetation and greater exposure to the sun (not transformed) Sensor 3: below a tree or a vegetation (not transformed).

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

External subcontracting

Yes, the sensor provider

Calculation formula

Tropical nights: Count of nights for a given year where Tmin >20°C
Hot days: Count of days for a given year where Tmax>35°C

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

5.1.3.5 Mean Or Peak Daytime Local Temperatures (°C)

- **Code**: Jerome_Well05
- **Environmental Sector:** Air Temperature Comfort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for people.

The mean or peak daytime local temperatures (°C) is the highest temperature recorded during the daytime hours (from sunrise to sunset) which helps assess local heat conditions and the effectiveness of green infrastructure in cooling the environment.

Expected evolution of the indicator

Tendency: Mean and peak daytime temperatures are expected to decrease with the maturation of green infrastructure. Vegetation provides shade and promotes evapotranspiration, leading to a cooling effect, especially during the hottest parts of the day.

Optimal value range: Ideally, peak daytime temperatures would stay below heat stress thresholds (often around 30–35ºC, depending on local climate conditions).

Data obtention

Required data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors in each campus at 2 meters (sensor 1: will take data before the nature-based solution application and will be in charge of taking measurements after the transformation; Sensor 2: without vegetation and greater exposure to the sun (not transformed) Sensor 3: below a tree or a vegetation (not transformed).

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

External subcontracting

Yes, the sensor provider.

Calculation formula

Obtention of the highest temperature every day of the year.
Mean of the highest temperatures during the year.

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

5.1.3.6 Monthly Mean Value of Daily Maximum Temperature (TXx)

- **Code:** Jerome_Well06
- **Environmental Sector:** Air Temperature Comfort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for people.

This indicator calculates the monthly average of the daily maximum temperatures over a given month which helps assess local heat conditions and the effectiveness of green infrastructure in cooling the environment.

Expected evolution of the indicator

Tendency: The monthly mean of daily maximum temperatures is expected to decrease with effective greening interventions, particularly during the hottest months. Green infrastructure mitigates extreme heat by providing shade and cooling the air through transpiration.

Optimal value range: The optimal value depends on the region's climate. Generally, a lower mean daily maximum temperature during summer months is desirable to avoid heat stress.

Possible relationship with other air temperature analyses

Jerome_Well01 to 05 and 07.

Data obtention

Required data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors in each campus at 2 meters (sensor 1: will take data before the nature-based solution application and will be in charge of taking measurements after the transformation; Sensor 2: without vegetation and greater exposure to the sun (not transformed) Sensor 3: below a tree or a vegetation (not transformed).

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

External subcontracting

Yes, the sensor provider.

Calculation formula

$$TXx = \frac{1}{n}\sum_{i=1}^{n} T_{max,i}$$

Where:

- *Tmax* is the daily maximum temperature for day *i*
- *n* is the number of days in the month

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

5.1.3.7 Monthly Mean Value of Daily Minimum Temperature (TNn)

- **Code:** Jerome_Well07
- **Environmental Sector**: Air Temperature Comfort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for people.

This indicator measures the monthly average of the daily minimum temperatures over a given month which helps assess local heat conditions and the effectiveness of green infrastructure in cooling the environment.

Expected evolution of the indicator

Tendency: The monthly mean of daily minimum temperatures could decrease slightly with increased greening, as vegetation helps release heat more gradually at night, reducing the "urban heat island" effect. However, the change in nighttime temperatures may be less pronounced than daytime changes.

Optimal value range: The optimal value would be moderately low but above a threshold that ensures comfort during nighttime. In warm regions, values closer to 15–20ºC are often desirable to avoid discomfort during tropical nights.

Possible relationship with other air temperature analyses

Jerome_Well01 to 06 and 08.

Data obtention

Required data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors in each campus at 2 meters (sensor 1: will take data before the nature-based solution application and will be in charge of taking measurements after the transformation; Sensor 2: without vegetation and greater exposure to the sun (not transformed) Sensor 3: below a tree or a vegetation (not transformed).

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

External subcontracting

Yes, the sensor provider.

Calculation formula

$$TNn = \frac{1}{n}\sum_{i=1}^{n} T_{min,i}$$

Where:

- *Tmin* is the daily minimum temperature for day *i*
- *n* is the number of days in the month

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

5.1.3.8 Relative Humidity (%)

- **Code:** Jerome_Well08
- **Environmental Sector**: Air Temperature Comfort
- **Units:** %

Meaning and importance of the indicator

Relative humidity (RH) is a measure of the amount of moisture in the air compared to the maximum amount of moisture the air can hold at a given temperature. It is crucial to monitor because it impacts the comfort levels, plant growth, and the microclimate of the schoolyard. In the context of greening, a balanced RH indicates improved air quality and ecosystem health, as vegetation influences moisture retention and evaporation rates, leading to a more stable microclimate.

Expected evolution of the indicator

After implementing greening solutions, the relative humidity is expected to increase slightly during the day due to increased transpiration from plants. At night, the RH may remain stable or slightly higher as the vegetation retains moisture. The optimal value range for relative humidity is generally between 40% and 60% for human comfort and plant health, but this may vary slightly depending on the local climate.

Data obtention

Required data:

- Relative humidity every 15 minutes

Possible relationship with other air temperature analyses

Jerome_Well01 to 07.

Data obtention

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors in each campus at 2 meters (sensor 1: will take data before the nature-based solution application and will be in charge of taking measurements after the transformation; Sensor 2: without vegetation and greater exposure to the sun (not transformed) Sensor 3: below a tree or a vegetation (not transformed).

Sampling calendar

A relative humidity sensor will be installed prior to the transformations, and it will need to measure continuously over the following years to establish control and compare the results. The sensor should record relative humidity at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records relative humidity at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

External subcontracting

Yes, the sensor provider.

Calculation formula

Once relative humidity is obtained at 15 minutes intervals you can calculate the following data:
Daily relative humidity range
Monthly mean value of daily relative humidity

References

- Coutts, A. M., Tapper, N. J., Beringer, J., Loughnan, M., & Demuzere, M. (2013). Watering our cities: The capacity for Water Sensitive Urban Design to support urban cooling and improve human thermal comfort in the Australian context. *Progress in Physical Geography, 37*(1), 2-28.
- Armson, D., Stringer, P., & Ennos, A. R. (2012). The effect of tree shade and grass on surface and globe temperatures in an urban area. *Urban Forestry & Urban Greening, 11*(3), 245-255.

5.1.3.9 PM10

- **Code**: Jerome_Well09
- **Environmental Sector**: Air Quality
- **Units:** Micrograms Per Cubic Meter

Meaning and importance of the indicator

PM10 is a mixture of particles suspended in the air that do not exceed 10 micrograms in diameter. It is harmful because it contains benzopyrenes, furans, dioxins and in short, carcinogenic heavy metals. According to the WHO, the limit value of the average daily concentration of this particulate matter is 50 micrograms per cubic meter, and the annual limit value is 20 micrograms per cubic meter.
PM10 air quality has a negative effect on the respiratory system. It is responsible for coughing attacks, wheezing, and the worsening of conditions for people with asthma or acute bronchitis. *PM10* also indirectly affects the rest of the body, including an increase in risk of a myocardial infarction and stroke. Benzopyrene is also highly carcinogenic. To conclude, aerosols of this type are very harmful to humans. Measuring PM10 is crucial in university campus greening projects as vegetation can help reduce airborne particulate pollution, improving air quality and creating a healthier environment for students.

Expected Evolution of The Indicator

After greening initiatives, PM10 levels are expected to decrease over time, as vegetation acts as a natural filter, capturing dust and other particles. The optimal value would be a reduction in PM10 concentrations to levels within the recommended limits set by health organizations.

Possible relationship with other analyses

Jerome_Well10.

Data obtention

Required data:

- Continuous data every 15 minutes

Sampling plan:

Automatic sampling with a sensor. A PM10 sensor should be measured at multiple points (3-5 points, consider putting them at the same place where the air temperature/humidity sensors are installed) within and around the campus to assess the variation in air quality due to different sources of pollution. The sampling devices should be placed at a height corresponding to human breathing levels (1.5 to 2 meters above ground or above if there is a risk of vandalism) and in locations with and without vegetation to compare the effects.

Sampling calendar

A sensor will be installed prior to the transformations, and it will need to measure continuously over the following years to establish control and compare the results. The sensor should record at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

Air quality sensor. Some examples are PurpleAir PA-II, Aeroqual Series 200/300/500 with PM Sensor or Atmotube Pro but many others are available.

External subcontracting

Yes, the sensor provider.

Calculation formula

Once the concentration is obtained at 15 minutes intervals you can calculate the following data:
Average daily concentration of PM10 (the limit daily value for WHO is 45 micrograms per cubic meter)
Average montly concentration of PM10
Average annual concentration of PM10 (the annual limit value for WHO is 15 micrograms per cubic meter)

References

- Janhäll, S. Review on Urban Vegetation and Particle Air Pollution – Deposition and Dispersion. Atmospheric Environment 2015, 105, 130–137.
- Tomson, M.; Kumar, P.; Barwise, Y.; Perez, P.; Forehead, H.; French, K.; Morawska, L.; Watts, J. Green Infrastructure for Air Quality Improvement in Street Canyons. Environment International 2021, 146.
- World Health Organization (WHO) air quality guidelines.

5.1.3.10 PM2.5

- **Code:** Jerome_Well10
- **Environmental Sector**: Air Quality
- **Units:** Micrograms Per Cubic Meter

Meaning and importance of the indicator

PM 2.5 are atmospheric aerosols with a maximum diameter of 2.5 micrometres. This type of suspended particulate matter is considered the most dangerous to human health. This is due to its very fine nature, and its ability to penetrate directly into the bloodstream.

Expected evolution of the indicator

After greening initiatives, PM2.5 levels are expected to decrease over time, as vegetation acts as a natural filter, capturing dust and other particles. The optimal value would be a reduction in PM2.5 concentrations to levels within the recommended limits set by health organizations.

Possible relationship with other analyses

Jerome_Well09.

Data obtention

Required data:

- Continuous data every 15 minutes

Sampling plan:

Automatic sampling with a sensor. A PM2.5 sensor should be measured at multiple points (3-5 points, consider putting them at the same place where the air temperature/humidity sensors are installed) within and around the campus to assess the variation in air quality due to different sources of pollution. The sampling devices should be placed at a height corresponding to human breathing levels (1.5 to 2 meters above ground or above if there is a risk of vandalism) and in locations with and without vegetation to compare the effects.

Sampling calendar

A sensor will be installed prior to the transformations, and it will need to measure continuously over the following years to establish control and compare the results. The sensor should record at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

Air quality sensor. Some examples are PurpleAir PA-II, Aeroqual Series 200/300/500 with PM Sensor or Atmotube Pro but many others are available.

External subcontracting

Yes, the sensor provider.

Calculation formula

Once the concentration is obtained at 15 minutes intervals you can calculate the following data:
Average daily concentration of PM2.5 (the limit daily value for WHO is 15 micrograms per cubic meter)
Average monthly concentration of PM2.5
Average annual concentration of PM2.5 (the annual limit value for WHO is 5 micrograms per cubic meter)

References

- Janhäll, S. Review on Urban Vegetation and Particle Air Pollution – Deposition and Dispersion. Atmospheric Environment 2015, 105, 130–137.
- Tomson, M.; Kumar, P.; Barwise, Y.; Perez, P.; Forehead, H.; French, K.; Morawska, L.; Watts, J. Green Infrastructure for Air Quality Improvement in Street Canyons. Environment International 2021, 146.
- World Health Organization (WHO) air quality guidelines.

5.1.3.11 Recreational Opportunities Provided by Green Infrastructure

- **Code:** Jerome_Well11
- **Environmental Sector:** Social
- **Units:** Number

Meaning and importance of the indicator

Recreational opportunities provided by green infrastructure refer to the ways in which urban green spaces enable physical activities, relaxation, social interactions, and connection with nature. These opportunities are vital for improving public health, reducing stress, and enhancing the quality of life in urban environments. By offering accessible areas for leisure and exercise, green spaces contribute to both mental and physical well-being.

Expected evolution of the indicator

As green infrastructure expands and improves, recreational opportunities should increase in both quantity and quality. An optimal scenario would see more diverse activities available, greater public use of green spaces, and enhanced accessibility for all demographics. This could be reflected in higher usage rates, improved public health metrics, and community satisfaction.

Data obtention

Sampling plan:

Field sampling. To measure recreational opportunities on a university campus, a combination of surveys and observational studies can be used. Surveys should target students, faculty, and staff to gather data on the frequency and type of recreational activities they engage in within the campus green spaces (e.g., walking, sports, studying outdoors). Additionally, observational counts of users in key areas like lawns, gardens, and walking paths should be conducted at different times of the day and week. Specific attention should be given to how green spaces are used during breaks, between classes, and for organized recreational events. The sampling should also account for different types of activities, such as informal social gatherings, exercise, and academic-related uses like outdoor studying or reading.

Sampling calendar

Data should be collected throughout the academic year to capture variations in recreational use during different semesters, exam periods, and holidays. Sampling should be done weekly during peak campus hours (e.g., lunch breaks, late afternoons) and at different times of the day to understand daily patterns of space usage. Additionally, seasonal variations should be considered, with data collection occurring in both warmer and colder months to observe how weather influences recreational activities. Special attention should be paid to key events like orientation weeks, graduation, or campus sports events, which may significantly impact how green spaces are used.

References

- Kabisch, N., & Haase, D. (2014). Green spaces of European cities revisited for 1990–2006. *Landscape and Urban Planning*, 110, 113-122.

5.1.3.12 Self-Reported Well-Being/ Good Moods

- **Code:** Jerome_Well12
- **Environmental Sector**: Social
- **Units:** Unitless

Meaning and importance of the indicator

The "Self-reported well-being/Good Moods" indicator measures individuals' subjective sense of well-being and emotional state after interacting with green spaces. It is essential because it reflects the psychological and emotional benefits of nature, such as reduced stress, improved mood, and enhanced life satisfaction. This indicator is particularly relevant in urban greening projects, as it provides direct feedback from users, helping assess the success of nature-based interventions in improving quality of life.

Expected evolution of the indicator

Over time, the indicator is expected to show an increase in positive moods and a decrease in negative emotions as people spend more time in the green space. Ideally, a consistent shift towards positive feelings like happiness, calmness, and relaxation should be observed. There is no strict optimal range for well-being, but a noticeable upward trend in positive responses would indicate the success of the intervention.

Possible relationship with other analyses

Jerome_Well11.

Data obtention

Required data:

- Surveys

Sampling plan:

Field sampling or automatic sampling. Create a simple online or paper survey with two main questions**:**
"How do you feel?" This question should be answered before entering the nature-based solution
"How do you feel?" This question should be answered when leaving the nature-based solution
The survey should include a list of mood words option, both positive (Happy, Peaceful, Excited, Calm, Rested) and negative (Sad, Anxious, Angry, Tired, Frustrated), from which participants can choose one or more.
Share the survey link or paper copies with the whole university community. Ensure the survey is accessible to different ages.
Encourage participants to complete the survey both upon entering and leaving the nature-based solution.

If you use paper surveys, you can follow this suggestion:
Purchase a small box or use a weatherproof envelope. Inside the box, insert two simple letter-sized envelopes—one labelled "How I Feel Walking into the Nature based solution" and the other labeled "How I Feel Walking out of the Nature based solution." Post the flyers and the box (or envelope) near the

entrance to the Nature based solution, being careful to protect the paper from rain and wind. Invite people to tear off a word from the flyer and drop it into the “How I Feel Walking into the Nature based solution” envelope each time they enter. They should do the same as they leave the Nature based solution.

Sampling calendar

Sampling should be conducted regularly throughout the year to account for seasonal changes in mood and the space’s usability. A good approach would be to survey participants every month for at least one year. Additionally, sampling should occur both before and after the implementation of the nature-based solutions to measure their immediate and long-term impacts.

Calculation formula

The formula for calculating the "Self-reported well-being/Good Moods" indicator could be expressed as:

$$\text{Well-being score} = \frac{\text{Number of positive mood reports}}{\text{Total number of mood reports}} \times 100$$

This will provide a percentage of positive mood responses out of the total collected data, giving a clear overview of the space's impact on well-being.
It can be calculated for the surveys done before the implementation of the nature-based solution and after.

References

- EdiCitNet (a network for urban Food)
- Five Borough urban farm project toolkit
- Eiter, S., Fjellstad, W., Metselaar, K., & Teixeira da Silva, R. (2022). Prioritised indicators and baseline (D5.5).

5.1.3.13 Normalised Difference Vegetation Index (NDVI)

- **Code**: Jerome_Well13
- **Environmental Sector**: Biodiversity
- **Units:** Number

Meaning and importance of the indicator

The Normalised Difference Vegetation Index (NDVI) is a crucial measure that quantifies vegetation health and density. By evaluating NDVI, we can assess the effectiveness of greening initiatives in schoolyards, which is essential for understanding the ecological impact and overall improvement of the environment.

Expected evolution of the indicator

NDVI values are used to classify vegetation cover and health
NDVI < 0 reflects water or artificial cover
0 < NDVI < 0.2 reflects soil and/or death vegetation
0.2 < NDVI < 0.4 reflects disperse vegetation
0.4 < NDVI < 0.6 reflects abundant vegetation
NDVI > 0.6 reflects very abundant and vigorous vegetation

Following greening interventions, we expect to see an upward trend in NDVI values over time, reflecting increased vegetation cover and health as the project matures.

Data obtention

Required data:
To calculate NDVI, you need satellite data that provides reflectance measurements in the near-infrared (NIR) and red (RED) spectral bands

Sampling plan

Satellite data.

Sampling calendar

Measurements should be obtained seasonally, ideally at the beginning and end of each growing season, to capture variations in NDVI due to seasonal changes in vegetation. Additional measurements can be taken immediately after the implementation of greening actions for baseline data.

Data Sources

To calculate NDVI, you need satellite data that provides reflectance measurements in the near-infrared (NIR) and red (RED) spectral bands. Here are some commonly used satellite sources:

1. Landsat: Landsat satellites (e.g., Landsat 8) provide high-resolution imagery with distinct NIR and RED bands.
2. MODIS: The Moderate Resolution Imaging Spectroradiometer (MODIS) onboard NASA's Terra and Aqua satellites offers daily global coverage with suitable spectral bands for NDVI calculations.
3. Sentinel-2: The Sentinel-2 Satellites from the European Space Agency Provide High-Resolution Images with multiple spectral bands.

1. Website: Copernicus Open Access Hub.
2. Register for a free account to access and download Sentinel-2 imagery. You can search by location, date, and other criteria.

Tips for downloading

- Make sure to select cloud-free images for better NDVI calculations.
- Each platform has its own guidelines for searching and downloading data, so refer to their documentation if needed.

Calculation Formula

Here you have an example of the workflow to Calculate NDVI in R but you can use other ways to calculate NDVI.

1. Install Required Packages

Make sure you have the necessary packages installed. You'll typically need `raster` for handling raster data and `rgdal` for reading geospatial data.

2. Load Libraries

Load the required libraries.

3. Download Satellite Data

You can use data from sources like Landsat, Sentinel-2, or MODIS. For demonstration, let's assume you have downloaded a raster file for the NIR and RED bands.

4. Load the Data

Load the NIR and RED bands into R.

5. Calculate NDVI

Use the NDVI formula to calculate the index.

6. Plot NDVI

You can visualize the NDVI results using the `plot` function.

7. Export NDVI

If you want to save the NDVI raster as a new file:

Example Code

Here's the complete code in one block:

```R
# Install required packages if not already installed
install.packages(c("raster", "rgdal"))

# Load libraries
library(raster)
library(rgdal)

# Load the NIR and RED bands
red_band <- raster("path/to/red_band.tif")
nir_band <- raster("path/to/nir_band.tif")

# Calculate NDVI
```

```
ndvi <- (nir_band - red_band) / (nir_band + red_band)

# Plot NDVI
plot(ndvi, main = "NDVI", col = terrain.colors(100), axes = TRUE)

# Save NDVI raster
writeRaster(ndvi, "path/to/ndvi_output.tif", format="GTiff", overwrite=TRUE)
```

Additional Notes
- Make sure the bands are properly georeferenced and have the same resolution.
- You can adjust the file paths and names according to your data structure.
- Consider using cloud-free imagery for more accurate NDVI calculations.

References

- Turner, W., Spector, J., Garder, A., & Vörösmarty, C. (2010). Remote sensing for applied ecologists: A guide to using satellite data in conservation and resource management. Frontiers in Ecology and the Environment, 8(7), 365-373. doi:10.1890/090203

5.1.3.14 Number of trees

- **Code:** Jerome_Well14
- **Environmental Sector**: Social
- **Units:** Number

Meaning and importance of the indicator

The number of trees per person in urban areas is a crucial indicator of environmental quality and human well-being. Trees provide essential ecosystem services, such as air purification, cooling, carbon sequestration, and mental health benefits. Increasing the number of trees in urban spaces helps reduce pollution, mitigate the urban heat island effect, and enhance overall liveability, making it an important factor in urban greening projects.

Expected evolution of the indicator

As urban greening projects advance, we expect to see an increase in the number of trees per person and an expansion in urban tree canopy cover. An optimal outcome would include a balance between increasing the tree population and ensuring trees are strategically placed to maximize benefits.

Sampling plan

Field sampling.

Sampling calendar

A first sampling should be done prior to the transformation and then a sampling should be done once per year. Regular assessments are important to observe long-term trends and account for factors like seasonal growth and tree mortality.

References

- Browning, M. H. E. M., Locke, D. H., Konijnendijk, C., Labib, S. M., Rigolon, A., Yeager, R., Bardhan, M., Berland, A., Dadvand, P., Helbich, M., Li, F., Li, H., James, P., Klompmaker, J., Reuben, A., Roman, L. A., Tsai, W.-L., Patwary, M., O'Neil-Dunne, J., Ossola, A., Wang, R., Yang, B., Yi, L., Zhang, J., & Nieuwenhuijsen, M. (2024). Measuring the 3-30-300 rule to help cities meet nature access thresholds. *Science of The Total Environment*, 907, 167739.
- Nieuwenhuijsen, M. J., Dadvand, P., Márquez, S., Bartoll, X., Barboza, E. P., Cirach, M., Borrell, C., & Zijlema, W. L. (2022). The evaluation of the 3-30-300 green space rule and mental health. *Environmental Research*, 215(Part 2), 114387.

5.1.4 Energy Indicators

5.1.4.1 Air temperature reduction in case study areas

- **Code**: Jerome_Energy01
- **Environmental Sector**: Energy
- **Units**: ºC

Meaning and importance of the indicator

"Air temperature reduction in case study areas" measures the decrease in air temperature achieved through specific interventions or strategies implemented in targeted urban zones, known as case study areas. This indicator is crucial for assessing the effectiveness of urban planning and climate mitigation efforts, such as the introduction of green spaces, reflective materials, and improved urban design. By quantifying the reduction in air temperature, this indicator helps urban planners and policymakers evaluate the success of these interventions in mitigating the urban heat island effect, improving thermal comfort, and enhancing public health. Additionally, it provides valuable data to support the replication of successful strategies in other urban areas. Monitoring this indicator contributes to the broader goals of sustainable urban development, energy efficiency, and climate resilience, making cities more liveable and better equipped to handle the impacts of climate change.

Expected evolution of the indicator

The expected evolution of the indicator "Air temperature reduction in case study areas" is towards a noticeable decrease in urban air temperatures, reflecting the successful implementation of strategies aimed at mitigating the urban heat island (UHI) effect.

Data Obtention

Field measurement.

Frequency

Once per month.

5.1.4.2 Energy use for irrigation purposes

- **Code**: Jerome_Energy02
- **Environmental Sector**: Energy
- **Units**: kWh/m^2 land

Meaning and importance of the indicator

"Energy use " measures the amount of energy consumed in irrigation activities. This indicator is crucial for assessing the energy efficiency and environmental impact of irrigation practices. High electricity consumption can indicate inefficiencies, leading to increased operational costs and higher carbon emissions. Conversely, optimizing electricity use enhances sustainability by reducing greenhouse gas emissions and lowering production costs, which is vital for the economic viability of farming. Monitoring this indicator helps identify opportunities for implementing energy-saving technologies and practices, such as precision agriculture, renewable energy integration, and efficient irrigation systems. Ultimately, reducing electricity use supports broader sustainability goals, including resource conservation, climate change mitigation, and the promotion of eco-friendly irrigation practices.

Expected evolution of the indicator

The expected evolution of the indicator "Energy use in irrigation" is towards greater efficiency and sustainability, driven by technological advancements, economic considerations, and environmental regulations.

Data obtention

Field measurement or assessment based on amount of irrigated water. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

5.1.5 Biodiversity Indicators

5.1.5.1 Plant Mortality Rate

- **Code:** Jerome_Bio01
- **Environmental Sector**: Plant / Plant Biodiversity
- **Units:** Percentage

Meaning and importance of the indicator

The European Union and a number of organisations, including the United Nations Environment Programme (UNEP) or the Food and Agriculture Organisation (FAO), are advocating the transformation of urban cities into more environmentally sustainable and resilient "green cities", with an enhanced role for trees in addressing the challenges faced by urban areas. According to the World Health Organization, the minimum urban vegetation-covered area per person should be of 9 m^2, with an ideal value of 50 m^2. The EU restoration law requires to increase urban green space and urban tree canopy cover. The presence of trees and other woody plants in urban environments provide multiple benefits, like the reduction of outdoor and indoor temperatures, energy savings, carbon sequestration, increase of infiltration rates and reduction of stormwater run-off. Additionally, they contribute to improve air and noise pollution, promote biodiversity, enhance human health and wellbeing, and enhance urban aesthetics. The number of trees planted is an important indicator to be applied over the restoration process, but once the restoration is complete, a key indicator to evaluate the success and effectiveness of the plantations is to determine the survival rate of planted trees over time. Plant (or tree) mortality rate refers to the percentage of trees that die after a specific period of time following planting.

Expected evolution of the indicator

Mortality rates for planted plants is expected to increase over time, with a higher rate of increase in the first year, followed by a gradual stabilization with low mortality rates. Mortality rates differed significantly between territories, species, habitat types, elevation, soil types, climatology, planting methods, pre- and post-treatments, plant densities, etc. Therefore, expected or optimal values for plant mortality cannot be specified. However, if the mortality rate is high, it is important to plant more plants but previously identify the underlying causes and implement measures to avoid any potential errors that may have contributed to the plant mortality.

Data obtention

Required data:

- Number of planted plants that die each year after the restoration works.

Sampling plan:

Field sampling. The number of plants that die each year after planting is completed will always be counted at the same time of the year, preferably after the dry season, and avoiding winter for deciduous species to avoid confusion between dead and dormant individuals. All planted plants will be counted and classified as live or dead, indicating the species if there are more than one species.

Sampling calendar

The proposed sampling plan will be conducted every year for 10 years, prior to the implementation of restoration actions and subsequently in years following the completion of restoration.

Calculation formula

Mortality rate (MR) is the number of dead plants (NDP) at the time of data collection, divided by the total number of planted plants (TNPP):

$$MR = NDP/ TNPP * 100$$

References

- Castellari, S., Zandersen, M., Davis, M., Veerkamp, C., Förster, J., Marttunen, M., ... & Picatoste, J. R. (2021). Nature-based solutions in Europe policy, knowledge and practice for climate change adaptation and disaster risk reduction. European Environment Agency.
- Davies, C., De Vreese, R., Biernacka, M., Wilkes-Allemann, J., Zivojinovic, I. (2024). Guidelines for Urban Forests as Nature-Based Solutions: Planning, Policy and Delivery. Horizon 2020 CLEARING HOUSE project, grant agreement no. 821242. DOI: 10.5281/zenodo.10819200.
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- Official Journal of the European Union (2024). Regulation (EU) 2024/1991 of the European Parliament and of the Council of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869 (Text with EEA relevance). https://eur-lex.europa.eu/eli/reg/2024/1991/oj
- Sutherland, W. J. (Ed.). (2006). Ecological census techniques: a handbook. Cambridge university press.
- Southwood, T. R. E., & Henderson, P. A. (2009). Ecological methods. John Wiley & Sons.
- Wheater, C. P., Bell, J. R., & Cook, P. A. (2020). Practical field ecology: a project guide. John Wiley & Sons.

5.1.5.2 Canopy Cover Growth Rate

- **Code:** Jerome_Bio02
- **Environmental Sector**: Plant / Plant Biodiversity
- **Units:** Percentage

Meaning and importance of the indicator

The presence of trees and other woody plants in urban environments provide multiple benefits, like the reduction of outdoor and indoor temperatures, energy savings, carbon sequestration, increase of infiltration rates and reduction of stormwater run-off, improve air and noise pollution, promote biodiversity, enhance human health and wellbeing, and enhance urban aesthetics. The EU restoration law requires to increase urban green space and urban tree canopy cover. Planted individuals are usually young and do not yet display the expected characteristics until they reach a certain age. Canopy cover growth rate is an indicator of tree or shrub growth and is related to a number of factors, including temperature reduction, carbon sequestration, infiltration rates or reduction of stormwater run-off.

Expected evolution of the indicator

Canopy cover growth rate is expected to increase over time, with a higher rate of increase in the firsts years and stabilizing at plant maturity. However, canopy cover growth rate differed significantly between species, species age, pre- and post-treatments, plant densities, artificial irrigation, soil types, climatology, etc. Therefore, expected or optimal values for canopy cover growth rate cannot be specified.

Possible relationship with other biodiversity analyses

Jerome _Bio01.

Data obtention

Required data:

- Canopy cover of planted trees and shrubs.

Sampling plan:

Field sampling and aerial images. The canopy cover growth rate of planted trees and shrubs will be determined by one or more of the following methods, depending on the data and techniques available:

- Field sampling: 5-10% of planted trees and shrubs will be randomly selected and their cover canopy estimated as the vertical projection of the outermost perimeter of the natural spread of foliage of a plant, from the ground as viewed from above. Measurements will take the longest and shortest directions to calculate the dimensions of an ellipsoid. Once the data from the second year has been collected, the growth rate of the canopy cover can be calculated.
- Automatic or semi-automatic sampling: canopy cover can be extracted from aerial images or LIDAR datasets. From aerial images, the data can be extracted using automatic image classification or by digitising of tree and shrub cover from images. LIDAR (Light Detection and Ranging) is a remote sensing method that, depending on the resolution, can estimate tree and shrub canopy. Once the data from the second year has been collected, the growth rate of the canopy cover can be calculated.

In both cases, the canopy cover will be sampled at the same time of year. The optimal period is after the dry season, and winter should be avoided for deciduous species to prevent confusion between dead and dormant individuals.

Sampling calendar

The proposed sampling plan will be conducted every year for 10 years following the plantation.

Data sources

European Environment Agency (https://www.eea.europa.eu/en/analysis/maps-and-charts/urban-tree-cover-dashboards)
Copernicus (https://land.copernicus.eu/en/products/high-resolution-layer-tree-cover-density)
Institut National de l'Information Géographique et Forestière - geóservices (https://geoservices.ign.fr/bdortho; https://geoservices.ign.fr/lidarhd)

Calculation formula

Canopy cover is calculated by the following formula:

$$Canopy\ cover = \left[\frac{D_1 + D_2}{2}\right]\pi$$

Where:
D_1 is the major axis length and D_2 is the length of the minor axis of the ellipsoid formed to circumscribe the tree canopy.
The overall canopy cover is calculated as the mean value all measured plants, separating for species.
The canopy cover growth rate (CCGR) is obtained by dividing the actual canopy cover (ACC) by the initial canopy cover (ICC), and multiplied by 100:
CCGR = ACC / ICC * 100
The overall canopy cover growth rare is calculated as the mean value all measured plants, separating for species.

References

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- Official Journal of the European Union (2024). Regulation (EU) 2024/1991 of the European Parliament and of the Council of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869 (Text with EEA relevance). https://eur-lex.europa.eu/eli/reg/2024/1991/oj
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- Southwood, T. R. E., & Henderson, P. A. (2009). Ecological methods. John Wiley & Sons.

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5.1.5.3 Edible Fruits Produced by Planted Plants

- **Code:** Jerome_Bio03
- **Environmental Sector**: Plant / Plant Biodiversity
- **Units:** Kg Or Kg/M^2

Meaning and importance of the indicator

The European Union and a number of organisations, including the United Nations Environment Programme (UNEP) or the Food and Agriculture Organisation (FAO), are advocating the transformation of urban cities into more environmentally sustainable and resilient "green cities", with an enhanced role for trees in addressing the challenges faced by urban areas. The presence of trees and other woody plants in urban environments provide multiple benefits, like the reduction of outdoor and indoor temperatures, energy savings, carbon sequestration, increase of infiltration rates and reduction of stormwater run-off. Additionally, they contribute to improve air and noise pollution, promote biodiversity, enhance human health and wellbeing, enhance urban aesthetics and can be a source of edible fruits. As a result, green space management in many urban areas turns out to plant fruit trees to supply edible fruits, although policy instruments are needed to regulate health and environmental policies. One of the indicators to assess the ecosystem services provided by planted plants is the overall fruit production.

Expected evolution of the indicator

Fruit production is expected to increase over time, particularly if planted plants are immature or young and have not yet reached their full fruiting potential.

Possible relationship with other biodiversity analyses

Jerome _Bio01; Jerome _Bio02.

Data obtention

Required data:

- Total kilograms of fruits produced per species.
- Total kilograms of fruits produced per species related to the area.

Sampling plan:

Field sampling. The production of fruits of each species will be recorded every year, distinguishing between the total kilograms of fruit produced per species and the total kilograms of fruit produced per species in relation to the area.

Sampling calendar

Each fruit harvested for each species will be weighted, the total production (kg) will be calculated each year.

Equipment

A balance.

References

- Castellari, S., Zandersen, M., Davis, M., Veerkamp, C., Förster, J., Marttunen, M., ... & Picatoste, J. R. (2021). Nature-based solutions in Europe policy, knowledge and practice for climate change adaptation and disaster risk reduction. European Environment Agency.
- Davies, C., De Vreese, R., Biernacka, M., Wilkes-Allemann, J., Zivojinovic, I. (2024). Guidelines for Urban Forests as Nature-Based Solutions: Planning, Policy and Delivery. Horizon 2020 CLEARING HOUSE project, grant agreement no. 821242. DOI: 10.5281/zenodo.10819200.
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5.1.5.4 Species Richness (Trees, Shrubs and Herbaceous Plants), Jaccard Index (Inter-Annual Similarity)

- **Code:** Jerome _Bio04
- **Environmental Sector:** Plant / Plant Biodiversity
- **Units:** Numerical

Meaning and importance of the indicator

Species richness is the number of different species present within the limits of an area. It is a critical component of biodiversity and is one of the most commonly used indicators to assess biodiversity, as it has an important role in the functioning of ecosystem services and the health of the environment and society. Trends in species richness over time are a very valuable information, but the measure of similarity between inventories of species richness at different times is also very informative and can be calculated using the Jaccard index. This index is calculated as the number of species that are shared by the two sites divided by the total number of species found at both sites combined.

Expected evolution of the indicator

The expected evolution of species richness of planted trees, shrubs and herbaceous plants (total, per hectare or linear meter) is an increase over the restoration actions, as several species will be planted. After planting, an increase in species richness is also expected because other species could appear through seed dispersal (by animals, by wind) or seed bank, but this increase will be smaller.
In the case of the Jaccard index, the expected evolution is also an increase over the restoration actions as several species will be planted. However, the expected value after the planting will depend on the mortality of the planted species and the colonisation of new species. This index ranges from 0 if there are no shared species to 1 if the two datasets have the same species.
An increase in species richness over time is desirable, but not if this increase is due to the appearance of invasive species, which can spread into natural habitats and compete with planted species. In the latter case, this competition could reduce or eliminate some planted species and thus reduce the Jaccard index.

Data obtention

Required data:

- Number of plants (including trees, shrubs and herbaceous plants) per species each year.

Possible relationship with other biodiversity analyses: St Charles_Plant3
Data obtention method (field sampling / automatic sampling / aerial images / survey / existing data?

Sampling plan:

Field sampling. The number of species (including trees, shrubs and herbaceous plants) present in the unsealed paved soils around the campus will be sampled. This sampling will be carried out at the same time of the year, preferably in spring when the majority of plants are flowering and avoiding autumn and winter to avoid confusion between species.

Sampling calendar

The proposed sampling plan will be conducted every year for 10 years, prior to the implementation of restoration measures and subsequently in years following the completion of restoration.

Calculation formula

The Jaccard index is calculated counting the number of species shared between years, divided by the total number of species in both years:

$$Jaccard\ index = \frac{c}{a+b+c} Jaccard\ index = \frac{c}{a+b+c}$$

Were:

- *a* is the number of species present only in one sample,
- *b* is the number of species present only in the other sample, and *c* is the number of species present in both samples.

References

- Dumitru, A., & Wendling, L. (2021). Evaluating the impact of nature-based solutions: A handbook for practitioners. European Commission. doi:10.2777/244577
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5.1.5.5 Number off Planted Trees and Shrubs

- **Code:** Jerome _Bio05
- **Environmental Sector:** Plant / Plant Biodiversity
- **Units:** ordinal number

Meaning and importance of the indicator

The European Union and a number of organisations, including the United Nations Environment Programme (UNEP) or the Food and Agriculture Organisation (FAO), are advocating the transformation of urban cities into more environmentally sustainable and resilient "green cities", with an enhanced role for trees in addressing the challenges faced by urban areas. The EU restoration law requires to increase urban green space and urban tree canopy cover. The presence of trees and other woody plants in urban environments provide multiple benefits, like the reduction of outdoor and indoor temperatures, energy savings, carbon sequestration, increase of infiltration rates and reduction of stormwater run-off. Additionally, they contribute to improve air and noise pollution, promote biodiversity, enhance human health and wellbeing, and enhance urban aesthetics. The number of trees planted is an important indicator of restoration progress, but once the restoration is complete, counting the number of trees can be an indicator of success or failure to achieve the project objectives.

Expected evolution of the indicator

The expected trend in the number of trees planted (total, per hectare or linear meter) is an increase over the restoration actions. After the restoration works, the number of trees should be stable over years.

Data obtention

Required data:

Number of trees planted per day for the duration of the restoration works.

Number of planted trees each year after the restoration works.

Possible relationship with other biodiversity analyses: St Charles_Plant4

Sampling plan:

Field sampling. Over the restoration actions the trees planted should be counted every day to determine the total number of trees planted (or total trees planted per hectare or linear meter). After the restoration works the trees planted should be counted each year at the same time of the year, preferably after the dry season, and avoiding winter for deciduous species to avoid confusion between dead and dormant individuals.

Sampling calendar

Every day during the restoration works, the total number of trees planted (or total trees planted per hectare or linear meter) should be counted. After the restoration works the trees planted should be counted each year.

References

- Castellari, S., Zandersen, M., Davis, M., Veerkamp, C., Förster, J., Marttunen, M., ... & Picatoste, J. R. (2021). Nature-based solutions in Europe policy, knowledge and practice for climate change adaptation and disaster risk reduction. European Environment Agency.
- Davies, C., De Vreese, R., Biernacka, M., Wilkes-Allemann, J., Zivojinovic, I. (2024). Guidelines for Urban Forests as Nature-Based Solutions: Planning, Policy and Delivery. Horizon 2020 CLEARING HOUSE project, grant agreement no. 821242. DOI: 10.5281/zenodo.10819200.
- Dumitru, A., & Wendling, L. (2021). Evaluating the impact of nature-based solutions: A handbook for practitioners. European Commission. doi:10.2777/244577
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- FAO. 2016. Guidelines on urban and peri-urban forestry, by F. Salbitano, S. Borelli, M. Conigliaro and Y. Chen. FAO Forestry Paper No. 178. Rome, Food and Agriculture Organization of the United Nations.
- Official Journal of the European Union (2024). Regulation (EU) 2024/1991 of the European Parliament and of the Council of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869 (Text with EEA relevance). https://eur-lex.europa.eu/eli/reg/2024/1991/oj
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5.1.5.6 Mosquito bites

- **Code**: Jerome _Bio06
- **Environmental Sector**: Biodiversity / Human health
- **Units:** daily/weekly mosquito bites

Meaning and importance of the indicator

The frequency of mosquito bites on humans plays a critical role in understanding the interaction between humans and the environment, especially in regions with a high presence of mosquitoes. Mosquito bites can cause discomfort and allergic reactions, impacting daily life and well-being. In areas where mosquito-borne diseases such as malaria or dengue are present, reducing mosquito bites is essential for minimizing health risks. Preventative measures, such as using insect repellents, wearing protective clothing, and managing standing water sources, can significantly reduce mosquito bites and improve the quality of life in affected areas.

Expected evolution of the indicator

Ideally the number of bites should remain as the baseline measured, or even go lower due to the introduction of habitats suitable for natural enemies of the mosquito. However, those same habitats can also be used and exploited by the different mosquito species, so an initial increase in mosquito bites would not be rare.

Data Obtention

Required data:

All the data needed to obtain this indicator is obtained through the app Mosquito Alert. Mosquito Alert is a non-profit cooperative citizen science project, coordinated by different public research centres. Its goal is to study, monitor, and fight the spread of invasive mosquitoes capable of transmitting global diseases. The tiger mosquito and the yellow fever mosquito are some of the invasive species that Mosquito Alert watches out for.

Digital sampling:

Surveillance is carried out with the Mosquito Alert app, which allows anyone to notify, by means of a photo, the possible discovery of one of the mosquitoes studied, as well as that of their breeding places in public spaces. Along with the photo the location of the observation and other necessary information to help in the identification of the species are collected. A human team of expert entomologists oversees validating the photos received and notifying the participant of the result. Finally, the result is published on the public map, where anybody can consult and download the observations recorded since 2014, as well as explore the probability models developed from the citizen observations.

The first step is to organize a focused communication campaign in the campus and centered on students and staff to download the Mosquito Alert app and start using it, to report mosquito bites and sightings. Then the Demo leaders will be able to download the datasets generated by the app at the frequency desired and obtain the total and average daily or weekly mosquito bites.

References

- https://www.mosquitoalert.com/en/project/what-is-mosquito-alert/

DEMO5.2: St. Charles

In subdemo 5.2, the implementation will begin with surface unsealing and terracing of an area of approximately 4000 m^2, followed by the installation of porous asphalt and concrete to enhance water infiltration. In the second phase, a green corridor will be planted to increase the area's green cover and contribute to urban cooling. Mulching will be used around the trees to help retain soil moisture, suppress weeds, and regulate soil temperature. This will achieve two goals, to improve the quality of life by alleviating heatwave intensity and improving air quality, and to reduce the pollution that ends up in the sea caused by rain and stormwater runoff. After the unsealing, the areas will be renaturalized with local trees and shrubs to increase shading areas and biodiversity benefits.

5.2.1 Soil Indicators

5.2.1.1 Soil Physical and Chemical Fertility

- **Code:** Charles_Soil01
- **Environmental Sector**: Soil / Soil Health
- **Units:** A Multi-Component Indicator. Diverse Units for Specific Components

Meaning and importance of the indicator

Soil fertility, its capacity to sustain plant growth, depends on complex interactions between biological, chemical and physical properties. Achieving and maintaining appropriate levels of physical and chemical fertility is of paramount importance to support urban green. In natural soils, nutrients come from minerals, water, atmospheric deposition, and recycling of plant and animal residues but their availability to plants is significantly affected by soil acidity (pH), and nutrient presence in the soil solution is highly dependent on soil texture and soil cation exchange capacity. Water retention in soils and progressive release to plants is notably improved by soil organic matter, which is particularly important in Mediterranean regions under increasing aridity. Urban soils are highly heterogeneous and are frequently called “technosoils”. Soils are made of human-transported substrates, or are native soils highly transformed by anthropization. Urban soils are very often compacted and polluted, but they perform multiple unvaluable ecosystem services when returned to health, particularly in water and carbon cycles, and play a pivotal role in human wellbeing trough supporting healthy vegetation. Soil analysis is the basic tool to evaluate soil fertility and to guide city managers towards sustainable soil management.

Expected evolution of the indicator

There are recommended ranges and critical values for most of the soil properties to be analyzed. For urban gardens, together with the results of soil analyses agricultural laboratories provide an evaluation of the level of each analysed parameter (deficient – correct – excessive or similar). The value of each parameter should evolve towards these reference values and will guide gardeners in designing fertilization or any other correction. You will find some values for vegetated soils in Mediterranean cities in Dondini et al. (2024)

Data obtention

Required data:

To be analysed only the first time: soil texture (% sand; % clay; % silt); textural class.

To be analysed at each soil sampling campaign: pH; Electrical conductivity (CEC); Total organic carbon (%, dry soil basis); Carbonates; Total nitrogen (Kjeldahl); Available phosphorus (Olsen); Cation exchange capacity; Interchangeable bases (Ca, Mg, Na and K); Micronutrients (Fe, Zn, Mn).

Sampling plan:

Field sampling followed by lab analyses. Soil will always be sampled at the same moment of the year (set a fixed spring month), preferably avoiding temporal proximity to gardening interventions (or any other type of actions affecting soil (tree pruning, plantation, grass sowing, fertilization, etc.)

In homogeneous landscapes, two samples per hectare may be a standard sampling density, but the 10.000 m^2 unsealed in St. Jerôme and St. Charles are not homogeneous and are distributed in islands of unknown size and quality. Let's sample the four biggest islands created at each site.
At each island, take two soil samples from two points randomly selected. The two samples will be mixed into a unique plastic zip bag duly labelled with the date and the identification of the garden island. Soil must be sampled at 15 cm depth with soil samplers similar to those described in the "equipment" section.
The resulting eight soil samples (4 from St Charles and 4 from St Jerôme) will be sent to an expert lab for analysis as soon as possible. The soil lab must have been previously consulted for instructions about the preparation of the samples before shipping.

Sampling calendar

The gardens will be sampled in the proposed season every 2 years for 10 years (5 times).

Equipment

Samples will be extracted from soil with soil borers of similar and known (the same for all samples at each sampling campaign) depth and diameter. The borer should be 15 cm long and the recommended diameter is 5 cm.
Some providers of these soil samplers are: https://www.ams-samplers.com/soil-augers/; https://www.vanwalt.com/equipment/telescoping-augers/. Any other equivalent sampler of these dimensions is acceptable (but try to respect the 15 cm depth)
Some small field materials, such as zip bags.

External subcontracting

Yes. A trustable lab delivering soil fertility analyses must be hired.

References

- Dondini, C., Úbeda, X., Certini, G., Francos, M. (2024). Soil quality in the urban gardens of Barcelona (Spain). *Journal of Soils and Sediments*, 1-13.
- Kortleve, A. J., Mogollón, J. M., Heimovaara, T. J., Gebert, J. (2023). Topsoil carbon stocks in urban greenspaces of The Hague, the Netherlands. *Urban Ecosystems*, *26*(3), 725-742.
- For soil fertility in gardens: https://extension.umaine.edu/gardening/manual/soils/interpreting-soil-tests/

5.2.1.2 Soil Organic Carbon Content

- **Code:** Charles_Soil02
- **Environmental Sector**: Soil / Soil Health
- **Units:** %C

Meaning and importance of the indicator

Soil organic carbon (SOC) constitutes about 58% of soil organic matter (SOM) that is a chief indicator of soil health. SOC enters the soil through the decomposition of plant and animal residues, root exudates and living and dead soil biota (including microorganisms). Plant carbon comes from the C that plants remove from the atmosphere (photosynthesis), and animals obtain C from plant ingestion; therefore, the final origin of SOC is atmospheric CO_2. The stable fraction of SOC (the soil fraction that stays in soil for longtime periods and resists microbial attack) is considered "sequestered carbon" and contributes to climate change mitigation.

Expected evolution of the indicator

%C should increase over time. As a reference, organic carbon content in the vegetated areas of the city of Barcelona (Spain) ranges from 0.33% to 4.5%.

Data obtention

Sampling plan:

Soil organic carbon analysis is included in the analyses of soil physical and chemical fertility (Charles_Soil01).

Sampling calendar

This indicator will be produced every two years for a total of 10 years, coinciding with the evaluation of soil physical and chemical fertility (Charles_Soil01).

Equipment

See Charles_Soil01.

External subcontracting

Yes. A trustable lab delivering soil fertility analyses must be hired.

References

- Dondini, C., Úbeda, X., Certini, G., Francos, M. (2024). Soil quality in the urban gardens of Barcelona (Spain). *Journal of Soils and Sediments*, 1-13.
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- Scharenbroch, B. C., Lloyd, J. E., Johnson-Maynard, J. L. (2005). Distinguishing urban soils with physical, chemical, and biological properties. *Pedobiologia*, *49*(4), 283-296

5.2.1.3 Soil Bulk Density (ρ)

- **Code:** Charles_Soil03
- **Environmental Sector** : Soil / Soil Health
- **Units:** g cm^{-3}

Meaning and importance of the indicator

Bulk density indicates the degree of soil compaction. Bulk density is inversely related to soil porosity which allows air and water to move through the soil and facilitates plant root penetration through the soil. Compaction is the main feature of urban soils, very specially when they have been sealed, since sealing most often is preceded by removal of topsoil horizons and mechanic compaction that induces heavy alteration of the soil pore space and architecture. Compaction is among the main features of physical degradation of urban soils and is accompanied by low water holding capacity, low biological activity and low chemical quality and capacity to sustain healthy plants.

Expected evolution of the indicator

Bulk density is affected by soil texture (sand, silt, and clay proportion) and organic matter content. Fine-textured soils (such as silt and clay loams) with good structure have lower bulk density compared to sandy soils. According to data from the EU Joint Research Centre, mean European values for soil bulk density are 1.26 g cm^{-3} for arable lands, 1.23 g cm^{-3} for permanent crops, and 1.14 g cm^{3} for heterogeneous agricultural areas. In highly disturbed urban soils, bulk density can range from 1.5 g cm^{3} in lawns to densities that approach those of concrete in heavily trodden paths of sport yards (2.2 g cm^{3}). Bulk density should decrease as soil recovers its structure and gains organic matter.

Data obtention

Sampling plan:

Field sampling followed by a very simple analysis. Soil will always be sampled for density at the same moment of the year (make it match the soil fertility sampling date), preferably avoiding temporal proximity to gardening interventions (or any other type of action implying soil trampling or compaction)

At each sampling date, you will take two independent samples for soil density assessment from each the four biggest islands created in St. Jerôme and St. Charles, in the vicinity of the points where you have already sampled soils for fertility (8 points in St Jerôme and 8 points in St. Charles).

A detailed explanation of the sampling method is provided in the USDA Soil Quality Test Kit Guide (1999), pg.9 (see references).

In short for each sample, drive the metal cylinder all the way into the ground until its upper edge is level with the surface of the ground (using a mallet and a block of wood). Remove the ring taking great care not to lose soil. To do so, dig around the ring and with a trowel underneath it, carefully lift it out. Remove excess soil from the sample with a flat-bladed knife. The top and bottom of the soil sample should be flat and even with the edges of the ring. Using the flat-bladed knife, push out the entire soil sample into a plastic zip bag. Label the bag correctly.

Take the samples to the lab (or any other place where there is a scale - with two decimal places of accuracy- and a drying oven). Transfer each sample individually from the plastic bag to a foil or paper tray duly labelled. Put the soil samples to dry at 100 degrees until constant weight (usually 4 days is enough). Weight the dry soil (in g) and register it in your soil data worksheet. If a drying oven is not

available, you can use a microwave (see the method in the USDA Soil Quality Test Kit Guide (in references).

Sampling calendar

Bulk density will be measured together with soil fertility (Charles_Soil01), every two years for ten years.

Equipment

Bulk density is the ratio between soil dry weight and soil volume. Therefore, soil samples will be taken with a stainless-steel cylinder of perfectly know volume. The recommended dimensions for this case are 10 cm deep and 8 cm in diameter.
Additional field materials: a mallet, a block of wood, a trowel, a knife and zip-bags.

External subcontracting

If a reliable scale and a microwave are available, bulk density can be obtained very simply without the need of an expert lab.

Calculation formula

$$\rho = M / V$$

ρ is estimated as g cm^{-3}; M is the **dry** weight of the sample in g, and V the volume of the soil cylinder (in cm^3).
For each garden island, calculate the average of the two estimates of density

References

- Can Urban Soil Compaction Be Reversed? Technical Note #108 from Watershed Protection Techniques. 1(4): 666-66. https://owl.cwp.org/mdocs-posts/elc_pwp37/
- Effect of Urban Soil Compaction on Infiltration Rate https://owl.cwp.org/mdocs-posts/effect-of-urban-soil-compaction-on-infiltration-rate/
- O'Riordan, R., Davies, J., Stevens, C., Quinton, J. N. (2021). The effects of sealing on urban soil carbon and nutrients. *Soil*, *7*(2), 661-675.
- Paradelo, R., Herbón, C., Barral, M. T. (2024). Physical properties of the urban soils of Santiago de Compostela (Spain). *Journal of Soils and Sediments*, 1-10.
- Soil Quality Indicators. Bulk Density. USDA Natural Resources Conservation Service https://www.nrcs.usda.gov/sites/default/files/2022-10/nrcs142p2_051591.pdf
- Soil Quality Test Kit Guide. USDA Natural Resources Conservation Service. 1999. https://efotg.sc.egov.usda.gov/references/public/WI/Soil_Quality_Test_Kit_Guide.pdf
- The Compaction of Urban Soils. Technical Note #107 from Watershed Protection Techniques. 3(2): 661-665. https://owl.cwp.org/mdocs-posts/elc_pwp36/

5.2.1.4 Water Holding Capacity

- **Code:** Charles_Soil04
- **Environmental Sector** : Soil / Soil Health
- **Units:** %

Meaning and importance of the indicator

The water holding capacity (WHC) is an important agronomic characteristic. The WHC of a soil is the maximum amount of water a soil can hold under standard conditions. Water holding capacity is affected by soil texture (sand, silt, and clay proportion) and soil structure (pore size, porosity, pores connectivity distribution and characteristics are essential determinants).

A soil with a limited WHC reaches sooner the saturation than a soil with a higher WHC, especially between sandy soils as they tend to have low water storage capacity.

Expected evolution of the indicator

Soil structure can be improved by adding organic matter content to stimulate the soil porosity, which increases the water holding capacity. Also, a better water holding capacity of the soil can be accomplished by increasing soil organic carbon. However, deforestation and farming activities may decrease soil water holding capacity.

Data obtention

Required data:

It needs to be analysed the first time and every two years for 10 years (5 times) (See Charles_Soil01).

Sampling plan:

Field sampling followed by lab analyses Field sampling followed by lab analyses (See Charles_Soil01). Collect the sample using a soil core, air dry it, break the aggregates and pass through a 2.0 mm sieve. Place the core containing soil in a water tray for saturation overnight and then place the sample in an oven at 105º C for 24-48 h. Finally, weight the core sample. For further instructions go to the Practical manual on measurement of soil physical properties, in page 34.

Sampling calendar

This indicator will be produced every two years for a total of 10 years, coinciding with the evaluation of soil physical and chemical fertility (See Charles_Soil01).

Equipment

Additional field materials: A soil cylinder /core, a tray, filter papers, a spatula, a sieve, water try, a balance and a drying oven (See Charles_Soil01).

External subcontracting

If a reliable scale and an oven are available, WHC can be obtained very simply without the need of an expert lab. If not, a trustable lab delivering soil fertility analyses must be hired (See Charles_Soil01).

Calculation formula

$$WHC\% = (Vw/Vt) * 100,$$

while Vw is volume of water and Vt, is total volume of saturated soil.

References

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5.2.1.5 Soil Sealing

- **Code:** Charles_Soil05
- **Environmental Sector** : Soil / Soil Health
- **Units:** % Area (as an indicator is usually calculated as percentage (sealed area per total area)

Meaning and importance of the indicator

Soil sealing represents one of the major threats of our decade from soil degradation, one of the main environmental issues. Impacts of soil sealing affects ecosystems and furthermore, carbon sequestration, degradation and pollution mitigation. As the main biodiversity is in soil, soil sealing affects both below and above the ground biodiversity, which entails a considerable loss due to topsoil is removed. Soil sealing also increases the risk of flooding and reduces the total and microbial content of carbon and nitrogen, and soil respiration.

Soil sealing as an indicator corresponds to an irreversible loss of soil and its biological functions and loss of biodiversity.

Expected evolution of the indicator

The current methods to measure soil sealing are satellite methods, computation based on land use data from cadastres or aerial pictures. Measures to reduce soil sealing inside urban areas are promoted. Sealing rates are usually low in peri-urban areas with on average 10 % and very high in core cities, with on average 36 %.

Data obtention

Required data:

See Charles_Soil01.

Sampling plan:

Field sampling followed by lab analyses (See Charles_Soil01).

Sampling calendar

This indicator will be produced every two years for a total of 10 years, coinciding with the evaluation of soil physical and chemical fertility (See Charles_Soil01).

Equipment

See Charles_Soil01.

External subcontracting

Yes. A trustable lab delivering must be hired (See Charles_Soil1).

References

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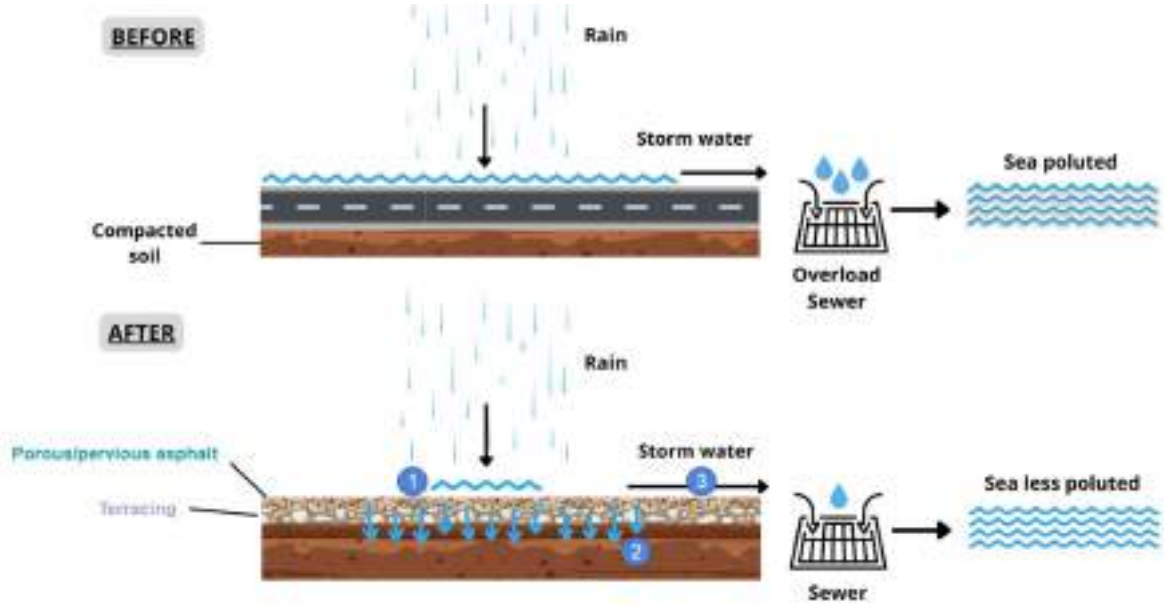
- https://www.eea.europa.eu/publications/soil-monitoring-in-europe

5.2.2 Water Indicators

5.2.2.1 Water Monitoring Plan

Sampling points

From Concrete to green: A Natural-Driven Journey Towards Sustainability.



Sampling points

Sampling point	Location	Purpose
SP-01	Inlet of the porous/pervious asphalt	Monitor the rainfall/stormwater (volume)
SP-02	Outlet of the porous/pervious asphalt	Monitor the infiltration rate
SP-03	Inlet of the sewer	Monitor the rainfall/stormwater availability and storage (volume)

Parameters to be analyzed

Parameter	Applicable Sampling point	Related indicators	Type
Volume of rainfall over the NBS	SP-01	WA; RI	water flow measurements [volume/time]

Water infiltration velocity through the soil	SP-02	IR	water flow measurements [volume/time]
Volume of water availability	SP-03	WSC; WA	water flow measurements [volume/time] and infiltration rate

Sampling method

Water flow measurements:

Direct measurement of volume provided during a time period or water flow with flow meters and/or water level sensors.

c) Automatic method

Automatic flow meters can be installed at the recommended sampling points (SP). For the automatisation process, it is recommended to register the measurements with a datalogger/digital control system in the DEMO. It is recommended to measure the flow at the recommended sampling points (SP).

Data should be stored in a datalogger/digital control system and then be able to be exported in a spreadsheet to calculate the associated indicators. When this is not possible, manual readings of the flow meters can be done instead.

d) Manual method

This could be applied as the last option if there is no possibility to apply the automatic method.

- Periodic manual measurements.
- If no devices are available to measure, correct and reliable estimates must be made to assess the indicator.

Rainwater/stormwater data:

For the registration of rainwater or stormwater data, it is more recommended to apply online and automatic methods.

c) Automatic method

Drone-derived orthophotos or satellite data can be used to measure the rainfall/stormwater. Also information from nearby meteorological/weather stations.

d) Manual method

Manual simple measurements using rain gauges could be used as the last option. These methods can give less accurate data.

Infiltration rate:

The infiltration rate is a type of water flow measurement, very related to the soil. Also, as other indicators, there are automatic and manual methods:

c) Automatic method

To measure infiltration rate automatically in the NBS, a tensiometer-based system or automated infiltrometer can be employed. These systems consist of soil moisture sensors or pressure transducers installed in the ground at various depths to continuously measure changes in soil moisture content or water pressure. The automated system periodically adds a controlled amount of water to the surface,

imitating rainfall or irrigation. The sensors monitor how quickly the water infiltrates and how the moisture levels change over time. Data is collected in real-time and transmitted to a central data logger or computer for analysis, calculating the infiltration rate without manual intervention.

d) Manual method

To manually sample the infiltration rate, it's needed to use a ring infiltrometer. An example of this process is the following. First, hammer a 30 cm diameter ring about 15 cm into the soil, and place a measuring rod inside. Then, hammer a 60 cm diameter ring around the first one (or build an earthen bund) to prevent lateral water movement. Pour water into both rings to a depth of 70-100 mm, and record the time. Measure the drop in water level at regular intervals, adding water to maintain the initial level. Continue until the water drop rate stabilizes, which represents the basic infiltration rate. Repeat the test at least twice for accuracy.

Sampling calendar

Water flow measurements and infiltration rate:

Data should be collected frequently for a relevant time period (e.g., daily, weekly, monthly) to allow for accumulation over the entire reporting period (yearly). This high frequency is also relevant to study seasonal variations.

Rainwater/stormwater data:

Data should be collected every time there is a rain event.

Equipment

c) Water flow measurements:

Water flow meters are essential tools for monitoring and assessing the efficiency of these systems, as they provide real-time data. In this DEMO, the main water flow measurement is about rainwater, so there are different rain gauges that can be used for it.

Some indicative providers of these are:

- OMEGA
- Amazon

Also, for water availability water flow meters can be used. Some providers are:

- Endress+Hauser
- Systec Controls
- Aobo instrument

Any equivalent water flow meter is acceptable, these are given as examples.

d) Rainwater/stormwater data:

In this DEMO, the main water flow measurements would be rainwater/stormwater, so there are different rain gauges that can be used for it.

Some indicative providers of are:

- OMEGA
- Amazon

Any equivalent water level sensor is acceptable, this is given as an example.

Infiltration rate:

Some indicative providers are:

- Manual infiltrometer - Eijkelkamp
- Manual infiltrometer - ELE International

- Automated infiltrometer - SATURO

*For manual infiltrometers, take into account that you may need a hammer, a watch or clock, a bucket, a timber, or any other instrument to work together.
Any equivalent water flow meter is acceptable, these are given as examples.

External subcontracting

Yes. A trustable laboratory delivering water quality analyses must be hired if not available internally.

5.2.2.2 Water Availability (WA)

- **Code**: Charles_Water01
- **Environmental Sector:** Water / Freshwater supply / Resource efficiency
- **Units:** m^3/year

Meaning and importance of the indicator

The indicator refers to the volume of water available provided by the DEMO for its reuse in various applications (e.g. aquifer recharge, ecosystem restoration, on site reuse, irrigation, industrial activities, etc.). The water available should comply with quality standards required for different reuses as per current legislation.

Expected evolution of the indicator

The baseline for this indicator is the initial water availability capacity, which may start at 0 m^3/year. It is expected to increase over time once the DEMO is operating and optimized, reflecting an improvement in water availability for reuse and ecosystem services. Ensure that 100% of the water provided by the DEMO is available for reuse.

Possible relationship with other water indicators

Water footprint, Water provision by the ecosystem.

Data obtention

Sampling plan:

- Direct annual flow of the effluent or annual volume provided by the DEMO for specific purposes (e.g., aquifer recharge, ecosystem restoration, etc.) (m^3/year).
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total volume water available in the DEMO (WA) (m^3/year).

Calculation formula

$$WA = Water\ inflows\ (WI) - Water\ losses\ (WL)$$

Where:

- WI: Total water entering the DEMO system (e.g., precipitation, surface water, groundwater recharge, recycled water) (m^3)
- WL: Total water lost (due to evaporation (m^3))

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/
- United Nations Conference on Trade and Development (2023). Environmental indicators: Module B Core SDG Indicators for Entity Reporting Training Manual. https://unctad.org/system/files/information-document/UNCTAD_GCI_MANUAL_ENVIRONMENTAL-FINAL.pdf
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5.2.2.3 Water Storage Capacity (WSC)

- **Code:** Charles_Water02
- **Environmental Sector:** Water / Effectiveness of the adaptive change towards resilient infrastructure
- **Units:** days

Meaning and importance of the indicator

The indicator assesses the resilience and efficiency of water supply systems. It is defined as the ratio between the total volume of available storage (e.g., water supply tanks, reservoirs for rainwater harvesting, and reclaimed water storage) and the average flow rate either provided to or demanded by the system. This flow rate encompasses all demands associated with distribution systems, rainwater harvesting infrastructure, and treatment facilities. The indicator provides insightful information about the number of days that the system can handle relying on the potential stored volume of water, not on the actual volume of stored water.

Expected evolution of the indicator

The WSC indicator will vary by region, depending on local water availability, climate conditions, and demand patterns in the DEMO. The optimal value is context-specific, but generally, a higher WSC indicates a more resilient water supply system capable of withstanding longer periods without external water inputs. However, as water supply systems integrate more non-conventional water sources (e.g., rainwater harvesting, reclaimed water, etc.), the WSC is expected to increase, improving the system's sustainability and resilience.

Possible relationship with other water indicators

Water availability, Captured runoff.

Data obtention

Sampling plan:

- Total operational volume of storage capacity, such as supply tanks, reservoirs, and reclaimed water storage (m^3)
  Fixed value of the operational volume of the storage capacity.
- Daily average inflow entering or being demanded to the DEMO system (m^3/day)
  The average can be done from data obtained from sampling at the DEMO.

Calculation formula

$$WSC = \frac{V_t}{Q_S}$$

Where:

- WSC: Water Storage Capacity (days),
- V_t: Total operational volume of storage capacity (m^3),
- Q_s: Daily average inflow entering or being demanded to the system (m^3/day).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/
- Carollo, M., Butera, I., & Revelli, R. (2022). Water savings and urban stormwater management: Evaluation of the potentiality of rainwater harvesting systems from the building to the city scale. PLOS ONE, 17(11), e0278107. https://doi.org/10.1371/journal.pone.0278107
- Donatello S., Dodd N. & Cordella M. (2021). Level(s) indicator 3.1: Use stage water consumption user manual: introductory briefing, instructions and guidance (Publication version 1.1). JRC, European Commission.

5.2.2.4 Rainfall Interception of NBS (RI)

- **Code**: Charles_Water03
- **Environmental Sector:** Water / Rainwater management and flood protection
- **Units:** mm/h

Meaning and importance of the indicator

The indicator measures the rate at which rainfall is intercepted by the NBS. This indicator is important for assessing the effectiveness of NBS in managing rainwater, reducing surface runoff, and mitigating flood risks. The interception capacity of NBS directly influences the hydrological balance and contributes to water retention in the ecosystem, thereby playing a vital role in flood prevention and sustainable water management.

Expected evolution of the indicator

Baseline: Initial interception capacity of the NBS.

Target: The optimal value would be a higher rate of rainfall interception compared to the baseline scenario and conventional infrastructure, leading to reduced surface runoff and enhanced groundwater recharge. This should ideally increase over time as the NBS matures and vegetation coverage expands.

Possible relationship with other water indicators

Captured runoff, Flood excess volume, Avoided floods.

Data obtention

Sampling plan:

- Volume of rainfall intercepted by the NBS (mm)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Time duration of the rainfall event (h)

Calculation formula

$$RI = \frac{Vrainfall\ NBS}{t}$$

Where:

- RI: Rainfall Interception Rate (mm/h),
- Vrainfall NBS: The total volume of rainfall intercepted by the NBS during a given time period (mm),
- t: time duration of the rainfall event (h).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: a handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577

5.2.2.5 Infiltration Rate (IR)

- **Code**: Charles_Water04
- **Environmental Sector:** Water / Water management
- **Units:** m/d or mm/h

Meaning and importance of the indicator

The indicator reflects the speed at which water penetrates the soil or a porous surface, typically measured in units of depth per time (e.g., m/d or mm/h). It is influenced by factors such as soil texture, moisture content, and the presence of vegetation or surface structures.

Expected evolution of the indicator

Baseline: Initial recharge capacity based on the natural soil or site specifications. An increase in infiltration rate is expected over time with DEMO implementation, leading to higher recharge volumes compared to areas without the solution. Dependent on the specific NBS and local soil conditions; typically, higher infiltration rates indicate more effective water management, although very high rates could lead to groundwater contamination if not managed properly. The following table shows the basic infiltration rate for various soil types:

Soil type	Basic infiltration rate (mm/hour)
sand	less than 30
sandy loam	20 - 30
loam	10 - 20
clay loam	5 - 10
clay	1 - 5

Note: FAO (n.d.)

Possible relationship with other water indicators

Increased groundwater recharge.

Data obtention

Sampling plan:

- Infiltration rate: Direct measurement of the amount of water that penetrates the ground surface over time (m/d or mm/h).
  Cumulative values during a period will be needed, measuring in terms of time, such as days or hours. If this is not possible, average values can be obtained. The average can be done from daily average data obtained from sampling at the DEMO.
- Area of the infiltration surface (m^2).
- Darcy velocity: Hydraulic conductivity of the material, infiltration area, and difference in water level between the inlet and outlet points.

Calculation formula

$$q_{boundary} = \frac{Q_{out}}{S_b}$$

$$Q_{out} = -K \cdot \frac{dh}{dl} \cdot A$$

or

$$q = \frac{K \cdot A \cdot \Delta h}{L}$$

Where:

- $q_{boundary}$ and q: is the infiltration rate (in units of volume per area and time, such as $m^3/s \cdot m^2$ or m/d or mm/h),
- Q_{out} is the total infiltrated flow (m^3/s), calculated as the integration of the Darcy velocity over the entire infiltration surface,
- K is the hydraulic conductivity of the material (m/s), which depends on the properties of the porous medium,
- A is the infiltration area, which in this case is the cross-sectional area of the material through which the water flows (m^2),
- Δh is the hydraulic head difference (or difference in water level) between the inlet and outlet points (m),
- L is the length of the water flow path through the porous medium (m),
- Sb is the area of the infiltration surface (m^2).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- Bouwer, H. (2017). Water infiltration in an aquifer recharge basin affected by temperature and air entrapment. ResearchGate. https://www.researchgate.net/publication/318655137_Water_infiltration_in_an_aquifer_recharge_basin_affected_by_temperature_and_air_entrapment
- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: a handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577
- European Commission. (2021). *EU biodiversity strategy for 2030: Bringing nature back into our lives*. Publications Office of the European Union. https://doi.org/10.2779/677548
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5.2.3 Human Well-being Indicators

5.2.3.1 Air temperature at 2 meters (daytime and night-time)

- **Code:** Charles_Well01
- **Environmental Sector**: Air Temperature comfort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for people.

Expected evolution of the indicator

The temperature indicator is expected to show a gradual decrease as vegetation matures and green infrastructure becomes more established. The tendency should reflect a cooling effect, particularly during warmer months, as plants provide shade, increase evapotranspiration, and mitigate heat absorption from hard surfaces. The optimal value range will vary depending on the local climate, but ideally, temperatures in greened areas should be noticeably lower than in non-greened parts of the campus, contributing to a more comfortable and cooler environment.

Possible relationship with other air temperature analyses

Charles_Well02 to 07.

Data obtention

Required data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Place three sensors at the campus, each at a height of 2 meters, with the following configurations: Sensor 1: Positioned within the area that will be transformed by the nature-based solution. This sensor will collect baseline data before the installation and continue to take measurements after the transformation. Sensor 2: Positioned outside the NBS in a location with high sun exposure, serving as a control site in an area that is not transformed. Sensor 3: Positioned outside the NBS in a location with low sun exposure, also serving as a control site in an area that is not transformed.

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH)

Calculation formula

Collect temperature data at 15-minute intervals throughout the 24-hour period.
Segregate the data into daytime and nighttime intervals (from sunrise to sunset for daytime and from sunset to sunrise for nighttime).
Calculate the average temperature for both periods using the formulas

$$T_{day} = \frac{1}{n_{day}} \sum_{i=1}^{n_{day}} T_i$$

Where:

- Ti is the temperature recorded at the i-th 15-minute interval during the daytime

nday is the number of 15-minute intervals during daytime

$$T_{night} = \frac{1}{n_{night}} \sum_{j=1}^{n_{night}} T_j$$

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

5.2.3.2 Daily Temperature Range (Difference Between the Daily Maximum and Daily Minimum Temperature)

- **Code:** Charles_Well02
- **Environmental Sector:** Air Temperature Comfort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for people.
In particular, this indicator shows how much the temperature fluctuates throughout the day, often used to assess climate variability and the effect of green infrastructure on stabilizing temperature extremes.

Expected evolution of the indicator

Tendency: As green infrastructure, such as tree planting and vegetation, matures, the daily temperature range is expected to narrow. Vegetation helps moderate both daytime highs and nighttime lows by providing shade during the day and trapping heat during the night.
Optimal value range: A moderate daily temperature range (DTR) is often considered optimal, with smaller fluctuations typically indicating a healthier microclimate. The exact value range depends on the local climate, but in urban areas, a reduction in DTR could indicate improved thermal regulation due to greening projects.

Possible relationship with other air temperature analyses

Charles_Well01 and from 03 to 07.

Data obtention

Required Data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors in each campus at 2 meters (sensor 1: will take data before the nature-based solution application and will be in charge of taking measurements after the transformation; Sensor 2: without vegetation and greater exposure to the sun (not transformed) Sensor 3: below a tree or a vegetation (not transformed).

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

Calculation formula

$$Daily\ Temperature\ Range = Tmax - Tmin$$

Where:

- Tmax is the daily maximum temperature (from sunrise to sunset)
- Tmin is the daily minimum temperature (from sunset to sunrise)

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

5.2.3.3 Days With Temperature >90th Percentile (TX90p)

- **Code:** Charles_Well03
- **Environmental Sector**: Air Temperature Comfort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for people.

TX90p is the number of days where the maximum daily temperature exceeds the 90th percentile of the long-term reference period. This indicator is often used to assess heatwave frequency and climate change impacts.

Expected evolution of the indicator

Tendency: Without intervention, the number of days with temperatures above the 90th percentile is likely to increase due to climate change, especially in urban areas. However, the implementation of nature-based solutions (such as urban greening) can slow or reduce this trend by cooling the environment.

Optimal value range: Ideally, the number of days exceeding the 90th percentile should remain low. While occasional days above this threshold are normal, a high or increasing trend could indicate vulnerability to heat stress.

Possible relationship with other air temperature analyses

Charles_Well01 to 02 and 04 to 07

Data obtention

Required data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors in each campus at 2 meters (sensor 1: will take data before the nature-based solution application and will be in charge of taking measurements after the transformation; Sensor 2: without vegetation and greater exposure to the sun (not transformed) Sensor 3: below a tree or a vegetation (not transformed).

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

Calculation formula

First, calculate the 90th percentile of maximum temperatures for a reference period (e.g. 30 years), then count how many days in a specific time period (e.g. every year of sampling) exceed this value.

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

5.2.3.4 Heatwave Risks (Number of Combined Tropical Nights (>20ºc) and Hotdays (>35ºc))

- **Code:** Charles_Well04
- **Environmental Sector**: Air Temperature Comfort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for people.

This indicator counts the number of nights where the temperature does not fall below 20ºC (tropical nights) combined with days where the temperature exceeds 35ºC (hot days) to assess potential risks related to human health and infrastructure due to heat stress during heatwaves.

Expected evolution of the indicator

Tendency: In urban areas, the risks of tropical nights and hot days are expected to increase over time due to global warming. However, greening projects can mitigate some of these effects by lowering both daytime and nighttime temperatures, reducing the frequency of tropical nights (>20ºC) and hot days (>35ºC).

Optimal value range: Ideally, the number of tropical nights and hot days should be minimized, as both pose significant risks to human health. The optimal value would be near zero for tropical nights and hot days during most of the year, particularly in regions not typically exposed to extreme heat.

Possible relationship with other air temperature analyses

Charles_Well01 to 03 and 05 to 07.

Data obtention

Required data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors in each campus at 2 meters (sensor 1: will take data before the nature-based solution application and will be in charge of taking measurements after the transformation; Sensor 2: without vegetation and greater exposure to the sun (not transformed) Sensor 3: below a tree or a vegetation (not transformed).

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

Calculation formula

Tropical nights: Count of nights for a given year where Tmin >20°C
Hot days: Count of days for a given year where Tmax>35°C

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

5.2.3.5 Mean Or Peak Daytime Local Temperatures

- **Code**: Charles_Well05
- **Environmental Sector:** Air Temperature Comfort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for people.

The mean or peak daytime local temperatures (ºC) is the highest temperature recorded during the daytime hours (from sunrise to sunset) which helps assess local heat conditions and the effectiveness of green infrastructure in cooling the environment.

Expected evolution of the indicator

Tendency: Mean and peak daytime temperatures are expected to decrease with the maturation of green infrastructure. Vegetation provides shade and promotes evapotranspiration, leading to a cooling effect, especially during the hottest parts of the day.

Optimal value range: Ideally, peak daytime temperatures would stay below heat stress thresholds (often around 30–35ºC, depending on local climate conditions).

Possible relationship with other air temperature analyses

Charles_Well01 to 04 and 06 to 07.

Data obtention

Required data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors in each campus at 2 meters (sensor 1: will take data before the nature-based solution application and will be in charge of taking measurements after the transformation; Sensor 2: without vegetation and greater exposure to the sun (not transformed) Sensor 3: below a tree or a vegetation (not transformed).

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

Calculation formula

Obtention of the highest temperature every day of the year.
Mean of the highest temperatures during the year.

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

5.2.3.6 Monthly Mean Value of Daily Maximum Temperature (Txx)

- **Code:** Charles_Well06
- **Environmental Sector:** Air Temperature Comfort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for people.

This indicator calculates the monthly average of the daily maximum temperatures over a given month which helps assess local heat conditions and the effectiveness of green infrastructure in cooling the environment.

Expected evolution of the indicator

Tendency: The monthly mean of daily maximum temperatures is expected to decrease with effective greening interventions, particularly during the hottest months. Green infrastructure mitigates extreme heat by providing shade and cooling the air through transpiration.

Optimal value range: The optimal value depends on the region's climate. Generally, a lower mean daily maximum temperature during summer months is desirable to avoid heat stress.

Possible relationship with other air temperature analyses

Charles_Well01 to 05 and 07.

Data obtention

Required data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors in each campus at 2 meters (sensor 1: will take data before the nature-based solution application and will be in charge of taking measurements after the transformation; Sensor 2: without vegetation and greater exposure to the sun (not transformed) Sensor 3: below a tree or a vegetation (not transformed).

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

Calculation formula

$$TXx = \frac{1}{n}\sum_{i=1}^{n} T_{max,i}$$

Where:

- *Tmax*,is the daily maximum temperature for day *i*
- *n* is the number of days in the month

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

5.2.3.7 Monthly Mean Value of Daily Minimum Temperature (Tnn)

- **Code:** Charles_Well07
- **Environmental Sector**: Air Temperature Comfort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for people.

This indicator measures the monthly average of the daily minimum temperatures over a given month which helps assess local heat conditions and the effectiveness of green infrastructure in cooling the environment.

Expected evolution of the indicator

Tendency: The monthly mean of daily minimum temperatures could decrease slightly with increased greening, as vegetation helps release heat more gradually at night, reducing the "urban heat island" effect. However, the change in nighttime temperatures may be less pronounced than daytime changes.

Optimal value range: The optimal value would be moderately low but above a threshold that ensures comfort during nighttime. In warm regions, values closer to 15–20ºC are often desirable to avoid discomfort during tropical nights.

Possible relationship with other air temperature analyses

Charles_Well01 to 06 and 08.

Data obtention

Required data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors in each campus at 2 meters (sensor 1: will take data before the nature-based solution application and will be in charge of taking measurements after the transformation; Sensor 2: without vegetation and greater exposure to the sun (not transformed) Sensor 3: below a tree or a vegetation (not transformed).

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

Calculation formula

$$TNn = \frac{1}{n}\sum_{i=1}^{n} T_{min,i}$$

Where:

- *Tmin* is the daily minimum temperature for day i
- n is the number of days in the month

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

5.2.3.8 Relative humidity

- **Code:** Charles_Well08
- **Environmental Sector**: Air Temperature Comfort
- **Units:** %

Meaning and importance of the indicator

Relative humidity (RH) is a measure of the amount of moisture in the air compared to the maximum amount of moisture the air can hold at a given temperature. It is crucial to monitor because it impacts the comfort levels, plant growth, and the microclimate of the schoolyard. In the context of greening, a balanced RH indicates improved air quality and ecosystem health, as vegetation influences moisture retention and evaporation rates, leading to a more stable microclimate.

Expected evolution of the indicator

After implementing greening solutions, the relative humidity is expected to increase slightly during the day due to increased transpiration from plants. At night, the RH may remain stable or slightly higher as the vegetation retains moisture. The optimal value range for relative humidity is generally between 40% and 60% for human comfort and plant health, but this may vary slightly depending on the local climate.

Possible relationship with other air temperature analyses

Charles_Well01 to 07.

Data obtention

Required data:

- Relative humidity every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors in each campus at 2 meters (sensor 1: will take data before the nature-based solution application and will be in charge of taking measurements after the transformation; Sensor 2: without vegetation and greater exposure to the sun (not transformed) Sensor 3: below a tree or a vegetation (not transformed).

Sampling calendar

A relative humidity sensor will be installed prior to the transformations, and it will need to measure continuously over the following years to establish control and compare the results. The sensor should record relative humidity at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records relative humidity at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

Calculation formula

Once relative humidity is obtained at 15 minutes intervals you can calculate the following data:

Daily relative humidity range
Monthly mean value of daily relative humidity

References

- Coutts, A. M., Tapper, N. J., Beringer, J., Loughnan, M., & Demuzere, M. (2013). Watering our cities: The capacity for Water Sensitive Urban Design to support urban cooling and improve human thermal comfort in the Australian context. *Progress in Physical Geography, 37*(1), 2-28.
- Armson, D., Stringer, P., & Ennos, A. R. (2012). The effect of tree shade and grass on surface and globe temperatures in an urban area. *Urban Forestry & Urban Greening, 11*(3), 245-255.

5.2.3.9 PM10

- **Code**: Charles_Well09
- **Environmental Sector**: Air Quality
- **Units:** Micrograms Per Cubic Meter

Meaning and importance of the indicator

PM10 is a mixture of particles suspended in the air that do not exceed 10 micrograms in diameter. It is harmful because it contains benzopyrenes, furans, dioxins and in short, carcinogenic heavy metals. According to the WHO, the limit value of the average daily concentration of this particulate matter is 50 micrograms per cubic meter, and the annual limit value is 20 micrograms per cubic meter.

PM10 air quality has a negative effect on the respiratory system. It is responsible for coughing attacks, wheezing, and the worsening of conditions for people with asthma or acute bronchitis. *PM10* also indirectly affects the rest of the body, including an increase in risk of a myocardial infarction and stroke. Benzopyrene is also highly carcinogenic. To conclude, aerosols of this type are very harmful to humans. Measuring PM10 is crucial in university campus greening projects as vegetation can help reduce airborne particulate pollution, improving air quality and creating a healthier environment for students.

Expected Evolution of The Indicator

After greening initiatives, PM10 levels are expected to decrease over time, as vegetation acts as a natural filter, capturing dust and other particles. The optimal value would be a reduction in PM10 concentrations to levels within the recommended limits set by health organizations.

Possible relationship with other analyses

Charles_Well010.

Data obtention

Required data:

- Continuous data every 15 minutes

Sampling plan:

Automatic sampling with a sensor. A PM10 sensor should be measured at multiple points (3-5 points, consider putting them at the same place where the air temperature/humidity sensors are installed) within and around the campus to assess the variation in air quality due to different sources of pollution. The sampling devices should be placed at a height corresponding to human breathing levels (1.5 to 2 meters above ground or above if there is a risk of vandalism) and in locations with and without vegetation to compare the effects.

Sampling calendar

A sensor will be installed prior to the transformations, and it will need to measure continuously over the following years to establish control and compare the results. The sensor should record at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

Air quality sensor. Some examples are PurpleAir PA-II, Aeroqual Series 200/300/500 with PM Sensor or Atmotube Pro but many others are available.

Calculation formula

Once the concentration is obtained at 15 minutes intervals you can calculate the following data:
Average daily concentration of PM10 (the limit daily value for WHO is 45 micrograms per cubic meter)
Average montly concentration of PM10
Average annual concentration of PM10 (the annual limit value for WHO is 15 micrograms per cubic meter)

References

- Janhäll, S. Review on Urban Vegetation and Particle Air Pollution – Deposition and Dispersion. Atmospheric Environment 2015, 105, 130–137.
- Tomson, M.; Kumar, P.; Barwise, Y.; Perez, P.; Forehead, H.; French, K.; Morawska, L.; Watts, J. Green Infrastructure for Air Quality Improvement in Street Canyons. Environment International 2021, 146.
- World Health Organization (WHO) air quality guidelines.

5.2.3.10 PM2.5

- **Code:** Charles_Well10
- **Environmental Sector**: Air Quality
- **Units:** Micrograms Per Cubic Meter

Meaning and importance of the indicator

PM 2.5 are atmospheric aerosols with a maximum diameter of 2.5 micrometers. This type of suspended particulate matter is considered the most dangerous to human health. This is due to its very fine nature, and its ability to penetrate directly into the bloodstream.

Expected evolution of the indicator

After greening initiatives, PM2.5 levels are expected to decrease over time, as vegetation acts as a natural filter, capturing dust and other particles. The optimal value would be a reduction in PM2.5 concentrations to levels within the recommended limits set by health organizations.

Possible relationship with other analyses

Charles_Well09.

Data obtention

Required data:

- Continuous data every 15 minutes

Sampling plan:

Automatic sampling with a sensor. A PM2.5 sensor should be measured at multiple points (3-5 points, consider putting them at the same place where the air temperature/humidity sensors are installed) within and around the campus to assess the variation in air quality due to different sources of pollution. The sampling devices should be placed at a height corresponding to human breathing levels (1.5 to 2 meters above ground or above if there is a risk of vandalism) and in locations with and without vegetation to compare the effects.

Sampling calendar

A sensor will be installed prior to the transformations, and it will need to measure continuously over the following years to establish control and compare the results. The sensor should record at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

Air quality sensor. Some examples are PurpleAir PA-II, Aeroqual Series 200/300/500 with PM Sensor or Atmotube Pro but many others are available.

Calculation formula

Once the concentration is obtained at 15 minutes intervals you can calculate the following data:
Average daily concentration of PM2.5 (the limit daily value for WHO is 15 micrograms per cubic meter)

Average montly concentration of PM2.5
Average annual concentration of PM2.5 (the annual limit value for WHO is 5 micrograms per cubic meter)

References

- Janhäll, S. Review on Urban Vegetation and Particle Air Pollution – Deposition and Dispersion. Atmospheric Environment 2015, 105, 130–137.
- Tomson, M.; Kumar, P.; Barwise, Y.; Perez, P.; Forehead, H.; French, K.; Morawska, L.; Watts, J. Green Infrastructure for Air Quality Improvement in Street Canyons. Environment International 2021, 146.
- World Health Organization (WHO) air quality guidelines.

5.2.3.11 Recreational opportunities provided by green infrastructure

- **Code:** Charles_Well11
- **Environmental Sector:** Social
- **Units:** Number

Meaning and importance of the indicator

Recreational opportunities provided by green infrastructure refer to the ways in which urban green spaces enable physical activities, relaxation, social interactions, and connection with nature. These opportunities are vital for improving public health, reducing stress, and enhancing the quality of life in urban environments. By offering accessible areas for leisure and exercise, green spaces contribute to both mental and physical well-being.

Expected evolution of the indicator

As green infrastructure expands and improves, recreational opportunities should increase in both quantity and quality. An optimal scenario would see more diverse activities available, greater public use of green spaces, and enhanced accessibility for all demographics. This could be reflected in higher usage rates, improved public health metrics, and community satisfaction.

Data obtention

Sampling plan:

Field sampling. To measure recreational opportunities on a university campus, a combination of surveys and observational studies can be used. Surveys should target students, faculty, and staff to gather data on the frequency and type of recreational activities they engage in within the campus green spaces (e.g., walking, sports, studying outdoors). Additionally, observational counts of users in key areas like lawns, gardens, and walking paths should be conducted at different times of the day and week. Specific attention should be given to how green spaces are used during breaks, between classes, and for organized recreational events. The sampling should also account for different types of activities, such as informal social gatherings, exercise, and academic-related uses like outdoor studying or reading.

Sampling calendar

Data should be collected throughout the academic year to capture variations in recreational use during different semesters, exam periods, and holidays. Sampling should be done weekly during peak campus hours (e.g., lunch breaks, late afternoons) and at different times of the day to understand daily patterns of space usage. Additionally, seasonal variations should be considered, with data collection occurring in both warmer and colder months to observe how weather influences recreational activities. Special attention should be paid to key events like orientation weeks, graduation, or campus sports events, which may significantly impact how green spaces are used.

References

- Kabisch, N., & Haase, D. (2014). Green spaces of European cities revisited for 1990–2006. *Landscape and Urban Planning*, 110, 113-122.

5.2.3.12 Self-reported well-being/ Good Moods

- **Code:** Charles_Well012
- **Environmental Sector**: Social
- **Units:** _

Meaning and importance of the indicator

The "Self-reported well-being/Good Moods" indicator measures individuals' subjective sense of well-being and emotional state after interacting with green spaces. It is essential because it reflects the psychological and emotional benefits of nature, such as reduced stress, improved mood, and enhanced life satisfaction. This indicator is particularly relevant in urban greening projects, as it provides direct feedback from users, helping assess the success of nature-based interventions in improving quality of life.

Expected evolution of the indicator

Over time, the indicator is expected to show an increase in positive moods and a decrease in negative emotions as people spend more time in the green space. Ideally, a consistent shift towards positive feelings like happiness, calmness, and relaxation should be observed. There is no strict optimal range for well-being, but a noticeable upward trend in positive responses would indicate the success of the intervention.

Possible relationship with other analyses

Charles_Well11.

Data obtention

Required data:

- Surveys

Sampling plan:

Field sampling or automatic sampling. Create a simple online or paper survey with two main questions**:**

- "How do you feel?" This question should be answered before entering the nature-based solution
- "How do you feel?" This question should be answered when leaving the nature-based solution

The survey should include a list of mood words option, both positive (Happy, Peaceful, Excited, Calm, Rested) and negative (Sad, Anxious, Angry, Tired, Frustrated), from which participants can choose one or more. Share the survey link or paper copies with the whole university community. Ensure the survey is accessible to different ages.

Encourage participants to complete the survey both upon entering and leaving the nature-based solution. If you use paper surveys, you can follow this suggestion:

Purchase a small box or use a weatherproof envelope. Inside the box, insert two simple letter-sized envelopes—one labelled “How I Feel Walking into the Nature based solution” and the other labelled “How I Feel Walking out of the Nature based solution.” Post the flyers and the box (or envelope) near the entrance to the Nature based solution, being careful to protect the paper from rain and wind. Invite people to tear off a word from the flyer and drop it into the “How I Feel Walking into the Nature based

solution" envelope each time they enter. They should do the same as they leave the Nature based solution.

Sampling calendar

Sampling should be conducted regularly throughout the year to account for seasonal changes in mood and the space's usability. A good approach would be to survey participants every month for at least one year. Additionally, sampling should occur both before and after the implementation of the nature-based solutions to measure their immediate and long-term impacts.

Calculation formula

The formula for calculating the "Self-reported well-being/Good Moods" indicator could be expressed as:

$$\text{Well-being score} = \frac{\text{Number of positive mood reports}}{\text{Total number of mood reports}} \times 100$$

This will provide a percentage of positive mood responses out of the total collected data, giving a clear overview of the space's impact on well-being.
It can be calculated for the surveys done before the implementation of the nature-based solution and after.

References

- EdiCitNet (a network for urban Food)
- Five Borough urban farm project toolkit
- Eiter, S., Fjellstad, W., Metselaar, K., & Teixeira da Silva, R. (2022). Prioritised indicators and baseline (D5.5).

5.2.3.13 Normalised Difference Vegetation Index (NDVI)

- **Code**: Charles_Well013
- **Environmental Sector**: Biodiversity
- **Units:** Number

Meaning and importance of the indicator

The Normalised Difference Vegetation Index (NDVI) is a crucial measure that quantifies vegetation health and density. By evaluating NDVI, we can assess the effectiveness of greening initiatives in schoolyards, which is essential for understanding the ecological impact and overall improvement of the environment.

Expected evolution of the indicator

NDVI values are used to classify vegetation cover and health
NDVI < 0 reflects water or artificial cover
0 < NDVI < 0.2 reflects soil and/or death vegetation
0.2 < NDVI < 0.4 reflects disperse vegetation
0.4 < NDVI < 0.6 reflects abundant vegetation
NDVI > 0.6 reflects very abundant and vigorous vegetation

Following greening interventions, we expect to see an upward trend in NDVI values over time, reflecting increased vegetation cover and health as the project matures.

Data obtention

Required data:
To calculate NDVI, you need satellite data that provides reflectance measurements in the near-infrared (NIR) and red (RED) spectral bands

Sampling plan:
Satellite data

Sampling calendar

Measurements should be obtained seasonally, ideally every 30 days, to capture variations in NDVI due to seasonal changes in vegetation. Additional measurements can be taken immediately after the implementation of greening actions for baseline data.

Data sources

To calculate NDVI, you need satellite data that provides reflectance measurements in the near-infrared (NIR) and red (RED) spectral bands. Here are some commonly used satellite sources (the exact satellite should be decided depending on the offered resolution):

4. Landsat: Landsat satellites (e.g., Landsat 8) provide high-resolution imagery with distinct NIR and RED bands.
5. MODIS: The Moderate Resolution Imaging Spectroradiometer (MODIS) onboard NASA's Terra and Aqua satellites offers daily global coverage with suitable spectral bands for NDVI calculations.

6. Sentinel-2: The Sentinel-2 Satellites from the European Space Agency Provide High-Resolution Images with multiple spectral bands
    1. Website: Copernicus Open Access Hub
    2. Register for a free account to access and download Sentinel-2 imagery. You can search by location, date, and other criteria.

Tips for downloading

- Make sure to select cloud-free images for better NDVI calculations.
- Each platform has its own guidelines for searching and downloading data, so refer to their documentation if needed.

Calculation formula

Here you have an example of the workflow to Calculate NDVI in R but you can use other ways to calculate NDVI.

1. Install Required Packages

Make sure you have the necessary packages installed. You'll typically need `raster` for handling raster data and `rgdal` for reading geospatial data.

2. Load Libraries

Load the required libraries.

3. Download Satellite Data

You can use data from sources like Landsat, Sentinel-2, or MODIS. For demonstration, let's assume you have downloaded a raster file for the NIR and RED bands.

4. Load the Data

Load the NIR and RED bands into R.

5. Calculate NDVI

Use the NDVI formula to calculate the index.

6. Plot NDVI

You can visualize the NDVI results using the `plot` function.

7. Export NDVI

If you want to save the NDVI raster as a new file:

Example Code

Here's the complete code in one block:

```R
# Install required packages if not already installed
install.packages(c("raster", "rgdal"))

# Load libraries
library(raster)
library(rgdal)

# Load the NIR and RED bands
red_band <- raster("path/to/red_band.tif")
nir_band <- raster("path/to/nir_band.tif")
```

```
# Calculate NDVI
ndvi <- (nir_band - red_band) / (nir_band + red_band)

# Plot NDVI
plot(ndvi, main = "NDVI", col = terrain.colors(100), axes = TRUE)

# Save NDVI raster
writeRaster(ndvi, "path/to/ndvi_output.tif", format="GTiff", overwrite=TRUE)
```

Additional Notes
- Make sure the bands are properly georeferenced and have the same resolution.
- You can adjust the file paths and names according to your data structure.
- Consider using cloud-free imagery for more accurate NDVI calculations.

References

- Turner, W., Spector, J., Garder, A., & Vörösmarty, C. (2010). Remote sensing for applied ecologists: A guide to using satellite data in conservation and resource management. Frontiers in Ecology and the Environment, 8(7), 365-373. doi:10.1890/090203

5.2.3.14 Number of Tree

- **Code:** Charles_Well014
- **Environmental Sector**: Social
- **Units:** Number

Meaning and importance of the indicator

The number of trees per person in urban areas is a crucial indicator of environmental quality and human well-being. Trees provide essential ecosystem services, such as air purification, cooling, carbon sequestration, and mental health benefits. Increasing the number of trees in urban spaces helps reduce pollution, mitigate the urban heat island effect, and enhance overall liveability, making it an important factor in urban greening projects.

Expected evolution of the indicator

As urban greening projects advance, we expect to see an increase in the number of trees per person and an expansion in urban tree canopy cover. An optimal outcome would include a balance between increasing the tree population and ensuring trees are strategically placed to maximize benefits.

Data obtention

Sampling plan:
Field sampling.

Sampling calendar

A first sampling should be done prior to the transformation and then a sampling should be done once per year. Regular assessments are important to observe long-term trends and account for factors like seasonal growth and tree mortality.

References

- Browning, M. H. E. M., Locke, D. H., Konijnendijk, C., Labib, S. M., Rigolon, A., Yeager, R., Bardhan, M., Berland, A., Dadvand, P., Helbich, M., Li, F., Li, H., James, P., Klompmaker, J., Reuben, A., Roman, L. A., Tsai, W.-L., Patwary, M., O'Neil-Dunne, J., Ossola, A., Wang, R., Yang, B., Yi, L., Zhang, J., & Nieuwenhuijsen, M. (2024). Measuring the 3-30-300 rule to help cities meet nature access thresholds. *Science of The Total Environment*, 907, 167739.
- Nieuwenhuijsen, M. J., Dadvand, P., Márquez, S., Bartoll, X., Barboza, E. P., Cirach, M., Borrell, C., & Zijlema, W. L. (2022). The evaluation of the 3-30-300 green space rule and mental health. *Environmental Research*, 215(Part 2), 114387.

5.2.4 Energy Indicators

5.2.4.1 Air temperature reduction in case study areas

- **Code**: Charles_Energy01
- **Environmental Sector**: Energy
- **Units**: °C

Meaning and importance of the indicator

"Air temperature reduction in case study areas" measures the decrease in air temperature achieved through specific interventions or strategies implemented in targeted urban zones, known as case study areas. This indicator is crucial for assessing the effectiveness of urban planning and climate mitigation efforts, such as the introduction of green spaces, reflective materials, and improved urban design. By quantifying the reduction in air temperature, this indicator helps urban planners and policymakers evaluate the success of these interventions in mitigating the urban heat island effect, improving thermal comfort, and enhancing public health. Additionally, it provides valuable data to support the replication of successful strategies in other urban areas. Monitoring this indicator contributes to the broader goals of sustainable urban development, energy efficiency, and climate resilience, making cities more liveable and better equipped to handle the impacts of climate change.

Expected evolution of the indicator

The expected evolution of the indicator "Air temperature reduction in case study areas" is towards a noticeable decrease in urban air temperatures, reflecting the successful implementation of strategies aimed at mitigating the urban heat island (UHI) effect.

Data obtention

Field measurement.

Frequency

One per month.

5.2.4.2 Energy use for irrigation purposes

- **Code**: Charles_Energy02
- **Environmental Sector**: Energy
- **Units**: kWh/m^2 land

Meaning and importance of the indicator

"Energy use for irrigation purposes" measures the amount of energy consumed in irrigation activities. This indicator is crucial for assessing the energy efficiency and environmental impact of irrigation practices. High electricity consumption can indicate inefficiencies, leading to increased operational costs and higher carbon emissions. Conversely, optimizing electricity use enhances sustainability by reducing greenhouse gas emissions and lowering production costs, which is vital for the economic viability of farming. Monitoring this indicator helps identify opportunities for implementing energy-saving technologies and practices, such as precision agriculture, renewable energy integration, and efficient irrigation systems. Ultimately, reducing electricity use supports broader sustainability goals, including resource conservation, climate change mitigation, and the promotion of eco-friendly irrigation practices.

Expected evolution of the indicator

The expected evolution of the indicator "Energy use in irrigation" is towards greater efficiency and sustainability, driven by technological advancements, economic considerations, and environmental regulations.

Data obtention

Field measurement or assessment based on amount of irrigated water. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

5.2.5 Biodiversity Indicators

5.2.5.1 Plant Mortality Rate

- **Code:** Charles_Bio01
- **Environmental Sector**: Plant / Plant Biodiversity
- **Units:** Percentage

Meaning and importance of the indicator

The European Union and a number of organisations, including the United Nations Environment Programme (UNEP) or the Food and Agriculture Organisation (FAO), are advocating the transformation of urban cities into more environmentally sustainable and resilient "green cities", with an enhanced role for trees in addressing the challenges faced by urban areas. According to the World Health Organization, the minimum urban vegetation-covered area per person should be of 9 m^2, with an ideal value of 50 m^2. The EU restoration law requires to increase urban green space and urban tree canopy cover. The presence of trees and other woody plants in urban environments provide multiple benefits, like the reduction of outdoor and indoor temperatures, energy savings, carbon sequestration, increase of infiltration rates and reduction of stormwater run-off. Additionally, they contribute to improve air and noise pollution, promote biodiversity, enhance human health and wellbeing, and enhance urban aesthetics. The number of trees planted is an important indicator to be applied over the restoration process, but once the restoration is complete, a key indicator to evaluate the success and effectiveness of the plantations is to determine the survival rate of planted trees over time. Plant (or tree) mortality rate refers to the percentage of trees that die after a specific period of time following planting.

Expected evolution of the indicator

Mortality rates for planted plants is expected to increase over time, with a higher rate of increase in the first year, followed by a gradual stabilization with low mortality rates. Mortality rates differed significantly between territories, species, habitat types, elevation, soil types, climatology, planting methods, pre- and post-treatments, plant densities, etc. Therefore, expected or optimal values for plant mortality cannot be specified. However, if the mortality rate is high, it is important to plant more plants but previously identify the underlying causes and implement measures to avoid any potential errors that may have contributed to the plant mortality.

Data obtention

Required data:

- Number of planted plants that die each year after the restoration works.

Sampling plan:

Field sampling. The number of plants that die each year after planting is completed will always be counted at the same time of the year, preferably after the dry season, and avoiding winter for deciduous species to avoid confusion between dead and dormant individuals. All planted plants will be counted and classified as live or dead, indicating the species if there are more than one species.

Sampling calendar

The proposed sampling plan will be conducted every year for 10 years, prior to the implementation of restoration actions and subsequently in years following the completion of restoration.

Calculation formula

Mortality rate (MR) is the number of dead plants (NDP) at the time of data collection, divided by the total number of planted plants (TNPP):

$$MR = NDP/ TNPP * 100$$

References

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5.2.5.2 Canopy Cover Growth Rate

- **Code:** Charles_Bio02
- **Environmental Sector**: Plant / Plant Biodiversity
- **Units:** Percentage

Meaning and importance of the indicator

The presence of trees and other woody plants in urban environments provide multiple benefits, like the reduction of outdoor and indoor temperatures, energy savings, carbon sequestration, increase of infiltration rates and reduction of stormwater run-off, improve air and noise pollution, promote biodiversity, enhance human health and wellbeing, and enhance urban aesthetics. The EU restoration law requires to increase urban green space and urban tree canopy cover. Planted individuals are usually young and do not yet display the expected characteristics until they reach a certain age. Canopy cover growth rate is an indicator of tree or shrub growth and is related to a number of factors, including temperature reduction, carbon sequestration, infiltration rates or reduction of stormwater run-off.

Expected evolution of the indicator

Canopy cover growth rate is expected to increase over time, with a higher rate of increase in the firsts years and stabilizing at plant maturity. However, canopy cover growth rate differed significantly between species, species age, pre- and post-treatments, plant densities, artificial irrigation, soil types, climatology, etc. Therefore, expected or optimal values for canopy cover growth rate cannot be specified.

Possible relationship with other biodiversity analyses

Charles_Bio01.

Data obtention

Required data:

- Canopy cover of planted trees and shrubs.

Sampling plan:

Field sampling and aerial images. The canopy cover growth rate of planted trees and shrubs will be determined by one or more of the following methods, depending on the data and techniques available:

- Field sampling: 5-10% of planted trees and shrubs will be randomly selected and their cover canopy estimated as the vertical projection of the outermost perimeter of the natural spread of foliage of a plant, from the ground as viewed from above. Measurements will take the longest and shortest directions to calculate the dimensions of an ellipsoid. Once the data from the second year has been collected, the growth rate of the canopy cover can be calculated.
- Automatic or semi-automatic sampling: canopy cover can be extracted from aerial images or LIDAR datasets. From aerial images, the data can be extracted using automatic image classification or by digitising of tree and shrub cover from images. LIDAR (Light Detection and Ranging) is a remote sensing method that, depending on the resolution, can estimate tree and shrub canopy. Once the data from the second year has been collected, the growth rate of the canopy cover can be calculated.

In both cases, the canopy cover will be sampled at the same time of year. The optimal period is after the dry season, and winter should be avoided for deciduous species to prevent confusion between dead and dormant individuals.

Sampling calendar

The proposed sampling plan will be conducted every year for 10 years following the plantation.

Data sources

European Environment Agency (https://www.eea.europa.eu/en/analysis/maps-and-charts/urban-tree-cover-dashboards)
Copernicus (https://land.copernicus.eu/en/products/high-resolution-layer-tree-cover-density)
Institut National de l'Information Géographique et Forestière - geóservices (https://geoservices.ign.fr/bdortho; https://geoservices.ign.fr/lidarhd)

Calculation formula

Canopy cover is calculated by the following formula:

$$Canopy\ cover = \left[\frac{D_1 + D_2}{2}\right]\pi$$

Where:

- D_1 is the major axis length and D_2 is the length of the minor axis of the ellipsoid formed to circumscribe the tree canopy.
- The overall canopy cover is calculated as the mean value all measured plants, separating for species.
- The canopy cover growth rate (CCGR) is obtained by dividing the actual canopy cover (ACC) by the initial canopy cover (ICC), and multiplied by 100:
- CCGR = ACC / ICC * 100
- The overall canopy cover growth rare is calculated as the mean value all measured plants, separating for species.

References

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5.2.5.3 Edible Fruits Produced by Planted Plants

- **Code:** Charles_Bio03
- **Environmental Sector**: Plant / Plant Biodiversity
- **Units:** Kg Or Kg/M^2

Meaning and importance of the indicator

The European Union and a number of organisations, including the United Nations Environment Programme (UNEP) or the Food and Agriculture Organisation (FAO), are advocating the transformation of urban cities into more environmentally sustainable and resilient "green cities", with an enhanced role for trees in addressing the challenges faced by urban areas. The presence of trees and other woody plants in urban environments provide multiple benefits, like the reduction of outdoor and indoor temperatures, energy savings, carbon sequestration, increase of infiltration rates and reduction of stormwater run-off. Additionally, they contribute to improve air and noise pollution, promote biodiversity, enhance human health and wellbeing, enhance urban aesthetics and can be a source of edible fruits. As a result, green space management in many urban areas turns out to plant fruit trees to supply edible fruits, although policy instruments are needed to regulate health and environmental policies. One of the indicators to assess the ecosystem services provided by planted plants is the overall fruit production.

Expected evolution of the indicator

Fruit production is expected to increase over time, particularly if planted plants are immature or young and have not yet reached their full fruiting potential.

Possible relationship with other biodiversity analyses

Charles_Bio01; Charles_Bio02.

Data obtention

Required data:

- Total kilograms of fruits produced per species.
- Total kilograms of fruits produced per species related to the area.

Sampling plan:

Field sampling.The production of fruits of each species will be recorded every year, distinguishing between the total kilograms of fruit produced per species and the total kilograms of fruit produced per species in relation to the area.

Sampling calendar

Each fruit harvested for each species will be weighted, the total production (kg) will be calculated each year.

Equipment

A balance.

References

- Castellari, S., Zandersen, M., Davis, M., Veerkamp, C., Förster, J., Marttunen, M., ... & Picatoste, J. R. (2021). Nature-based solutions in Europe policy, knowledge and practice for climate change adaptation and disaster risk reduction. European Environment Agency.
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5.2.5.4 Species Richness (Trees, Shrubs and Herbaceous Plants), Jaccard Index (Inter-Annual Similarity)

- **Code:** Charles_Bio04
- **Environmental Sector:** Plant / Plant Biodiversity
- **Units:** Numerical

Meaning and importance of the indicator

Species richness is the number of different species present within the limits of an area. It is a critical component of biodiversity and is one of the most commonly used indicators to assess biodiversity, as it has an important role in the functioning of ecosystem services and the health of the environment and society. Trends in species richness over time are a very valuable information, but the measure of similarity between inventories of species richness at different times is also very informative and can be calculated using the Jaccard index. This index is calculated as the number of species that are shared by the two sites divided by the total number of species found at both sites combined.

Expected evolution of the indicator

The expected evolution of species richness of planted trees, shrubs and herbaceous plants (total, per hectare or linear meter) is an increase over the restoration actions, as several species will be planted. After planting, an increase in species richness is also expected because other species could appear through seed dispersal (by animals, by wind) or seed bank, but this increase will be smaller.
In the case of the Jaccard index, the expected evolution is also an increase over the restoration actions as several species will be planted. However, the expected value after the planting will depend on the mortality of the planted species and the colonisation of new species. This index ranges from 0 if there are no shared species to 1 if the two datasets have the same species.
An increase in species richness over time is desirable, but not if this increase is due to the appearance of invasive species, which can spread into natural habitats and compete with planted species. In the latter case, this competition could reduce or eliminate some planted species and thus reduce the Jaccard index.

Data obtention

Required data:

- Number of plants (including trees, shrubs and herbaceous plants) per species each year.

Possible relationship with other biodiversity analyses: St Charles_Plant3
Data obtention method (field sampling / automatic sampling / aerial images / survey / existing data?

Sampling plan:

Field sampling. The number of species (including trees, shrubs and herbaceous plants) present in the unsealed paved soils around the campus will be sampled. This sampling will be carried out at the same time of the year, preferably in spring when the majority of plants are flowering and avoiding autumn and winter to avoid confusion between species.

Sampling calendar

The proposed sampling plan will be conducted every year for 10 years, prior to the implementation of restoration measures and subsequently in years following the completion of restoration.

Calculation formula

The Jaccard index is calculated counting the number of species shared between years, divided by the total number of species in both years:

$$Jaccard\ index = \frac{c}{a+b+c} Jaccard\ index = \frac{c}{a+b+c}$$

Were:

- *a* is the number of species present only in one sample,
- *b* is the number of species present only in the other sample, and *c* is the number of species present in both samples.

References

- Dumitru, A., & Wendling, L. (2021). Evaluating the impact of nature-based solutions: A handbook for practitioners. European Commission. doi:10.2777/244577
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5.2.5.5 Number of Planted Trees and Shrubs

- **Code:** Charles_Bio05
- **Environmental Sector:** Plant / Plant Biodiversity
- **Units:** ordinal number

Meaning and importance of the indicator

The European Union and a number of organisations, including the United Nations Environment Programme (UNEP) or the Food and Agriculture Organisation (FAO), are advocating the transformation of urban cities into more environmentally sustainable and resilient "green cities", with an enhanced role for trees in addressing the challenges faced by urban areas. The EU restoration law requires to increase urban green space and urban tree canopy cover. The presence of trees and other woody plants in urban environments provide multiple benefits, like the reduction of outdoor and indoor temperatures, energy savings, carbon sequestration, increase of infiltration rates and reduction of stormwater run-off. Additionally, they contribute to improve air and noise pollution, promote biodiversity, enhance human health and wellbeing, and enhance urban aesthetics. The number of trees planted is an important indicator of restoration progress, but once the restoration is complete, counting the number of trees can be an indicator of success or failure to achieve the project objectives.

Expected evolution of the indicator

The expected trend in the number of trees planted (total, per hectare or linear meter) is an increase over the restoration actions. After the restoration works, the number of trees should be stable over years.

Data obtention

Required data:

Number of trees planted per day for the duration of the restoration works.

Number of planted trees each year after the restoration works.

Possible relationship with other biodiversity analyses: St Charles_Plant4

Sampling plan:

Field sampling. Over the restoration actions the trees planted should be counted every day to determine the total number of trees planted (or total trees planted per hectare or linear meter). After the restoration works the trees planted should be counted each year at the same time of the year, preferably after the dry season, and avoiding winter for deciduous species to avoid confusion between dead and dormant individuals.

Sampling calendar

Every day during the restoration works, the total number of trees planted (or total trees planted per hectare or linear meter) should be counted. After the restoration works the trees planted should be counted each year.

References

- Castellari, S., Zandersen, M., Davis, M., Veerkamp, C., Förster, J., Marttunen, M., ... & Picatoste, J. R. (2021). Nature-based solutions in Europe policy, knowledge and practice for climate change adaptation and disaster risk reduction. European Environment Agency.
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5.2.5.6 Mosquito bites

- **Code**: Charles_Bio06
- **Environmental Sector**: Biodiversity / Human health
- **Units:** daily/weekly mosquito bites

Meaning and importance of the indicator

The frequency of mosquito bites on humans plays a critical role in understanding the interaction between humans and the environment, especially in regions with a high presence of mosquitoes. Mosquito bites can cause discomfort and allergic reactions, impacting daily life and well-being. In areas where mosquito-borne diseases such as malaria or dengue are present, reducing mosquito bites is essential for minimizing health risks. Preventative measures, such as using insect repellents, wearing protective clothing, and managing standing water sources, can significantly reduce mosquito bites and improve the quality of life in affected areas.

Expected evolution of the indicator

Ideally the number of bites should remain as the baseline measured, or even go lower due to the introduction of habitats suitable for natural enemies of the mosquito. However, those same habitats can also be used and exploited by the different mosquito species, so an initial increase in mosquito bites would not be rare.

Data Obtention

Required data:

All the data needed to obtain this indicator is obtained through the app Mosquito Alert. Mosquito Alert is a non-profit cooperative citizen science project, coordinated by different public research centres. Its goal is to study, monitor, and fight the spread of invasive mosquitoes capable of transmitting global diseases. The tiger mosquito and the yellow fever mosquito are some of the invasive species that Mosquito Alert watches out for.

Digital sampling:

Surveillance is carried out with the Mosquito Alert app, which allows anyone to notify, by means of a photo, the possible discovery of one of the mosquitoes studied, as well as that of their breeding places in public spaces. Along with the photo the location of the observation and other necessary information to help in the identification of the species are collected. A human team of expert entomologists oversees validating the photos received and notifying the participant of the result. Finally, the result is published on the public map, where anybody can consult and download the observations recorded since 2014, as well as explore the probability models developed from the citizen observations.

The first step is to organize a focused communication campaign in the campus and cantered on students and staff to download the Mosquito Alert app and start using it, to report mosquito bites and sightings. Then the Demo leaders will be able to download the datasets generated by the app at the frequency desired and obtain the total and average daily or weekly mosquito bites.

References

- https://www.mosquitoalert.com/en/project/what-is-mosquito-alert/

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CLIMATE ADAPTATION AND RESILIENCE
DEMONSTRATED IN THE MEDITERRANEAN REGION

Deliverable 2.2

ANNEX F: DEMO6

DEMO6: Aragon

DEMO6.1: Teruel	Sector	Code
Percentage of Affected Trees by Degree of Infestation at Tree Level	Biodiversity	Teruel_Bio01
Number Of Parasitized Trees	Biodiversity	Teruel_Bio02
Number of Trees Removed	Biodiversity	Teruel_Bio03
Aboveground Carbon Stored (Trees)	Biodiversity	Teruel_Bio04
Aboveground Carbon Removed (Trees)	Biodiversity	Teruel_Bio05
Tree Regeneration	Biodiversity	Teruel_Bio06
Tree Mortality Rate	Biodiversity	Teruel_Bio07
Energy footprint per kg of food	Energy	Teruel_Energy01
Operational energy consumption	Energy	Teruel_Energy02
DEMO6.2: Zaragoza		
Soil Physical and Chemical Fertility	Soil	Zaragoza_Soil01
Soil Organic Carbon Content	Soil	Zaragoza_Soil02
Soil Bulk Density (P)	Soil	Zaragoza_Soil03
The Maturity Index of Bongers (MI)	Soil	Zaragoza_Soil04
Soil Sealing	Soil	Zaragoza_Soil05
Water Holding Capacity	Soil	Zaragoza_Soil06
Infiltration Rate (IR)	Water	Zaragoza_Water01
Rainfall Interception of NBS (RI)	Water	Zaragoza_Water02
Water Availability (WA)	Water	Zaragoza_Water03
Number of Planted Trees and Shrubs	Biodiversity	Zaragoza_Bio01
Tree Density	Biodiversity	Zaragoza_Bio02
Mosquito bites	Biodiversity	Zaragoza_Bio03
Air Temperature At 2 Meters (Daytime and Night-Time)	Human Well-being	Zaragoza_Well01
Daily Temperature Range (Difference Between the Daily Maximum and Daily Minimum Temperature)	Human Well-being	Zaragoza_Well02
Days With Temperature >90th Percentile (TX90p)	Human Well-being	Zaragoza_Well03
Heatwave risks (number of combined tropical nights (>20ºC) and hotdays (>35ºC))	Human Well-being	Zaragoza_Well04
Mean or peak daytime local temperatures (°C)	Human Well-being	Zaragoza_Well05
Monthly mean value of daily maximum temperature (TXx)	Human Well-being	Zaragoza_Well06
Monthly mean value of daily minimum temperature (TNn)	Human Well-being	Zaragoza_Well07
Relative humidity (%)	Human Well-being	Zaragoza_Well08
Normalized Difference Vegetation index (NDVI)	Human Well-being	Zaragoza_Well09
Number of trees	Human Well-being	Zaragoza_Well10
Recreational opportunities provided by green infrastructure	Human Well-being	Zaragoza_Well11
Self-reported well-being/ Good Moods	Human Well-being	Zaragoza_Well12
Energy savings for cooling	Energy	Zaragoza_Energy01
Air temperature reduction in building	Energy	Zaragoza_Energy02
Operational energy consumption	Energy	Zaragoza_Energy03

DEMO6.1: Teruel

In the forests near Teruel, Aragon (Spain) the infection of pine trees by mistletoe, a parasitic plant, has caused an increased pine mortality which also increased the forests vulnerability to wildfires. To control the expansion of mistletoe, a different approach to forest management is being developed. Mainly, this is done through three different actions. First, encouragement of local bird species which can consume and reduce mistletoe plants. Second, the elimination and thinning of most affected trees, to prevent mistletoe reproduction. And third, research in the valorization of mistletoe and the wood removed from infected trees.

6.1.1 Biodiversity Indicators

6.1.1.1 Percentage of Affected Trees by Degree of Infestation at Tree Level

- **Code:** Teruel_Bio01

- **Environmental Sector**: Plant / Plant Biodiversity
- **Units:** Percentage

Meaning and importance of the indicator

The Forest Condition in Europe (2022 assessment) shows that 5.1% of Mediterranean lowland pines were affected by the hemiparasite mistletoe (Viscum album), but some regions are more affected than others. The percentage of infected trees and the degree of infestation at the tree level can be very high, causing severe impacts on the water, carbon, and nutrient balance of the trees, which can accelerate tree canopy dieback, growth decline, tree mortality and facilitate wildfires, especially in water-stressed regions, causing significant productive and economic losses. Control methods include mechanical, chemical and biological, and it appears that mechanical control, such as pruning of infested branches or removal of infested trees, is the primary and most effective method. A key indicator to measure the success of these controls is to calculate the percentage of trees affected by the degree of infestation at the tree level.

Expected evolution of the indicator

The optimal value of the percentage of infected trees and the degree of infestation at the tree level is 0% immediately after the treatment. The expected trend is a gradual increase over time following the removal of mistletoe due to colonisation from nearby untreated trees. However, this increase will be influenced by a number of factors, including the extent of the infested trees and the degree of tree infestation in the surrounding area of the selected pilot demos. González de Andrés (2024) reported mistletoe infestation degree levels of 0,7 to 1,1 (on a scale between 0 and 6) in trees from which mistletoe was removed about two decades ago.

Possible relationship with other biodiversity analyses

Teruel_Bio02.

Data obtention

Required data:

- Affection at mass level: quantification of the area with presence of mistletoe at different levels.
- Tree-level affectation: quantification of the affectation of individuals, to be carried out in the areas with the highest level of affectation at the mass level.

Sampling plan:

The percentage of infected trees and the infestation degree at the tree level will be determined following the protocol for estimation of mistletoe levels in the field generated the CIRCE:

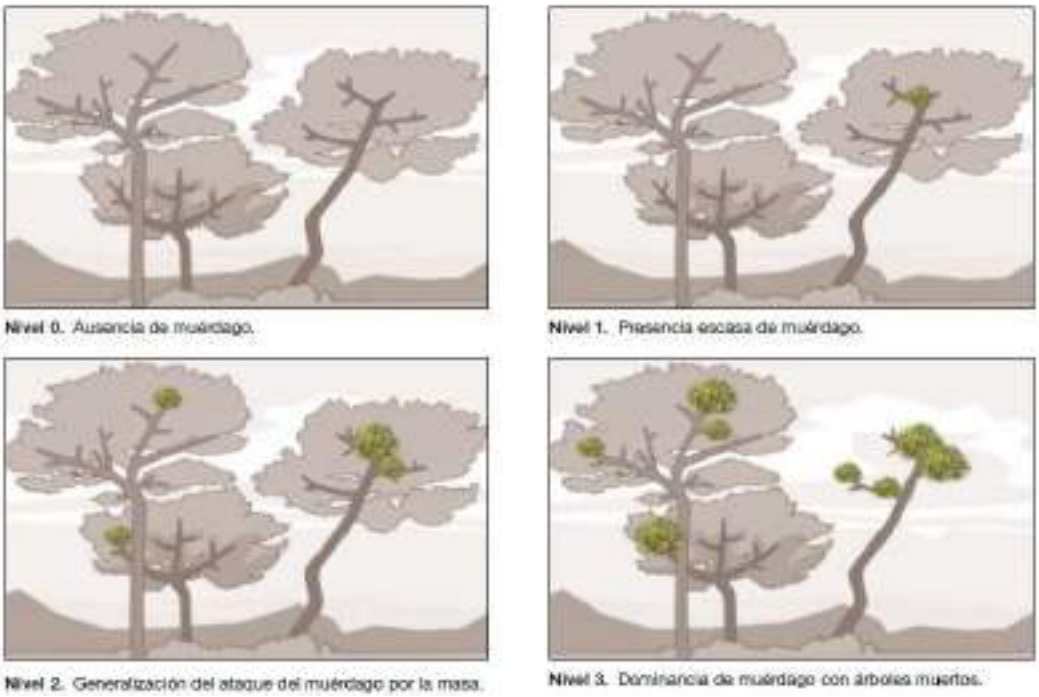
a) Affection at mass level: quantification of the area with presence of mistletoe at different levels, with the classical scale from 0 to 3, where:

M0: total absence of mistletoe.

M1: low presence of mistletoe.

M2: widespread presence of mistletoe, but not prominent in the canopy and without occurrence of dead trees.

M3: widespread presence of mistletoe, clearly visible in the canopy, and dead trees are present.



b) Tree-level affectation: quantification of the affectation of individuals, to be carried out in the areas with the highest level of affectation at the mass level, with the use of a scale from 0 to 4, where:

A0: tree not affected by mistletoe.

A1: tree with mistletoe only on branches.

A2: Tree with mistletoe on branches, including trunk, but with a dense foliage mass.

A3: Tree with mistletoe on trunk and branches, high crown transparency (excluding mistletoe) and higher volume of mistletoe clumps than leaf mass (in the upper third of the crown).

A4: crowned tree, with mistletoe and/or cronartium, and no primary growth (no apex visible above the mistletoe, or dead).

Example of A3: Tree with mistletoe on trunk and branches, high crown transparency and higher volume of mistletoe clumps than leaf mass	Example of A4: crowned tree, with mistletoe and/or cronartium, and no primary growth

The percentage of infected trees and the infestation degree at the tree level will be sampled at the same time of the year. The optimal period to sample is after the dry season because trees are more stressed then and can die from the combination of mistletoe and water stress.

6.1.1.2 Number Of Parasitized Trees

- **Code:** Teruel_Bio02
- **Environmental Sector**: Plant / Plant Biodiversity
- **Units:** Ordinal

Meaning and importance of the indicator

The Forest Condition in Europe (2022 assessment) shows that 5.1% of Mediterranean lowland pines were affected by the hemiparasite mistletoe (Viscum album), but some regions are more affected than others. The percentage of infected trees and the degree of infestation at the tree level can be very high, causing severe impacts on the water, carbon, and nutrient balance of the trees, which can accelerate tree canopy dieback, growth decline, tree mortality and facilitate wildfires, especially in water-stressed regions, causing significant productive and economic losses. Control methods include mechanical, chemical and biological, and it appears that mechanical control, such as pruning of infested branches or removal of infested trees, is the primary and most effective method. A key indicator to measure the success of these controls is to calculate the number of parasitized trees.

Possible relationship with other biodiversity analyses

Teruel_Bio01.

Expected evolution of the indicator

The optimal value of the number of parasitized trees is 0 immediately after the treatment. The expected trend is a gradual increase over time following mistletoe removal due to colonization from nearby untreated trees. However, this increase will be influenced by a number of factors, including the extent of the infested trees and the degree of tree infestation in the surrounding area of the selected pilot demos.

Data obtention

Required data:

- Number of parasitized trees.

Sampling plan:

The number of parasitized trees will be counted at the same time of year. The optimal period to sample is after the dry season when trees are more stressed then and may die from the combination of mistletoe and water stress.

Sampling calendar

Every year for 20 years, including before and after the treatment.

References

- González de Andrés E, Valeriano C, Camarero JJ. (2024). Long-Term Effects of Mistletoe Removal on Radial Growth of Semi-Arid Aleppo Pine Forests. Forests. 2024; 15(7):1113. https://doi.org/10.3390/f15071113
- Michel A, Kirchner T, Prescher A-K, Schwärzel K, editors (2022). Forest Condition in Europe: The 2022 Assessment. ICP Forests Technical Report under the UNECE Convention on Long-range

Transboundary Air Pollution (Air Convention). Eberswalde: Thünen Institute. https://doi.org/10.3220/ICPTR1656330928000

6.1.1.3 Number of Trees Removed

- **Code**: Teruel_Bio03
- **Environmental Sector**: Forest Ecosystem Service
- **Units:** Trees Ha^{-1}

Meaning and importance of the indicator

The Forest Condition in Europe (2022 assessment) shows that 5.1% of Mediterranean lowland pines were affected by the hemiparasite mistletoe (Viscum album), but some regions are more affected than others. The percentage of infected trees and the degree of infestation at the tree level can be very high, causing severe impacts on the water, carbon, and nutrient balance of the trees, which can accelerate tree canopy dieback, growth decline, tree mortality and facilitate wildfires, especially in water-stressed regions, causing significant productive and economic losses. Control methods include mechanical, chemical and biological, and it appears that mechanical control, such as pruning of infested branches or removal of whole trees, is the primary and most effective method. The control method of the hemiparasite mistletoe (*Viscum album*) in this demonstration site will be mechanical by removing all the infested trees. A key indicator to measure the effectiveness of these treatments in terms of lower degree of infestation is to calculate the number of trees removed.

Expected evolution of the indicator

It is not easy to predict the trend of this indicator after the intervention because there are multiple factors that can influence it (degree of infestation in the surrounding areas, bird demography and their activity as propagule dispersers, etc.). On the other hand, the number of trees removed will depend on the degree of infestation at the time of the intervention

Possible relationship with other forest ecosystem service analyses

Teruel_Bio02.

Data obtention

Required data:

- Field sampling plots where the number of trees removed are counted.

Sampling plan:

See Teruel_Bio04.

Sampling calendar

The first sampling campaign will be done prior to the implementation of forest treatment. The second campaign will be done just after the forest intervention to quantify the effect of treatments. No more campaigns will be needed after the second campaign.

Equipment

See Teruel_Bio04.

Calculation formula

The ratio between one hectare and the plot area will be the factor to multiply by the number of trees measured in the plot.

References

- González de Andrés E, Valeriano C, Camarero JJ. (2024). Long-Term Effects of Mistletoe Removal on Radial Growth of Semi-Arid Aleppo Pine Forests. Forests. 2024; 15(7):1113. https://doi.org/10.3390/f15071113
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- Pardé, J. 1988. Dendrométrie. par J. Pardé, J. Bouchon, 2e édition refondue. Nancy: École nationale du génie rural, des eaux et des forêts, 1988.
- Sutherland, W. J. (Ed.). (2006). Ecological census techniques: a handbook. Cambridge university press.
- Southwood, T. R. E., & Henderson, P. A. (2009). Ecological methods. John Wiley & Sons.
- Wheater, C. P., Bell, J. R., & Cook, P. A. (2020). Practical field ecology: a project guide. John Wiley & Sons.

6.1.1.4 Aboveground Carbon Stored (Trees)

- **Code:** Teruel_Bio04
- **Environmental Sector**: Forest Ecosystem Service
- **Units:** T C Ha^{-1}

Meaning and importance of the indicator

Aboveground carbon stored in trees refers to the CO_2 sequestered from the atmosphere over time as a result of the trees' accumulated growth. The time that carbon is sequestered in the form of wood, bark, leaves... is carbon that is not returned to the atmosphere, contributing to the mitigation of climate change. When a tree dies or is cut down, the process is reversed, and CO2 is re-emitted into the atmosphere. This process can be faster or slower depending on the rate of wood decomposition, whether the tree dies and remains in the forest or, if it is cut down, on the destination of the wood: CO2 emission will be instantaneous if it is used as fuel or long-lasting if it is transformed into furniture or any other long-lasting product. A tree can sequester carbon at a good rate for more than a hundred years and can keep carbon sequestered for centuries until its death.

Expected evolution of the indicator

The amount of carbon stored at the stand level increases over time as trees grow, but it eventually stabilizes. In the short and medium term, the accumulation rate is rapid but slows down with age and the reduction of resources due to competition from neighbouring trees. The rate of carbon accumulation depends mainly on the species, the amount of available resources (light, water, and nutrients), and the climate. After a forest treatment where trees are cut down, an increase in the individual growth of the trees that remain in the forest is expected, which translates, at the stand level, into a higher rate of CO2 sequestration than before the intervention.

Possible relationship with other forest ecosystem service analyses

Teruel_Bio05.

Data obtention

Required data:

Field sampling plots where different tree attributes are measured.

Sampling plan:

Circular permanent plots of a fixed radius and sufficient size to measure between 20 and 30 trees will be established. The plot centre will be marked with GPS and a wooden or metal stake. Within the sampling radius, all trees with a diameter at breast height (DBH) of at least 7.5 cm will be measured. For each live or dead tree, the species, diameter, and height will be recorded. Polar coordinates (direction and distance) will be recorded for each tree. The distance to the centre should be measured in the horizontal plane, i.e., with correction for slope. The location of the plot centre, along with the recorded coordinates of each tree, will allow for the relocation of the plot and the repetition of the tree-by-tree sampling.

Sampling calendar

This field sampling will be conducted every 5 years for a total of 10 years. The first sampling campaign will be done prior to the implementation of forest treatment. The second campaign will be done just after the forest intervention to quantify the effect of treatments.

Equipment

A Vertex Haglof digital rangefinder to measure the distance and height of each tree, and a diameter tape or forest caliper to measure DBH

Calculation formula

Based on the species, DBH, and height, the aboveground carbon (kg dry weight) of each tree will be estimated using one of the following equations:

$$ABGC = a \cdot DBH^b \cdot H^c \cdot [C]$$

$$ABGC = a \cdot DBH^b \cdot [C]$$

Where:

- *ABGC,* is the tree aboveground carbon (kg dry weight)
- *DBH,* is the diameter at breast height (cm)
- *H,* is the tree height (m)
- *a*, *b* and *c,* are the parameters of the equation
- *[C],* is the carbon concentration (g C/g OM, Organic Matter)

It can be assumed that the concentration of C ([C]) is 0.5 g C/g OM. The parameters of the equation vary depending on the species. There is a repository of biomass equations by species in https://laboratoriforestal.creaf.cat/allometrapp/.

Finally, the aboveground carbon stored per hectare is calculated by summing the aboveground carbon (ABGC) of all trees and then multiplying by the factor that converts the area of the plot to a hectare.

References

- Pardé, J. 1988. Dendrométrie. par J. Pardé, J. Bouchon, 2e édition refondue. Nancy: École nationale du génie rural, des eaux et des forêts, 1988.
- Ruiz-Peinado Gertrudix, R., Montero, G., & Del Rio, M. (2012). Biomass models to estimate carbon stocks for hardwood tree species. Forest Systems, 21(1), 42–52. https://doi.org/10.5424/fs/2112211-02193
- Ruiz-Peinado, R., del Rio, M., & Montero, G. (2011). New models for estimating the carbon sink capacity of Spanish softwood species. Forest Systems, 20(1), 176–188. https://doi.org/10.5424/fs/2011201-11643
- Whittaker R. H. i Woodwell G. M., 1969. Structure, production and diversity of the oak-pine forest at Brookhaven, New York. Journ. of Ecol. 57: 157-174.

6.1.1.5 Aboveground Carbon Removed (Trees)

- **Code:** Teruel_Bio05
- **Environmental Sector**: Forest Ecosystem Service
- **Units:** T C Ha^{-1}

Meaning and importance of the indicator

It is important to quantify the aboveground carbon removed because, depending on its destination, the carbon may be released into the atmosphere instantaneously. In DEMO6 Teruel, the plan is to use the pine wood removed from the forest due to mistletoe infection. Among the various possibilities, one potential use is as biomass to replace conventional fossil fuels in rural areas of Teruel.

Expected evolution of the indicator

It is not easy to predict the trend of this indicator after the intervention because there are multiple factors that can influence it (degree of infestation in the surrounding areas, bird demography and their activity as propagule dispersers, etc.). On the other hand, the amount of carbon removed will depend on the degree of infestation at the time of the intervention.

Possible relationship with other forest ecosystem service analyses

Teruel_Bio04.

Data obtention

Required data

- Field sampling plots where different tree attributes are measured. See Teruel_Bio04.

Sampling calendar

See Teruel_Bio04. It is necessary to carry out monitoring each time a new sanitary treatment is applied.

Equipment

See Teruel_Bio04.

Calculation formula

See Teruel_Bio04. Alternatively, the removed trees can be weighed. Although the moisture content of the wood is highly variable, it is generally accepted that the water content (air-dried) on a wet basis is 25-30%. Finally, to convert it to C, it must be multiplied by 0.5.

References

- Pardé, J. 1988. Dendrométrie. par J. Pardé, J. Bouchon, 2e édition refondue. Nancy: École nationale du génie rural, des eaux et des forêts, 1988.
- Ruiz-Peinado Gertrudix, R., Montero, G., & Del Rio, M. (2012). Biomass models to estimate carbon stocks for hardwood tree species. Forest Systems, 21(1), 42–52. https://doi.org/10.5424/fs/2112211-02193.

- Ruiz-Peinado, R., del Rio, M., & Montero, G. (2011). New models for estimating the carbon sink capacity of Spanish softwood species. Forest Systems, 20(1), 176–188. https://doi.org/10.5424/fs/2011201-11643.
- Whittaker R. H. i Woodwell G. M., 1969. Structure, production and diversity of the oak-pine forest at Brookhaven, New York. Journ. of Ecol. 57: 157-174.

6.1.1.6 Tree Regeneration

- **Code:** Teruel_Bio06
- **Environmental Sector**: Forest Ecosystem Service
- **Units:** Trees ha^{-1}

Meaning and importance of the indicator

After a sanitary treatment to remove trees infested by mistletoe, space is freed up, which may facilitate the establishment of a new cohort of trees through natural regeneration. The proportion of new open space will depend on the degree of infestation before the treatment (see Teruel_Plant1 & Teruel_Plant2). Monitoring the number of seedlings that germinate and later grow into adult individuals is crucial to ensure the forest's continuity in the medium and long term. This continuous monitoring will help determine the effectiveness of natural regeneration and, depending on its success, decide whether artificial replanting is necessary to reinforce regeneration.

Expected evolution of the indicator

The two affected species, *Pinus halepensis* and *Pinus sylvestris*, regenerate from seed and require plenty of light to survive. Higher seedling regeneration and survival are expected when there is more open space and more direct solar radiation. The subsequent survival of the seedlings and their likelihood of becoming adult trees will depend on the climatic conditions and the amount of direct light they receive over time.

Possible relationship with other forest ecosystem service analyses

Teruel_Bio04.

Data obtention

Required data

Field sampling plots where different tree attributes are measured.

Sampling plan:

Teruel_Bio04. In the same sampling plots (see Teruel_Bio04), circular plots with a 5-meter radius will be established, where the number of individuals will be counted by size classes. The classes will be: i) seedlings less than 30 cm in height; ii) seedlings between 30 and 130 cm in height; iii) individuals over 130 cm in height and less than 2.5 cm in DBH; and iv) trees between 2.5 cm and 7.5 cm in DBH. If regeneration is very abundant, smaller-radius plots may be established.

Sampling calendar

Monitoring will be conducted just before the sanitary treatment, then at the beginning of each year for two years, and subsequently at 5 and 10 years (see Teruel_Forest2). Sampling should be carried out during the autumn, following the summer, which is one of the most critical periods for the survival of individuals.

Calculation formula

The ratio between one hectare and the plot area will be used as the factor to multiply by the number of stems measured in the plot for each of the four size classes.

References

- Pardé, J. 1988. Dendrométrie. par J. Pardé, J. Bouchon, 2e édition refondue. Nancy: École nationale du génie rural, des eaux et des forêts, 1988.
- Serrada R., Montero G. Reque J.A. 2008. Compendio de Silvicultura Aplicada en España. INIA, 1178 pp.
- Whittaker R. H. i Woodwell G. M., 1969. Structure, production and diversity of the oak-pine forest at Brookhaven, New York. Journ. of Ecol. 57: 157-174.

6.1.1.7 Tree Mortality Rate

- **Code:** Teruel_Bio07
- **Environmental Sector**: Forest Ecosystem Service
- **Units:** Percentage

Meaning and importance of the indicator

The trees that remain in the stand after the treatment are in better condition (free of mistletoe and with reduced competition from neighboring trees) and should be able to grow and survive more easily. Consequently, a key indicator for evaluating the success and effectiveness of the sanitary treatment is determining the survival rate of the remaining trees over time. The tree mortality rate refers to the percentage of trees that are dead after a specific period following the forest treatment.

Expected evolution of the indicator

If the sanitary treatment is not effective and new infestations occur, the mortality rate of the remaining trees is expected to increase over time. However, the mortality rate may differ significantly between stands due to factors such as soil type, climatology, treatment intensity, previous degree of infestation, tree density before and after treatment, etc. If the mortality rate is high, it is essential to identify the underlying causes to avoid potential errors that may have contributed to the tree mortality in the future.

Possible relationship with other forest ecosystem analyses

Teruel_Bio04.

Data Obtention

Required data:

- Field sampling plots where different tree attributes are measured.

Sampling plan:

The sampling protocol is described in Teruel_Forest2. Specifically, the required data is to determine whether each tree is alive or dead.

Sampling calendar

See Teruel_Bio06.

Calculation formula

Mortality rate (MR) is calculated by dividing the number of dead trees (NDT) at the time of data collection by the total number of live trees in the previous monitoring period (NLT), and then dividing that result by the elapsed time between inventories (T2 - T1).

$$MR = (NDT/NLT)/(T2-T1) \cdot 100$$

References

- Pardé, J. 1988. Dendrométrie. par J. Pardé, J. Bouchon, 2e édition refondue. Nancy: École nationale du génie rural, des eaux et des forêts, 1988.

- Sutherland, W. J. (Ed.). (2006). Ecological census techniques: a handbook. Cambridge university press.
- Southwood, T. R. E., & Henderson, P. A. (2009). Ecological methods. John Wiley & Sons.
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6.1.2 Energy Indicators

6.1.2.1 Energy footprint per kg of food

- **Code:** Teruel_Energy01
- **Environmental Sector:** Energy
- **Units:** kWh/kg food

Meaning and importance of the indicator

"Energy footprint per kg of food" measures the total amount of energy consumed throughout the entire lifecycle of producing one kilogram of food, including energy used in farming, processing, transportation, and storage. This indicator is vital for assessing the environmental and economic sustainability of food production systems. A high energy footprint suggests inefficiencies and greater environmental impact, contributing to increased greenhouse gas emissions and higher production costs. Conversely, a lower energy footprint indicates more efficient and sustainable practices, reducing the overall environmental burden and conserving energy resources. By monitoring this indicator, stakeholders can identify areas for improvement, adopt energy-saving technologies, and implement best practices to enhance the sustainability of food production. Ultimately, reducing the energy footprint per kg of food supports global efforts towards sustainable agriculture, climate change mitigation, and resource conservation.

Expected evolution of the indicator

The expected evolution of the indicator "Energy footprint per kg of food" is towards a decreasing trend, reflecting improvements in the efficiency and sustainability of food production systems.

Data obtention

Field measurement or based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

Frequency

Continuous with field measurements or once per year when electrical capacities are used.

6.1.2.2 Operational energy consumption

- **Code:** Teruel_Energy02
- **Environmental sector:** Energy
- **Units:** kWh

Meaning and importance of the indicator

"Operational energy consumption" of a forestry system measures the amount of energy required to run all processes involved. This indicator is crucial for evaluating the efficiency and sustainability of forestry operations. High operational energy consumption can indicate inefficiencies and lead to increased operational costs and higher greenhouse gas emissions. Conversely, optimizing energy consumption enhances the sustainability of the forestry processes by reducing costs, minimizing environmental impact, and conserving energy resources. Monitoring this indicator helps identify areas for improvement, enabling the implementation of energy-saving technologies and practices. Ultimately, reducing operational energy consumption supports broader sustainability goals, including resource conservation, climate change mitigation, and the promotion of eco-friendly infrastructure.

Expected evolution of the indicator

The expected evolution of the indicator "Energy consumption" for a forestry system is towards a reduction in energy use per unit of forestry output, driven by technological advancements, process optimization, and regulatory and market pressures for greater sustainability.

Data obtention

Field measurement or assessment based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

DEMO6.2: Zaragoza

In Zaragoza, Aragon (Spain), two schools were selected for the renaturalization of their schoolyards. The schoolyards from the CEIP Maria Moliner and CEIP Vadorrey, were redesigned to increase their green spaces, which will provide an accessible way for urban children to interact with nature and to reduce temperature during heat-wave episodes.

6.2.1 Soil Indicators

6.2.1.1 Soil Physical and Chemical Fertility

- **Code:** Zaragoza_Soil01
- **Environmental Sector**: Soil / Soil Health
- **Units:** A Multi-Component Indicator. Diverse Units for Specific Components

Meaning and importance of the indicator

Soil fertility, its capacity to sustain plant growth, depends on complex interactions between biological, chemical and physical properties. Achieving and maintaining appropriate levels of physical and chemical fertility is of paramount importance to support urban green. In natural soils, nutrients come from minerals, water, atmospheric deposition, and recycling of plant and animal residues but their availability to plants is significantly affected by soil acidity (pH), and nutrient presence in the soil solution is highly dependent on soil texture and soil cation exchange capacity. Water retention in soils and progressive release to plants is notably improved by soil organic matter, which is particularly important in Mediterranean regions under increasing aridity. Urban soils are highly heterogeneous and are frequently called “technosoils”. Soils are made of human-transported substrates, or are native soils highly transformed by anthropization. Urban soils are very often compacted and polluted, but they perform multiple unvaluable ecosystem services when returned to health, particularly in water and carbon cycles, and play a pivotal role in human wellbeing trough supporting healthy vegetation. Soil analysis is the basic tool to evaluate soil fertility and to guide city managers towards sustainable soil management.

Expected evolution of the indicator

There are recommended ranges and critical values for most of the soil properties to be analysed. For urban gardens, together with the results of soil analyses agricultural laboratories provide an evaluation of the level of each analyzed parameter (deficient – correct – excessive or similar). The value of each parameter should evolve towards these reference values and will guide gardeners in designing fertilization or any other correction.

Data obtention

Required data:

- To be analysed only the first time: soil texture (% sand; % clay; % silt); textural class.
- To be analysed at each soil sampling campaign: pH; Electrical conductivity (CEC);

Sampling plan:

Field sampling followed by lab analyses. Soil will always be sampled at the same moment of the year (set a fixed spring month), preferably avoiding temporal proximity to gardening interventions (or any other type of interventions affecting soil (tree pruning, plantation, grass sowing, fertilization, etc.)

In homogeneous landscapes, two samples per hectare may be a standard sampling density. But it is not yet clear how many m^2 will be unsealed at the schoolyards of the CEIPs María Moliner and Vadorrey or the distribution of the newly landscaped space (continuous space). To face this uncertainty, based on current project drawings, let's sample the biggest islands created at each site, 2 of them in the CEIP Vadorrey and 3 in the CEIP María Moliner.

At each garden island, take two soil samples from two points randomly selected. Soil must be sampled at 15 cm depth with soil samplers similar to those described in the "equipment" section. The two samples will be mixed into a unique plastic zip bag duly labelled with the date and the identification of the garden island.

The resulting 5 soil samples (2 from CEIP Vadorrey and 3 from María Moliner) will be sent to an expert lab for analysis as soon as possible. The soil lab must have been previously consulted for instructions about the preparation of the samples before shipping.

Sampling calendar

The gardens will be sampled in the proposed season every 2 years for 10 years (5 times).

Equipment

Samples will be taken with soil borers of similar and known (the same for all samples at each sampling campaign) depth and diameter. The borer should be 15 cm long and the recommended diameter is 5 cm. Some providers of these soil samplers are: https://www.ams-samplers.com/soil-augers/; https://www.vanwalt.com/equipment/telescoping-augers/. Any other equivalent sampler of these dimensions is acceptable (but try to respect the 15 cm depth)

Some small field materials, such as zip bags.

External subcontracting

Yes. A trustable lab delivering soil fertility analyses must be hired.

References

- Dondini, C., Úbeda, X., Certini, G., Francos, M. (2024). Soil quality in the urban gardens of Barcelona (Spain). *Journal of Soils and Sediments*, 1-13.
- Kortleve, A. J., Mogollón, J. M., Heimovaara, T. J., Gebert, J. (2023). Topsoil carbon stocks in urban greenspaces of The Hague, the Netherlands. *Urban Ecosystems*, *26*(3), 725-742.

- Dondini, C., Úbeda, X., Certini, G., Francos, M. (2024). Soil quality in the urban gardens of Barcelona (Spain). *Journal of Soils and Sediments*, 1-13.
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- For soil fertility in gardens: https://extension.umaine.edu/gardening/manual/soils/interpreting-soil-tests/

6.2.1.2 Soil Bulk Density (P)

- **Code:** Zaragoza_Soil03
- **Environmental Sector** : Soil / Soil Health
- **Units:** G Cm^{-3}

Meaning and importance of the indicator

Bulk density is a soil property that indicates the degree of soil compaction. Bulk density is inversely related to soil porosity which allows air and water to move through the soil and facilitates plant root penetration through the soil. Compaction is the main feature of urban soils, very specially when they have been sealed beneath pavement, since sealing most often is preceded by removal of topsoil horizons and mechanic compaction that induces heavy alteration of the soil pore space and architecture. Compaction is among the main features of physical degradation of urban soils and is accompanied by low water holding capacity, low biological activity and low chemical quality and capacity to sustain healthy plants.

Expected evolution of the indicator

Bulk density is affected by soil texture (sand, silt, and clay proportion) and organic matter content. Fine-textured soils (such as silt and clay loams) with good structure have lower bulk density compared to sandy soils. According to data from the EU Joint Research Centre, mean European values for soil bulk density are 1.26 g cm^{-3} for arable lands, 1.23 g cm^{-3} for permanent crops, and 1.14 for heterogeneous agricultural areas. In highly disturbed urban soils, bulk density can range from 1.5 g cm^3 in lawns to densities that approach those of concrete in heavily trodden paths of sport yards (2.2 g cm^3). Bulk density should decrease as soil recovers its structure and gains organic matter.

Data obtention

Required data:

None. Measured from specific soil samples at each sampling campaign for soil fertility (Zaragoza_Soil01).

Sampling plan:

Field sampling followed by very a simple analysis. Samples will always be taken at the same moment of the year (make it match the soil fertility sampling date), preferably avoiding temporal proximity to gardening interventions (or any other type of interventions implying soil trampling or compaction)

At each sampling date, you will sample soil for bulk density in the same garden islands that you have sampled in the CEIP Vadorrey (2 islands) and the CEIP María Moliner (3 islands) and in the vicinity of the points where you have sampled soils for fertility (4 points in CEIP Vadorrey and 6 points in CEIP María Moliner) (Zaragoza_Soil01). A detailed explanation of the sampling method is provided in the USDA Soil Quality Test Kit Guide (1999), pg.9 (see references). In short for each sample, drive the metal cylinder all the way into the ground until its upper edge is level with the surface of the ground (using a mallet and a block of wood). Remove the ring taking great care not to lose soil. To do so, dig around the ring and with a trowel underneath it, carefully lift it out to prevent any loss of soil. Remove excess soil from the sample with a flat-bladed knife. The top and bottom of the soil sample should be flat and even with the edges of the ring. Using the flat-bladed knife, push out the entire soil sample into a plastic zip bag. Label the bag correctly.

Take the samples to the lab (or any other place where there is a scale - two decimal places of accuracy- and a drying oven). Transfer each sample individually from the plastic bag to a foil or paper tray duly labelled. Put the soil samples to dry at 100 degrees until constant weight (usually 4 days is enough). Weight the dry soil (in g) and register it in your soil data worksheet. If a drying oven is not available, you can use a microwave (see the method in the USDA Soil Quality Test Kit Guide (in references)

Sampling calendar

Bulk density will be measured together with soil fertility (Zaragoza_Soil01), every two years for ten years.

Equipment

Bulk density is the ratio between soil dry weight and soil volume. Therefore, soil samples will be taken with a stainless-steel cylinder of perfectly know volume. The recommended dimensions for this case are 10 cm deep and 8 cm in diameter.
Additional field materials: a mallet, a block of wood, a trowel, a knife and zip-bags.

External subcontracting

If a reliable scale and a microwave are available, bulk density can be obtained very simply without the need of an expert lab.

Calculation formula

$$\rho = M / V$$

- Where:
  ρ is estimated as g cm^{-3}
- M is the dry weight of the sample in g
- V the volume of the soil cylinder (in cm^3)
-

For each garden island, calculate the average of the two estimates of density

References

- Soil Quality Indicators. Bulk Density. USDA Natural Resources Conservation Service https://www.nrcs.usda.gov/sites/default/files/2022-10/nrcs142p2_051591.pdf
- Soil Quality Test Kit Guide. USDA Natural Resources Conservation Service. 1999. https://efotg.sc.egov.usda.gov/references/public/WI/Soil_Quality_Test_Kit_Guide.pdf
- Paradelo, R., Herbón, C., & Barral, M. T. (2024). Physical properties of the urban soils of Santiago de Compostela (Spain). *Journal of Soils and Sediments*, 1-10.
- O'Riordan, R., Davies, J., Stevens, C., & Quinton, J. N. (2021). The effects of sealing on urban soil carbon and nutrients. *Soil*, *7*(2), 661-675.
- The Compaction of Urban Soils. Technical Note #107 from Watershed Protection Techniques. 3(2): 661-665. https://owl.cwp.org/mdocs-posts/elc_pwp36/
- Can Urban Soil Compaction Be Reversed? Technical Note #108 from Watershed Protection Techniques. 1(4): 666-66. https://owl.cwp.org/mdocs-posts/elc_pwp37/

- Effect of Urban Soil Compaction on Infiltration Rate https://owl.cwp.org/mdocs-posts/effect-of-urban-soil-compaction-on-infiltration-rate/

6.2.1.3 Soil Sealing

- **Code:** Zaragoza_Soil05
- **Environmental Sector** : Soil / Soil Health
- **Units:** % Area (As an indicator is usually calculated as percentage (sealed area per total area) or as sealed area per capita for a given region or country).

Meaning and importance of the indicator

Soil sealing represents one of the major threats of our decade from soil degradation, one of the main environmental issues. Impacts of soil sealing affects ecosystems and furthermore, carbon sequestration, degradation and pollution mitigation. As the main biodiversity is in soil, soil sealing affects both below and above the ground biodiversity, which entails a considerable loss due to topsoil is removed. Soil sealing also increases the risk of flooding and reduces the total and microbial content of carbon and nitrogen, and soil respiration.
Soil sealing as an indicator corresponds to an irreversible loss of soil and its biological functions and loss of biodiversity.

Expected evolution of the indicator

The current methods to measure soil sealing are satellite methods, computation based on land use data from cadastres or aerial pictures. Measures to reduce soil sealing inside urban areas are promoted. Sealing rates are usually low in peri-urban areas with on average 10 % and very high in core cities, with on average 36 %.

Data obtention

Required data:
To be analysed only the first time (See Zaragoza_Soil01).

Sampling plan:
Field sampling followed by lab analyses (See Zaragoza_Soil01).

Sampling calendar

This indicator will be produced every two years for a total of 10 years, coinciding with the evaluation of soil physical and chemical fertility (See Zaragoza_Soil01).

Equipment

See Zaragoza_Soil01.

External subcontracting

Yes. A trustable lab delivering must be hired (See Zaragoza_Soil01).

References

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- https://recare-hub.eu/soil-threats/sealing
- https://www.eea.europa.eu/publications/soil-monitoring-in-europe

6.2.1.4 Water Holding Capacity

- **Code:** Zaragoza_Soil06
- **Environmental Sector** : Soil / Soil Health
- **Units:** %

Meaning and importance of the indicator

The water holding capacity (WHC) is an important agronomic characteristic. The WHC of a soil is the maximum amount of water a soil can hold under standard conditions. Water holding capacity is affected by soil texture (sand, silt, and clay proportion) and soil structure (pore size, porosity, pores connectivity distribution and characteristics are essential determinants).

A soil with a limited WHC reaches sooner the saturation than a soil with a higher WHC, especially between sandy soils as they tend to have low water storage capacity.

Expected evolution of the indicator

Soil structure can be improved by adding organic matter content to stimulate the soil porosity, which increases the water holding capacity. Also, a better water holding capacity of the soil can be accomplished by increasing soil organic carbon. However, deforestation and farming activities may decrease soil water holding capacity.

Data obtention

Required data:

It needs to be analysed the first time and every two years for 10 years (5 times (See Zaragoza_Soil01).

Sampling plan:

Field sampling followed by lab analyses Field sampling followed by lab analyses (See Zaragoza_Soil01). Collect the sample using a soil core, air dry it, break the aggregates and pass through a 2.0 mm sieve. Place the core containing soil in a water tray for saturation overnight and then place the sample in an oven at 105º C for 24-48 h. Finally, weight the core sample.

For further instructions go to the Practical manual on measurement of soil physical properties, on the page 34.

Sampling calendar

This indicator will be produced every two years for a total of 10 years, coinciding with the evaluation of soil physical and chemical fertility (See Zaragoza_Soil01).

Equipment

Additional field materials: A soil cylinder /core, a tray, filter papers, a spatula, a sieve, water try, a balance and a drying oven (See Zaragoza_Soil01).

External subcontracting

If a reliable scale and an oven are available, WHC can be obtained very simply without the need of an expert lab. If not, a trustable lab delivering soil fertility analyses must be hired (See Zaragoza_Soil01).

Calculation formula

$$WHC\% = (Vw/Vt) * 100$$

Where:

- Vw is volume of water
- Vt is total volume of saturated soil

References

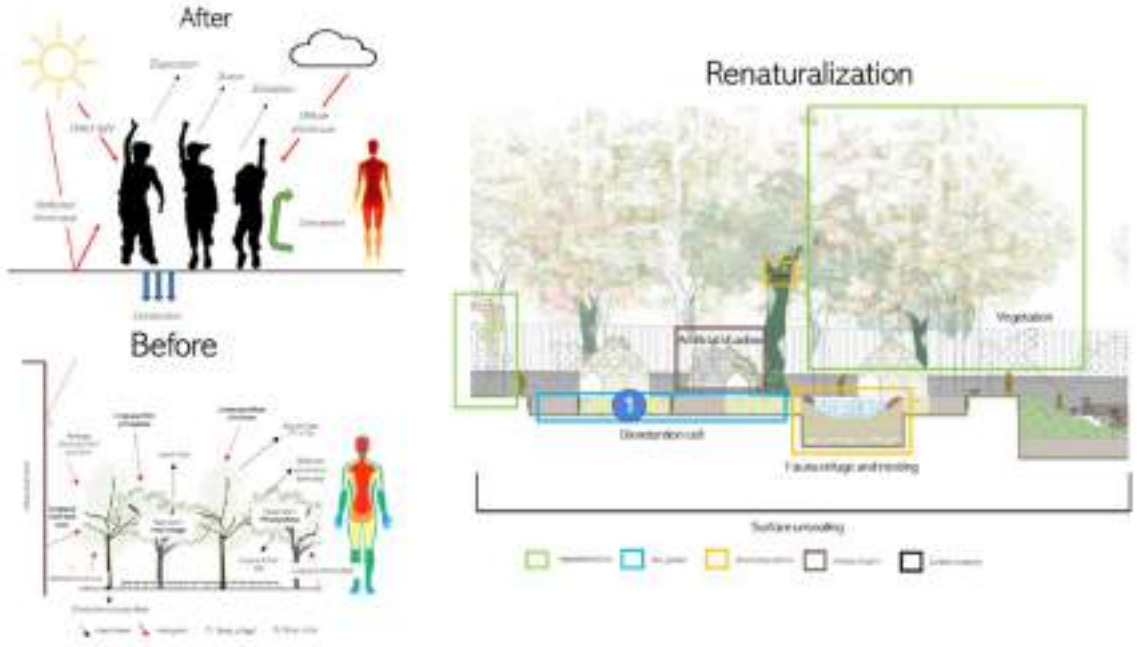
- Honghong, L., Xingwu, D., Yifan, D., Ronghua, Z., Li, R. & Jiangcheng, H. (2023). Responses of soil water-holding capacity to environmental changes in alpine ecosystems across the southern Tibetan Plateau in the past 35–40 years. *Catena*, 222,106840. https://doi.org/10.1016/j.catena.2022.106840.
- Soil Quality Test Kit Guide. USDA Natural Resources Conservation Service. 1999. https://efotg.sc.egov.usda.gov/references/public/WI/Soil_Quality_Test_Kit_Guide.pdf
- Role of Soil Physical Properties in Soil Health Management and Crop Productivity in Rainfed Systems-II Management Technologies and Crop Productivity ManualonPracticalsoilphysics.pdf
- https://www.nature.com/scitable/knowledge/library/soil-water-dynamics-103089121/
- Zhang, Y. & Wang, K. & Wang, J. & Changhai L. & Shangguan, Z. (2021). Changes in soil water holding capacity and water availability following vegetation restoration on the Chinese Loess Plateau. Scientific Reports. 11.10.1038/s41598-021-88914-0.

6.2.2 Water Indicators

6.2.2.1 Water Monitoring Plan

System diagram

Sustainable Learning Spaces: NBS Implementation in Zaragoza's Primary Schools.



Sampling points

Sampling point	Location	Purpose
SP-01	Bioretention cell	Monitor the rainfall/stormwater, and the infiltration rate (volume)

Parameters to be analyzed

Parameter	Applicable Sampling point	Related indicator/s	Type
Volume of rainfall over the NBS	SP-01	WA; RI	water flow measurements [volume/time]
Volume of water availability	SP-01	WA	water flow measurements [volume/time]

Water infiltration velocity through the soil	SP-01	IR	water flow measurements [volume/time]

Sampling method

Water flow measurements:

Direct measurement of volume provided during a time period or water flow with flow meters and/or water level sensors.

a) Automatic method

Automatic flow meters can be installed at the recommended sampling points (SP). For the automatization process, it is recommended to register the measurements with a datalogger/digital control system in the DEMO. It is recommended to measure the flow at the recommended sampling points (SP).

Data should be stored in a datalogger/digital control system and then be able to be exported in a spreadsheet to calculate the associated indicators. When this is not possible, manual readings of the flow meters can be done instead.

b) Manual method

This could be applied as the last option if there is no possibility to apply the automatic method.

- Periodic manual measurements.
- If no devices are available to measure, correct and reliable estimates must be made to assess the indicator.
- Measure the volume at the point of reuse or approximate the value based on the amount of water demand met by vegetation for reuse.

Rainwater/stormwater data:

For the registration of rainwater or stormwater data, it is more recommended to apply online and automatic methods.

a) Automatic method

Drone-derived orthophotos or satellite data can be used to measure the rainfall/stormwater. Also information from nearby meteorological/weather stations.

b) Manual method

Manual simple measurements using rain gauges could be used as the last option. These methods can give less accurate data.

Infiltration rate:

The infiltration rate is a type of water flow measurement, very related to the soil. Also, as other indicators, there are automatic and manual methods:

a) Automatic method

To measure infiltration rate automatically in a NBS, a tensiometer-based system or automated infiltrometer can be employed. These systems consist of soil moisture sensors or pressure transducers installed in the ground at various depths to continuously measure changes in soil moisture content or water pressure. The automated system periodically adds a controlled amount of water to the surface, imitating rainfall or irrigation. The sensors monitor how quickly the water infiltrates and how the moisture levels change over time. Data is collected in real-time and transmitted to a central data logger or computer for analysis, calculating the infiltration rate without manual intervention.

b) Manual method

To manually sample the infiltration rate, it's needed to use a ring infiltrometer. An example of this process is the following. First, hammer a 30 cm diameter ring about 15 cm into the soil, and place a measuring rod inside. Then, hammer a 60 cm diameter ring around the first one (or build an earthen bund) to prevent lateral water movement. Pour water into both rings to a depth of 70-100 mm and record the time. Measure the drop in water level at regular intervals, adding water to maintain the initial level. Continue until the water drop rate stabilizes, which represents the basic infiltration rate. Repeat the test at least twice for accuracy.

Sampling calendar

Water flow measurements and infiltration rate:

Data should be collected frequently for a relevant time period (e.g., daily, weekly, monthly) to allow for accumulation over the entire reporting period (yearly). This high frequency is also relevant to study seasonal variations.

Rainwater/stormwater data:

Data should be collected every time there is a rain event.

Equipment

a) Water flow measurements:

Water flow meters are essential tools for monitoring and assessing the efficiency of these systems, as they provide real-time data. In this DEMO, the main water flow measurement is about rainwater, so there are different rain gauges that can be used for it.

Some indicative providers of these are:

- OMEGA
- Amazon

Also, for water availability water flow meters can be used. Some indicative providers are:

- Endress+Hauser
- Systec Controls
- Aobo instrument

Any equivalent water flow meter is acceptable, these are given as examples.

b) Rainwater/stormwater data:

In this DEMO, the main water flow measurements would be rainwater/stormwater, so there are different rain gauges that can be used for it.

Some indicative providers of are:

- OMEGA
- Amazon

Any equivalent water level sensor is acceptable, this is given as an example.

c) Infiltration rate:

Some indicative providers are:

- Manual infiltrometer - Eijkelkamp
- Manual infiltrometer - ELE International
- Automated infiltrometer - SATURO

*For manual infiltrometers, take into account that you may need a hammer, a watch or clock, a bucket, a timber, or any other instrument to work together.

Any equivalent water flow meter is acceptable, these are given as examples.

External subcontracting required

Yes. A trustable laboratory delivering water quality analyses must be hired if not available internally.

6.2.2.2 Rainfall Interception of NBS (RI)

- **Code**: Zaragoza_Water02
- **Environmental Sector:** Water / Rainwater management and flood protection
- **Units:** mm/h

Meaning and importance of the indicator

The indicator measures the rate at which rainfall is intercepted by the NBS. This indicator is important for assessing the effectiveness of NBS in managing rainwater, reducing surface runoff, and mitigating flood risks. The interception capacity of NBS directly influences the hydrological balance and contributes to water retention in the ecosystem, thereby playing a vital role in flood prevention and sustainable water management.

Expected evolution of the indicator

Baseline: Initial interception capacity of the NBS.

Target: The optimal value would be a higher rate of rainfall interception compared to the baseline scenario and conventional infrastructure, leading to reduced surface runoff and enhanced groundwater recharge. This should ideally increase over time as the NBS matures and vegetation coverage expands.

Possible relationship with other water indicators

Captured runoff, Flood excess volume, Avoided floods.

Data obtention

Sampling plan:

- Volume of rainfall intercepted by the NBS (mm)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Time duration of the rainfall event (h)

Calculation formula

$$RI = \frac{Vrainfall\ NBS}{t}$$

Where:

- RI: Rainfall Interception Rate (mm/h),
- Vrainfall NBS: The total volume of rainfall intercepted by the NBS during a given time period (mm),
- t: time duration of the rainfall event (h).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: a handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577

6.2.2.3 Water Availability (WA)

- **Code**: Zaragoza_Water03
- **Environmental Sector:** Water / Freshwater supply / Resource efficiency
- **Units:** m^3/year

Meaning and importance of the indicator

The indicator refers to the volume of water available provided by the DEMO for its reuse in various applications (e.g. aquifer recharge, ecosystem restoration, on site reuse, irrigation, industrial activities, etc.). The water available should comply with quality standards required for different reuses as per current legislation.

Expected evolution of the indicator

The baseline for this indicator is the initial water availability capacity, which may start at 0 m^3/year. It is expected to increase over time once the DEMO is operating and optimized, reflecting an improvement in water availability for reuse and ecosystem services. Ensure that 100% of the water provided by the DEMO is available for reuse.

Possible relationship with other water indicators

Water footprint, Water provision by the ecosystem.

Data obtention

Sampling plan:

- Direct annual flow of the effluent or annual volume provided by the DEMO for specific purposes (e.g., aquifer recharge, ecosystem restoration, etc.) (m^3/year).
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total volume water available in the DEMO (WA) (m^3/year).

Calculation formula

$$WA = Water\ inflows\ (WI) - Water\ losses\ (WL)$$

Where:

- WI: Total water entering the DEMO system (e.g., precipitation, surface water, groundwater recharge, recycled water) (m^3)
- WL: Total water lost (due to evaporation (m^3))

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/
- United Nations Conference on Trade and Development (2023). Environmental indicators: Module B Core SDG Indicators for Entity Reporting Training Manual. https://unctad.org/system/files/information-document/UNCTAD_GCI_MANUAL_ENVIRONMENTAL-FINAL.pdf
- URBAN GreenUP (2019). D5. 3: City diagnosis and monitoring procedures. https://www.urbangreenup.eu/kdocs/1912498/urban_greenup_d5_3_city_diagnosis_and_monitoring_procedures.pdf
- U.S. Environmental Protection Agency (2024). Basic information about water reuse. https://www.epa.gov/waterreuse/basic-information-about-water-reuse

6.2.3 Biodiversity Indicators

6.2.3.1 Number of Planted Trees and Shrubs

- **Code**: Zaragoza_Bio01
- **Environmental Sector**: Plant / Plant Biodiversity
- **Units:** ordinal number

Meaning and importance of the indicator

The European Union and a number of organisations, including the United Nations Environment Programme (UNEP) or the Food and Agriculture Organisation (FAO), are advocating the transformation of urban cities into more environmentally sustainable and resilient "green cities", with an enhanced role for trees and shrubs in addressing the challenges faced by urban areas. The EU restoration law requires to increase urban green space and urban tree canopy cover. The presence of trees and other woody plants in urban environments provide multiple benefits, like the reduction of outdoor and indoor temperatures, energy savings, carbon sequestration, increase of infiltration rates and reduction of stormwater run-off. Additionally, they contribute to improve air and noise pollution, promote biodiversity, enhance human health and wellbeing, and enhance urban aesthetics. The number of trees planted is an important indicator of restoration progress, but once the restoration is complete, counting the number of trees can be an indicator of success or failure to achieve the project objectives.

Expected evolution of the indicator

The expected trend in the number of trees planted (total, per hectare or linear meter) is an increase over the restoration actions. After the restoration works, the number of trees should be stable over years.

Possible relationship with other biodiversity analyses

Zaragoza_Bio02.

Data obtention

Required data:

- Number of trees planted per day for the duration of the restoration works.
- Number of planted trees each year after the restoration works.

Sampling plan:

Over the restoration actions the trees planted should be counted every day to determine the total number of trees planted (or total trees planted per hectare or linear meter). After the restoration works the trees planted should be counted each year at the same time of the year, preferably after the dry season, and avoiding winter for deciduous species to avoid confusion between dead and dormant individuals.

Sampling calendar

Every day during the restoration works, the total number of trees planted (or total trees planted per hectare or linear meter) should be counted. After the restoration works the trees planted should be counted each year.

References

- Castellari, S., Zandersen, M., Davis, M., Veerkamp, C., Förster, J., Marttunen, M., ... & Picatoste, J. R. (2021). Nature-based solutions in Europe policy, knowledge and practice for climate change adaptation and disaster risk reduction. European Environment Agency.
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6.2.3.2 Tree Density

- **Code**: Zaragoza_Bio02
- **Environmental Sector**: Plant / Plant Biodiversity
- **Units:** individuals per square meter

Meaning and importance of the indicator

The European Union and a number of organisations, including the United Nations Environment Programme (UNEP) or the Food and Agriculture Organisation (FAO), are advocating the transformation of urban cities into more environmentally sustainable and resilient "green cities", with an enhanced role for trees and shrubs in addressing the challenges faced by urban areas. According to the World Health Organization, the minimum urban vegetation-covered area per person should be of 9 m^2, with an ideal value of 50 m^2. The EU restoration law requires to increase urban green space and urban tree canopy cover. The presence of trees and other woody plants in urban environments provide multiple benefits, like the reduction of outdoor and indoor temperatures, energy savings, carbon sequestration, increase of infiltration rates and reduction of stormwater run-off. Additionally, they contribute to improve air and noise pollution, promote biodiversity, enhance human health and wellbeing, and enhance urban aesthetics. Tree density is an important indicator to be monitored throughout the restoration process, as it allows the assessment of the project progress and goal. After restoration, this indicator provides a key information to detect tree mortality that could compromise the project objectives.

Expected evolution of the indicator

The expected trend in the tree density is to increase over the restoration period and remain stable over time.

Possible relationship with other biodiversity analyses

Zaragoza_Bio01.

Data obtention

Required data:

- Tree density during restoration works.
- Tree density after restoration works.

Sampling plan:

Tree density will be determined by one or both of the following methods, depending on the data and techniques available:

- Field sampling: counting all planted trees and the total area of the school playgrounds.
- Automatic or semi-automatic sampling: the number of planted trees can be extracted from aerial images or LIDAR datasets. From aerial images, the data can be extracted using automatic image classification or by digitising each tree from the images. LIDAR (Light Detection and Ranging) is a remote sensing method that depending on its resolution, can identify individual trees. Both aerial images and LIDAR techniques can be used to calculate the total area of the school playgrounds.

In both cases, the tree density will be measured at the same time of the year. The optimal period is after the dry season, and winter should be avoided for deciduous species to prevent confusion between dead and dormant individuals.

Sampling calendar

During restoration works tree density will be sampled every day or week. After restoration works tree density will be sampled every 3-5 years.

Data sources

National Center for Geographic Information
(http://centrodedescargas.cnig.es/CentroDescargas/buscadorCatalogo.do?)

Calculation formula

Tree density is calculated by counting all trees divided by the total area of the school playgrounds (in m^2).

References

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- Davies, C., De Vreese, R., Biernacka, M., Wilkes-Allemann, J., Zivojinovic, I. (2024). Guidelines for Urban Forests as Nature-Based Solutions: Planning, Policy and Delivery. Horizon 2020 CLEARING HOUSE project, grant agreement no. 821242. DOI: 10.5281/zenodo.10819200.
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6.2.4 Human Well-being

6.2.4.1 Air Temperature At 2 Meters (Daytime And Night-Time)

- **Code**: Zaragoza_Well01
- **Environmental Sector**: Air Temperature Comfort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for students and staff.

Expected evolution of the indicator

The temperature indicator is expected to show a gradual decrease as vegetation matures and green infrastructure becomes more established. The tendency should reflect a cooling effect, particularly during warmer months, as plants provide shade, increase evapotranspiration, and mitigate heat absorption from hard surfaces. The optimal value range will vary depending on the local climate, but ideally, temperatures in greened areas should be noticeably lower than in non-greened parts of the schoolyard, contributing to a more comfortable and cooler environment.

Possible relationship with other air temperature analyses

Zaragoza_Well02 to 08.

Data obtention

Required data:

- ºC every 30 or 60 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors in each schoolyard at 2 meters (sensor 1: will take data before the nature-based solution application and will be in charge of taking measurements after the transformation; Sensor 2: without vegetation and greater exposure to the sun (not transformed) Sensor 3: below a tree or a vegetation (not transformed).

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

Calculation formula

Collect temperature data at 15-minute intervals throughout the 24-hour period.
Segregate the data into daytime and nighttime intervals (from sunrise to sunset for daytime and from sunset to sunrise for nighttime).
Calculate the average temperature for both periods using the formulas

$$T_{day} = \frac{1}{n_{day}} \sum_{i=1}^{n_{day}} T_i$$

Where:

- Ti is the temperature recorded at the i-th 15-minute interval during the daytime
- n_{day} is the number of 15-minute intervals during daytime

$$T_{night} = \frac{1}{n_{night}} \sum_{j=1}^{n_{night}} T_j$$

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

6.2.4.2 Daily Temperature Range (Difference Between The Daily Maximum And Daily Minimum Temperature)

- **Code**: Zaragoza_Well02
- **Environmental Sector**: Air Temperature Comfort
- **UNITS:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for students and staff.
In particular, this indicator shows how much the temperature fluctuates throughout the day, often used to assess climate variability and the effect of green infrastructure on stabilizing temperature extremes.

Expected evolution of the indicator

Tendency: As green infrastructure, such as tree planting and vegetation, matures, the daily temperature range is expected to narrow. Vegetation helps moderate both daytime highs and nighttime lows by providing shade during the day and trapping heat during the night.
Optimal value range: A moderate daily temperature range (DTR) is often considered optimal, with smaller fluctuations typically indicating a healthier microclimate. The exact value range depends on the local climate, but in urban areas, a reduction in DTR could indicate improved thermal regulation due to greening projects.

Possible relationship with other air temperature analyses

Zaragoza_Well01 and from 02 to 08.

Data obtention

Required data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors in each schoolyard at 2 meters (sensor 1: will take data before the nature-based solution application and will be in charge of taking measurements after the transformation; Sensor 2: without vegetation and greater exposure to the sun (not transformed) Sensor 3: below a tree or a vegetation (not transformed).

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

Calculation formula

$$Daily\ Temperature\ Range = Tmax - Tmin$$

Where:

- Tmax is the daily maximum temperature (from sunrise to sunset)
- Tmin is the daily minimum temperature (from sunset to sunrise)

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

6.2.4.3 Days With Temperature >90th Percentile (TX90p)

- **Code**: Zaragoza_Well03
- **Environmental Sector**: Air Temperature Comfort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for students and staff.
TX90p is the number of days where the maximum daily temperature exceeds the 90th percentile of the long-term reference period. This indicator is often used to assess heatwave frequency and climate change impacts.

Expected evolution of the indicator

Tendency: Without intervention, the number of days with temperatures above the 90th percentile is likely to increase due to climate change, especially in urban areas. However, the implementation of nature-based solutions (such as urban greening) can slow or reduce this trend by cooling the environment.
Optimal value range: Ideally, the number of days exceeding the 90th percentile should remain low. While occasional days above this threshold are normal, a high or increasing trend could indicate vulnerability to heat stress.

Possible relationship with other air temperature analyses

Zaragoza_Well01 to 02 and 04 to 08.

Data Obtention

Required data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH).Put 3 sensors in each schoolyard at 2 meters (sensor 1: will take data before the nature-based solution application and will be in charge of taking measurements after the transformation; Sensor 2: without vegetation and greater exposure to the sun (not transformed) Sensor 3: below a tree or a vegetation (not transformed).

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

Calculation formula

First, calculate the 90th percentile of maximum temperatures for a reference period (e.g. 30 years), then count how many days in a specific time period (e.g. every year of sampling) exceed this value.

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

6.2.4.4 Heatwave risks (number of combined tropical nights (>20ºC) and hotdays (>35ºC))

- **Code**: Zaragoza_Well04
- **Environmental Sector**: Air Temperature Comfort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for students and staff.
This indicator counts the number of nights where the temperature does not fall below 20ºC (tropical nights) combined with days where the temperature exceeds 35ºC (hot days) to assess potential risks related to human health and infrastructure due to heat stress during heatwaves.

Expected evolution of the indicator

Tendency: In urban areas, the risks of tropical nights and hot days are expected to increase over time due to global warming. However, greening projects can mitigate some of these effects by lowering both daytime and nighttime temperatures, reducing the frequency of tropical nights (>20ºC) and hot days (>35ºC).
Optimal value range: Ideally, the number of tropical nights and hot days should be minimized, as both pose significant risks to human health. The optimal value would be near zero for tropical nights and hot days during most of the year, particularly in regions not typically exposed to extreme heat.

Possible relationship with other air temperature analyses

Zaragoza_Well01 to 03 and 05 to 08.

Data obtention

Required data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors in each schoolyard at 2 meters (sensor 1: will take data before the nature-based solution application and will be in charge of taking measurements after the transformation; Sensor 2: without vegetation and greater exposure to the sun (not transformed) Sensor 3: below a tree or a vegetation (not transformed).

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

Calculation formula

Tropical nights: Count of nights for a given year where Tmin >20°C
Hot days: Count of days for a given year where Tmax>35°C

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

6.2.4.5 Mean or peak daytime local temperatures (ºC)

- **Code**: Zaragoza_Well05
- **Environmental Sector**: Air Temperature Comfort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for students and staff.
The mean or peak daytime local temperatures (ºC) is the highest temperature recorded during the daytime hours (from sunrise to sunset) which helps assess local heat conditions and the effectiveness of green infrastructure in cooling the environment.

Expected evolution of the indicator

Tendency: Mean and peak daytime temperatures are expected to decrease with the maturation of green infrastructure. Vegetation provides shade and promotes evapotranspiration, leading to a cooling effect, especially during the hottest parts of the day.
Optimal value range: Ideally, peak daytime temperatures would stay below heat stress thresholds (often around 30–35ºC, depending on local climate conditions).

Possible relationship with other air temperature analyses

Zaragoza_Well01 to 04 and 06 to 08.

Data obtention

Required data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors in each schoolyard at 2 meters (sensor 1: will take data before the nature-based solution application and will be in charge of taking measurements after the transformation; Sensor 2: without vegetation and greater exposure to the sun (not transformed) Sensor 3: below a tree or a vegetation (not transformed)

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

Calculation formula

Obtention of the highest temperature every day of the year
Mean of the highest temperatures during the year

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

6.2.4.6 Monthly mean value of daily maximum temperature (TXx)

- **Code**: Zaragoza_Well06
- **Environmental Sector**: Air Temperature Comfort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for students and staff. This indicator calculates the monthly average of the daily maximum temperatures over a given month which helps assess local heat conditions and the effectiveness of green infrastructure in cooling the environment.

Expected evolution of the indicator

Tendency: The monthly mean of daily maximum temperatures is expected to decrease with effective greening interventions, particularly during the hottest months. Green infrastructure mitigates extreme heat by providing shade and cooling the air through transpiration.
Optimal value range: The optimal value depends on the region's climate. Generally, a lower mean daily maximum temperature during summer months is desirable to avoid heat stress.

Possible relationship with other air temperature analyses

Zaragoza_Well01 to 05 and 07 to 08.

Data obtention

Required data:

- ºC every 15 minutes

sampling plan:

Sensor (e.g. Lorawan EM300-TH).Put 3 sensors in each schoolyard at 2 meters (sensor 1: will take data before the nature-based solution application and will be in charge of taking measurements after the transformation; Sensor 2: without vegetation and greater exposure to the sun (not transformed) Sensor 3: below a tree or a vegetation (not transformed)

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

Calculation formula

$$TXx = \frac{1}{n}\sum_{i=1}^{n} T_{max,i}$$

Where:

- Tmax is the daily maximum temperature for day i
- n is the number of days in the month

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

6.2.4.7 Monthly mean value of daily minimum temperature (TNn)

- **Code**: Zaragoza_Well07
- **Environmental Sector**: Air Temperature Comfort
- **Units:** ºC

Meaning and importance of the indicator

Temperature data provides valuable insights into how vegetation and green spaces impact the local microclimate, especially in reducing the urban heat island effect. By monitoring temperature changes before and after the intervention, we can assess the effectiveness of green infrastructure in cooling the environment, improving thermal comfort, and enhancing overall well-being for students and staff. This indicator measures the monthly average of the daily minimum temperatures over a given month which helps assess local heat conditions and the effectiveness of green infrastructure in cooling the environment.

Expected evolution of the indicator

Tendency: The monthly mean of daily minimum temperatures could decrease slightly with increased greening, as vegetation helps release heat more gradually at night, reducing the "urban heat island" effect. However, the change in nighttime temperatures may be less pronounced than daytime changes. Optimal value range: The optimal value would be moderately low but above a threshold that ensures comfort during nighttime. In warm regions, values closer to 15–20ºC are often desirable to avoid discomfort during tropical nights.

Possible relationship with other air temperature analyses

Zaragoza_Well01 to 06 and 08.

Data obtention

Required data:

- ºC every 15 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors in each schoolyard at 2 meters (sensor 1: will take data before the nature-based solution application and will be in charge of taking measurements after the transformation; Sensor 2: without vegetation and greater exposure to the sun (not transformed) Sensor 3: below a tree or a vegetation (not transformed).

Sampling calendar

A temperature sensor will be installed prior to the transformations, and it will need to measure continuously over the following years in order to establish control and compare the results. The sensor should record temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records temperature at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

Calculation formula

$$TNn = \frac{1}{n}\sum_{i=1}^{n} T_{min,i}$$

Where:

- Tmin is the daily minimum temperature for day i
- n is the number of days in the month

References

- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147-155.
- Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences, 116*(15), 7575-7580.

6.2.4.8 Relative humidity (%)

- **Code**: Zaragoza_Well08
- **Environmental Sector**: Air Temperature Comfort
- **Units:** %

Meaning and importance of the indicator

Relative humidity (RH) is a measure of the amount of moisture in the air compared to the maximum amount of moisture the air can hold at a given temperature. It is crucial to monitor because it impacts the comfort levels, plant growth, and the microclimate of the schoolyard. In the context of greening, a balanced RH indicates improved air quality and ecosystem health, as vegetation influences moisture retention and evaporation rates, leading to a more stable microclimate.

Expected evolution of the indicator

After implementing greening solutions, the relative humidity is expected to increase slightly during the day due to increased transpiration from plants. At night, the RH may remain stable or slightly higher as the vegetation retains moisture. The optimal value range for relative humidity is generally between 40% and 60% for human comfort and plant health, but this may vary slightly depending on the local climate.

Possible relationship with other air temperature analyses

Zaragoza_Well01 to 07.

Data obtention

Required data:

- Relative humidity every 30 to 60 minutes

Sampling plan:

Sensor (e.g. Lorawan EM300-TH). Put 3 sensors in each schoolyard at 2 meters (sensor 1: will take data before the nature-based solution application and will be in charge of taking measurements after the transformation; Sensor 2: without vegetation and greater exposure to the sun (not transformed) Sensor 3: below a tree or a vegetation (not transformed).

Sampling calendar

A relative humidity sensor will be installed prior to the transformations, and it will need to measure continuously over the following years to establish control and compare the results. The sensor should record relative humidity at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis.

Equipment

A sensor that records relative humidity at 15-minute intervals daily, with the data either stored directly on the device or transmitted via the internet for remote access and analysis (e.g. Lorawan EM300-TH).

Calculation formula

Once relative humidity is obtained at 15 minutes intervals you can calculate the following data:

Daily relative humidity range
Monthly mean value of daily relative humidity

References

- Coutts, A. M., Tapper, N. J., Beringer, J., Loughnan, M., & Demuzere, M. (2013). Watering our cities: The capacity for Water Sensitive Urban Design to support urban cooling and improve human thermal comfort in the Australian context. *Progress in Physical Geography, 37*(1), 2-28.
- Armson, D., Stringer, P., & Ennos, A. R. (2012). The effect of tree shade and grass on surface and globe temperatures in an urban area. *Urban Forestry & Urban Greening, 11*(3), 245-255.

6.2.4.9 Number of trees

- **Code**: Zaragoza_Well10
- **Environmental Sector**: Social
- **Units:** Number

Meaning and importance of the indicator

The number of trees per person in urban areas is a crucial indicator of environmental quality and human well-being. Trees provide essential ecosystem services, such as air purification, cooling, carbon sequestration, and mental health benefits. Increasing the number of trees in urban spaces helps reduce pollution, mitigate the urban heat island effect, and enhance overall liveability, making it an important factor in urban greening projects.

Expected evolution of the indicator

As urban greening projects advance, we expect to see an increase in the number of trees per person and an expansion in urban tree canopy cover. An optimal outcome would include a balance between increasing the tree population and ensuring trees are strategically placed to maximize benefits.

Data obtention

Field sampling:

Count of number of trees planted

Sampling calendar

A first sampling should be done prior to the transformation and then a sampling should be done once per year. Regular assessments are important to observe long-term trends and account for factors like seasonal growth and tree mortality.

References

- Browning, M. H. E. M., Locke, D. H., Konijnendijk, C., Labib, S. M., Rigolon, A., Yeager, R., Bardhan, M., Berland, A., Dadvand, P., Helbich, M., Li, F., Li, H., James, P., Klompmaker, J., Reuben, A., Roman, L. A., Tsai, W.-L., Patwary, M., O'Neil-Dunne, J., Ossola, A., Wang, R., Yang, B., Yi, L., Zhang, J., & Nieuwenhuijsen, M. (2024). Measuring the 3-30-300 rule to help cities meet nature access thresholds. *Science of The Total Environment*, 907, 167739.
- Nieuwenhuijsen, M. J., Dadvand, P., Márquez, S., Bartoll, X., Barboza, E. P., Cirach, M., Borrell, C., & Zijlema, W. L. (2022). The evaluation of the 3-30-300 green space rule and mental health. *Environmental Research*, 215(Part 2), 114387.

6.2.4.10 Recreational opportunities provided by green infrastructure

- **Code**: Zaragoza_Well11
- **Environmental Sector**: Social
- **Units:** Number

Meaning and importance of the indicator

Recreational opportunities provided by green infrastructure refer to the ways in which urban green spaces enable physical activities, relaxation, social interactions, and connection with nature. These opportunities are vital for improving public health, reducing stress, and enhancing the quality of life in urban environments. By offering accessible areas for leisure and exercise, green spaces contribute to both mental and physical well-being.

Expected evolution of the indicator

As green infrastructure expands and improves, recreational opportunities should increase in both quantity and quality. An optimal scenario would see more diverse activities available, greater public use of green spaces, and enhanced accessibility for all demographics. This could be reflected in higher usage rates, improved public health metrics, and community satisfaction.

Data obtention

Field sampling: To measure recreational opportunities on a school, a combination of surveys and observational studies can be used. Surveys should target students, faculty, and staff to gather data on the frequency and type of recreational activities they engage in within the school green spaces (e.g., walking, sports, studying outdoors). Additionally, observational counts of users in key areas like lawns, gardens, and walking paths should be conducted at different times of the day and week. Specific attention should be given to how green spaces are used during breaks, between classes, and for organized recreational events. The sampling should also account for different types of activities, such as informal social gatherings, exercise, and academic-related uses like outdoor studying or reading.

Sampling calendar

Data should be collected throughout the academic year to capture variations in recreational use during different semesters, exam periods, and holidays. Sampling should be done weekly during peak school hours (e.g., lunch breaks, late afternoons) and at different times of the day to understand daily patterns of space usage. Additionally, seasonal variations should be considered, with data collection occurring in both warmer and colder months to observe how weather influences recreational activities. Special attention should be paid to key events like orientation weeks, graduation, or school sports events, which may significantly impact how green spaces are used.

References

- Kabisch, N., & Haase, D. (2014). Green spaces of European cities revisited for 1990–2006. *Landscape and Urban Planning*, 110, 113-122.

6.2.4.11 Self-reported well-being/ Good Moods

- **Code**: Zaragoza_Well12
- **Environmental Sector**: Social
- **Units:**

Meaning and importance of the indicator

The "Self-reported well-being/Good Moods" indicator measures individuals' subjective sense of well-being and emotional state after interacting with green spaces. It is essential because it reflects the psychological and emotional benefits of nature, such as reduced stress, improved mood, and enhanced life satisfaction. This indicator is particularly relevant in urban greening projects, as it provides direct feedback from users, helping assess the success of nature-based interventions in improving quality of life.

Expected evolution of the indicator

Over time, the indicator is expected to show an increase in positive moods and a decrease in negative emotions as people spend more time in the green space. Ideally, a consistent shift towards positive feelings like happiness, calmness, and relaxation should be observed. There is no strict optimal range for well-being, but a noticeable upward trend in positive responses would indicate the success of the intervention.

Possible relationship with other analyses

Zaragoza Well11.

Data obtention

Required data:

- Surveys

Sampling plan:

Field sampling or automatic sampling. Create a simple online or paper survey with two main questions**:**
"How do you feel?" This question should be answered before entering the schoolyard
"How do you feel?" This question should be answered when leaving the schoolyard
The survey should include a list of mood words options, both positive (Happy, Peaceful, Excited, Calm, Rested) and negative (Sad, Anxious, Angry, Tired, Frustrated), from which participants can choose one or more.
Share the survey link or paper copies with students and teachers. Ensure the survey is accessible to the whole school community from different ages.
Encourage participants to complete the survey both upon entering and leaving the garden. You can send reminders if necessary to ensure regular participation.

Sampling calendar

Sampling should be conducted regularly throughout the year to account for seasonal changes in mood and the space's usability. A good approach would be to survey participants every month for at least one

year. Additionally, sampling should occur both before and after the implementation of the nature-based solutions to measure their immediate and long-term impacts.

Calculation formula

The formula for calculating the "Self-reported well-being/Good Moods" indicator could be expressed as:

$$\text{Well-being score} = \frac{\text{Number of positive mood reports}}{\text{Total number of mood reports}} \times 100$$

This will provide a percentage of positive mood responses out of the total collected data, giving a clear overview of the space's impact on well-being.
It can be calculated for the surveys done before the implementation of the nature-based solution and after.

References

- EdiCitNet (a network for urban Food)
- Five Borough urban farm project toolkit
- Eiter, S., Fjellstad, W., Metselaar, K., & Teixeira da Silva, R. (2022). Prioritised indicators and baseline (D5.5).

6.2.5 Energy Indicators

6.2.5.1 Energy savings for cooling for the nearby school

- **Code**: Zaragoza_Energy01
- **Environmental Sector**: Energy
- **Units**: kWh

Meaning and importance of the indicator

"Energy savings for cooling for the nearby school" refers to the reduction in energy consumption associated with cooling systems compared to a baseline or historical energy consumption for cooling purposes. This indicator is crucial for assessing energy efficiency improvements, reducing operational costs, and mitigating environmental impacts such as greenhouse gas emissions. It reflects the effectiveness of energy-saving technologies and building designs, particularly in response to rising global temperatures due to climate change.

Expected evolution of the indicator

The expected trend is an increase in energy savings over time due to advancements in nature-based interventions and stricter energy regulations. Optimal values would vary depending on region, climate, and building use but generally aim for a reduction from current consumption levels, targeting anywhere from 20-50% savings as realistic goals.

Data obtention

Field measurement.

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

6.2.5.2 Air temperature reduction in school building

- **Code**: Zaragoza_Energy02
- **Environmental sector**: Energy
- **Units**: °C

Meaning and importance of the indicator

"Air temperature reduction in school building" measures the decrease in air temperature achieved through specific interventions or strategies implemented in targeted school building. This indicator is crucial for assessing the effectiveness of planning and climate mitigation efforts, such as the introduction of green spaces, reflective materials, and improved urban design. By quantifying the reduction in air temperature, this indicator helps urban planners and policymakers evaluate the success of these interventions in mitigating the urban heat island effect, improving thermal comfort, and enhancing public health. Additionally, it provides valuable data to support the replication of successful strategies in other urban areas. Monitoring this indicator contributes to the broader goals of sustainable urban development, energy efficiency, and climate resilience, making cities more livable and better equipped to handle the impacts of climate change.

Expected evolution of the indicator

The expected evolution of the indicator "Air temperature reduction in school building" is towards a noticeable decrease in internal air temperatures, reflecting the successful implementation of strategies aimed at reducing urban temperatures.

Data obtention

Field measurement with temperature sensors.

Frequency

Once per month with temperature sensors.

6.2.5.3 Operational energy consumption

- **Code**: Zaragoza_Energy03
- **Environmental** sector: Energy
- **Units**: kWh

Meaning and importance of the indicator

"Operational energy consumption" of a forestry management measures the amount of energy required to run all processes involved. This indicator is crucial for evaluating the efficiency and sustainability of forestry operations. High operational energy consumption can indicate inefficiencies and lead to increased operational costs and higher greenhouse gas emissions. Conversely, optimizing energy consumption enhances the sustainability of the forestry processes by reducing costs, minimizing environmental impact, and conserving energy resources. Monitoring this indicator helps identify areas for improvement, enabling the implementation of energy-saving technologies and practices. Ultimately, reducing operational energy consumption supports broader sustainability goals, including resource conservation, climate change mitigation, and the promotion of eco-friendly infrastructure.

Expected evolution of the indicator

The expected evolution of the indicator "Energy consumption" for a forestry management is towards a reduction in energy use per unit of forestry output, driven by technological advancements, process optimization, and regulatory and market pressures for greater sustainability.

Data obtention

Field measurement or assessment based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

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ANNEX G: DEMO7

DEMO 7: Central Alentejo

Alentejo is the hottest and driest region in mainland Portugal, which demands a restoration of landscape areas where climate change is more concerning, specially linked to water availability. This landscape restoration of riverside vegetation, caried out by the Évora University and the *Comunidade Intermunicipal do Alentejo Central*, consists of the rehabilitation of the riparian territory through the increase in connectivity, increase of local plant biodiversity through seeding, and the control of invasive species. The *montados*, the main agroforestry system in Portugal, consist of low-density trees combined with agriculture or livestock grazing. The landscape restoration is also be achieved by improving the restoration of degraded *montados* that have been invaded by brushy vegetation due to underexploitation.

DEMO7: Central Alentejo	Sector	Code
Soil Physical and Chemical Fertility	Soil	Alentejo_Soil01
Soil Organic Carbon Content	Soil	Alentejo_Soil02
Bulk Density (ρ)	Soil	Alentejo_Soil03
The Maturity Index of Bongers (Mi)	Soil	Alentejo_Soil04
Water Holding Capacity	Soil	Alentejo_Soil05
Aboveground Carbon Stored (Trees)	Biodiversity	Alentejo_Bio01
Tree Regeneration	Biodiversity	Alentejo_Bio02
Overall Conservation Status of Habitats Under the EU Habitats Directive	Biodiversity	Alentejo_Bio03
Number Of Habitats Under the EU Habitats Directive	Biodiversity	Alentejo_Bio04
Number Of Planted Trees	Biodiversity	Alentejo_Bio05
Number Of Planted Shrubs	Biodiversity	Alentejo_Bio06
Tax of Planted Trees Surviving Per Year	Biodiversity	Alentejo_Bio07
Tax of Planted Shrubs Surviving Per Year	Biodiversity	Alentejo_Bio08
Area Covered by Invasive Species	Biodiversity	Alentejo_Bio09
Linear Metres of Linear Landscape Elements Affected by Invasive Species	Biodiversity	Alentejo_Bio10
Area Of Habitats Restored	Biodiversity	Alentejo_Bio11
Area Of Habitats Under the EU Habitats Directive	Biodiversity	Alentejo_Bio12
Electricity use in agriculture	Energy	Alentejo_Energy01

7.1.1 Soil Indicators

7.1.1.1 Soil Physical and Chemical Fertility

- **Code:** Alentejo_Soil01
- **Environmental Sector**: Soil / Soil Health
- **Units:** A Multi-Component Indicator. Diverse Units for Specific Components

Meaning and importance of the indicator

Soil productive capacity (a key soil ecosystem service) is the result of complex interactions between biological, chemical and physical properties. Achieving and maintaining appropriate levels of physical and chemical soil fertility is of paramount importance for sustainable cropland management and, at large scale, for food security. Nutrients naturally arrive to soil from geological materials, from water, from atmospheric deposition and from decomposition of plant and animal residues. Nutrient availability to crops is significantly affected by soil acidity (pH), and nutrient presence in the soil solution is highly dependent on soil texture and soil cation exchange capacity; water provision to plants is notably improved by soil organic matter. Soil electrical conductivity warns about soil salinity, a serious risk for

crops under Mediterranean conditions. Soil analysis is the basic tool to evaluate soil fertility and to guide farmers towards sustainable management.

Expected evolution of the indicator

There are recommended ranges and critical values for most of the soil components to be analysed. For a given crop or pasture, these values are available from local and regional farmer associations. Most generally, together with the results of soil analyses, agricultural laboratories provide an evaluation of the level of each analysed parameter (deficient – correct – excessive or similar). The value of each parameter should evolve towards these reference values.

Data obtention

Required data:

To be analysed at each soil sampling campaign: Stoniness and soil texture (% sand; % clay; % silt); textural class; pH; Electrical conductivity (CEC); Total organic carbon (%, dry soil basis); Carbonates; Total nitrogen (Kjeldahl); Available phosphorus (Olsen); Cation exchange capacity; Interchangeable bases (Ca, Mg, Na and K); Micronutrients (Fe, Zn, Mn)

Sampling plan:

Field sampling followed by lab analysis. Samples will always be taken at the same moment of the year, preferably in spring (set your favorite month).

Only the montado where the intervention is previewed (Montado 6) will be sampled for soil fertility.

The montado spans a surface area of about 6 ha. In this field and, using a virtual regular square mesh (5 x 5 m) that can be projected on the field map, randomly choose 18 squares and sample them in the center.

Weight each soil sample in a field scale with two-decimal-points accuracy and register its total weight. Eliminate as many? stones as you can (preferably sieve the samples at 2mm) and weight the fine fraction of the sample again. Register the new weight, discard the stones and conserve the fine soil.

Group the 18 resulting soil samples into 6 groups of three and combine every group of three samples into a unique zip plastic bag duly labelled with sample number (1 to 6), site and date. Each composite sample should weigh at least 100 gr (dry weight) for lab analyses. In case that the composite sample weights less than100 gr, please combine 4 samples instead of 3.

The resulting 6 composite soil samples will be sent to an expert lab for analysis as soon as possible. The soil lab must have been previously consulted for instructions about the preparation of the samples before shipping.

Sampling calendar

The montado will be sampled in the proposed dates every two years for 10 years (5 times). The first sampling campaign must precede any intervention in the montado and the first post-operation sampling will be done two years later.

Equipment

Samples should be extracted from soil with soil borers of known and constant (the same for all samples at each sampling campaign) depth and diameter. Sampling lithosols requires patience and good equipment.

Normally, the borer should be 15 cm long and the recommended diameter is 5 cm. However, due to little soil development in lithosols, it is not sure that the soil is deep enough. In this case, drive the borer into the ground as deep as possible and take note of the thickness of the soil layer.

Some providers of soil samplers are: https://www.ams-samplers.com/soil-augers/; https://www.vanwalt.com/equipment/telescoping-augers/. Any other equivalent sampler of these dimensions is acceptable (but try to respect the 15 cm depth).

Given the previewed very high stoniness of these soils, we recommend this type of borer: https://www.royaleijkelkamp.com/products/augers-samplers/soil-samplers/hand-augers/stony-soil-auger/

You will also need a field scale, a small gardening spade and zip bags

External subcontracting

Yes. A trustable lab delivering soil fertility analyses must be hired.

References

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- For soil fertility in crops: https://www.agromatica.es/referencia-de-un-analisis-de-suelo/; https://www.fbn.com/community/blog/how-to-read-a-soil-analysis-report; https://pubs.nmsu.edu/_circulars/CR676/

7.1.1.2 Soil Organic Carbon Content

- **Code:** Alentejo_Soil02
- **Environmental Sector**: Soil / Soil Health
- **Units:** %C

Meaning and importance of the indicator

Soil organic carbon (SOC) constitutes about 58% of soil organic matter (SOM) and is a chief indicator of soil health. SOC enters the soil through the decomposition of plant and animal residues, root exudates and living and dead soil biota (including microorganisms). Plant carbon comes from the C that plants remove from the atmosphere (photosynthesis), and animals obtain C from plant ingestion; therefore, the final origin of SOC is atmospheric CO_2. The stable fraction of SOC (the soil fraction that stays in soil for longtime periods and resists microbial attack) is considered "sequestered carbon" and contributes to climate change mitigation.

Expected evolution of the indicator

Increasing % C over time until reaching the highest values reported for this indicator in the montados of the region.

Data Obtention

Sampling plan:

Soil organic carbon analysis is included in the analyses of soil physical and chemical fertility (Alentejo_Soil01).

Sampling calendar

This indicator will be produced every two years for a total of 10 years, coinciding with the evaluation of soil physical and chemical fertility (Alentejo_Soil01)

Equipment

See Alentejo_Soil01.

External subcontracting

No. This analysis is included in the general analyses of soil physical and chemical fertility (Alentejo_Soil01).

References

- Basch, G., Calado, J., Barros, J., Carvalho, M. (2012). Impact of soil tillage and land use on soil organic carbon decline under Mediterranean conditions. *Agrociencia Uruguay*. Special Issue. Striving for Sustainable High Productivity Through Improved Soil and Crop Management. ISSN 1510-0839
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7.1.1.3 Bulk Density (ρ)

- **Code:** Alentejo_Soil03
- **Environmental Sector**: Soil / Soil Health
- **Units:** G Cm^{-3}

Meaning and importance of the indicator

Bulk density (ρ) indicates the degree of soil compaction. Bulk density is inversely related to soil porosity which allows air and water to move through the soil and facilitates plant root penetration through the soil.

Expected evolution of the indicator

Bulk density is affected by soil texture (sand, silt, and clay proportion) and organic matter content. Fine-textured soils (such as silt and clay loams) with good structure have lower bulk density compared to sandy soils. According to data from the EU Joint Research Centre, mean European values for soil bulk density are 1.26 g cm^{-3} for arable lands, 1.23 g cm^{-3} for permanent crops, and 1.14 g cm^{-3} for heterogeneous agricultural areas. Bulk density should increase as soil organic carbon increases.

Data obtention

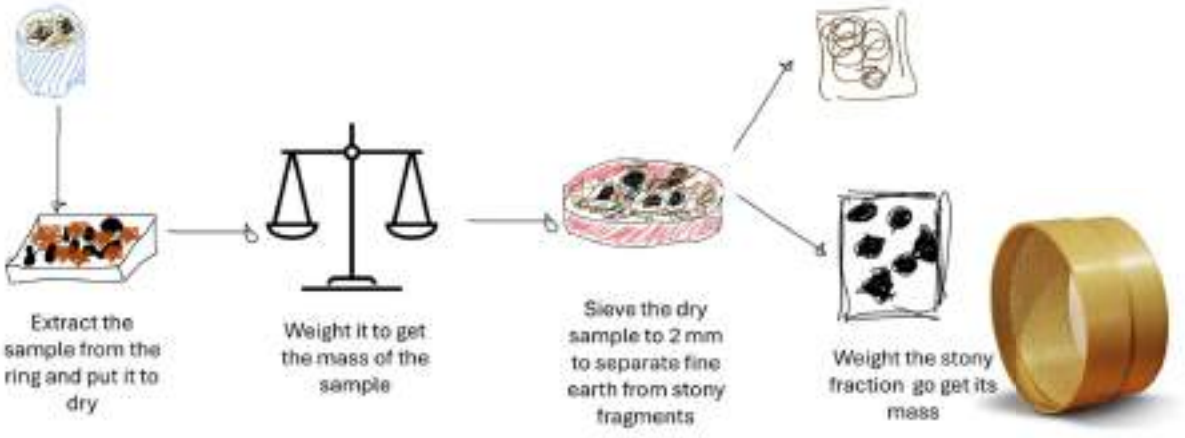
Sampling plan:

Field sampling followed by sample manipulation. Samples will always be taken at the same period of the year, preferably in spring (set your favorite month). Make it fit the sampling dates for soil fertility (Alentejo_Montados_Soil1). Only the montado where the intervention is previewed (Montado 6) will be sampled.

For soil bulk density assessment, you will follow the sampling pattern proposed for soil fertility, which will result in 18 sampling points that will be established in the vicinity of the points you have already sampled for fertility (but in this case, do not combine the samples).

Brief, for each sample, drive the density metal ring (see equipment) all the way into the ground until its upper edge is level with the surface of the ground (using a mallet and a block of wood). Remove the ring taking great care not to lose soil. To do so, dig around the ring and with a trowel underneath it, carefully lift it out. Remove excess soil from the sample with a flat-bladed knife. The top and bottom of the soil sample should be even with the edges of the ring.

Using the flat-bladed knife, push out the entire soil sample into a tray and let it dry in a drying oven at 100 ºC until constant weight (usually 4 days is enough). Record de total dry weight of the sample ($mass_{sample}$) in g before sieving it at 2 mm: this will separate the fine soil fraction from the rocky fraction. Register the weight of this rocky fraction ($mass_{rock\ fragments}$) in g. The measurement method is explained in the figure below.



Equipment

Bulk density is the ratio between soil weight and soil volume (in this case, corrected by stoniness). Therefore, soil samples will be taken with a stainless-steel ring of perfectly know volume. The recommended dimensions for this case are 15 cm deep and 15 cm in diameter.

Additional field materials: a mallet, a block of wood, a trowel, a knife and zip-bags. A plastic tray, a scale - two decimal places of accuracy-, a sieve (20 to 40 cm in diameter) with a mesh size of 2 mm (see the figure), and a drying oven.

Sampling calendar

Bulk density will be measured together with soil fertility (Alentejo_Soil01), every two years for ten years.

External subcontracting

If a reliable scale and a drying stove are available, bulk density can be obtained without the hiring an expert lab.

Calculation formula

$$BD_{fine\ soil} = \frac{mass_{sample} - mass_{rock\ fragments}}{volume_{sample} - \frac{mass_{rock\ fragments}}{\rho_{rock\ fragments}}}$$

(From Poeplau et al., 2017)

Where:

- $BD_{fine\ soil}$ is the bulk density of the fine soil fraction,
- $mass_{sample}$ is the dry weight of the total sample,
- $mass_{rock\ fragments}$ is the dry weight if the stony fraction,
- $volume_{sample}$ is the volume of the sample, calculated from the dimensions of the ring,
- $\rho_{rock\ fragments}$ is the bulk density adopted for stones.
-

Since ρ ranges from 2.40 to 2.80 g cm^{-3} for schists, in this case we will accept that $\rho_{rock\ fragments}$ = 2.6 g cm^{-3}

For each sampled zone, calculate the average of the two values obtained for bulk density

References

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- Soil Quality Test Kit Guide. USDA Natural Resources Conservation Service. 1999. https://efotg.sc.egov.usda.gov/references/public/WI/Soil_Quality_Test_Kit_Guide.pdf
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- Verbist, K. M. J., Cornelis, W. M., Torfs, S., Gabriels, D. (2013). Comparing methods to determine hydraulic conductivities on stony soils. *Soil Science Society of America Journal*, 77(1), 25-42.
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7.1.1.4 The Maturity Index of Bongers (Mi)

- **Code:** Alentejo_Soil04
- **Environmental Sector**: Soil / Soil Health
- **Units:** Number

Meaning and importance of the indicator

Nematodes are one of the soil invertebrates' groups that have been studied for their high ecological relevance with attributes that make them useful tools as environmental indicators, due to their contribution against pest regulation and diseases, and maintenance of nitrogen cycle and mineralization on the soil. The use of indicators to evaluate the quality of the ecosystems are used globally as this gives us an idea of the structure, function and composition of the ecosystems. Furthermore, the maturity index from Bongers (MI) is used to determine the diversity and distribution of the species, as nematodes are considered valuable indicators of soil ecosystem health.

Expected evolution of the indicator

The maturity index can be found between a range from 1-5. Low values (< 2) indicate a high level of disturbance with low soil food web structure, while intermediate values (2.5–3) indicate some soil food web maturity. High values (>3) indicate a well-structured and complex soil food web likely with connectivity and energy flow between trophic levels. The forest, which is an unaltered system, has the highest index, while perennial cultivation systems have higher rates than annual crops. Also, those organically managed systems had higher values than the respective conventional crops.

Data obtention

Required data:

It needs to be analysed only the first time (See Alentejo _Soil01).

Sampling plan:

Field sampling can be carried out using different tools and it will depend on the purpose of sampling. To avoid the dehydration, the samples are stored in plastic bags. Samples must be handled with care because nematodes may die from shock and friction. Finally, samples must be processed soon, because storage may cause changes in nematode numbers and composition (See Alentejo_Soil01).

Sampling calendar

This indicator will be produced every two years for a total of 10 years, coinciding with the evaluation of soil physical and chemical fertility (See Alentejo_Soil01).

Equipment

Additional field materials: A soil cylinder/core, zip bags, filter papers, a spatula and a balance (See Alentejo_Soil01).

External subcontracting

Yes. A trustable lab delivering analyses must be hired (See Alentejo_Soil01).

Calculation formula

MI= S v_i p_i, where v_i is the value c-p of the taxon i, and p_i is the proportion of the taxon from the sample.

References

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7.1.1.5 Water Holding Capacity

- **Code:** Alentejo_Soil05
- **Environmental Sector**: Soil / Soil Health
- **Units:** %

Meaning and importance of the indicator

The water holding capacity (WHC) is an important agronomic characteristic. The WHC of a soil is the maximum amount of water a soil can hold under standard conditions. Water holding capacity is affected by soil texture (sand, silt, and clay proportion) and soil structure (pore size, porosity, pores connectivity distribution and characteristics are essential determinants). A soil with a limited WHC reaches sooner the saturation than a soil with a higher WHC, especially between sandy soils as they tend to have low water storage capacity.

Expected evolution of the indicator

Soil structure can be improved by adding organic matter content to stimulate the soil porosity, which increases the water holding capacity. Also, a better water holding capacity of the soil can be accomplished by increasing soil organic carbon. However, deforestation and farming activities may decrease soil water holding capacity.

Data obtention

Required data:

It needs to be analysed the first time and every two years for 10 years (5 times) (See Alentejo_Soil01).

Sampling plan:

It could be challenging as the soil is affected by stoniness. Field sampling followed by lab analyses Field sampling followed by lab analyses (See Alentejo_Soil01). Collect the sample using a soil core, air dry it, break the aggregates and pass through a 2.0 mm sieve. Place the core containing soil in a water tray for saturation overnight and then place the sample in an oven at 105º C for 24-48 h. Finally, weight the core sample. For further instructions go to the Practical manual on measurement of soil physical properties, on page 34.

Sampling calendar

This indicator will be produced every two years for a total of 10 years, coinciding with the evaluation of soil physical and chemical fertility (See Alentejo_Soil01).

Equipment

Additional field materials: A soil cylinder /core, a tray, filter papers, a spatula, a sieve, water try, a balance and a drying oven (See Alentejo_Soil01). A metal square sampler will be used due to soil heterogeneity.

External subcontracting

If a reliable scale and an oven are available, WHC can be obtained very simply without the need of an expert lab. If not, a trustable lab delivering soil fertility analyses must be hired (See Alentejo_Soil01).

Calculation formula

WHC%= (Vw/Vt) * 100, while Vw is volume of water and Vt, is total volume of saturated soil.

References

- Honghong, L., Xingwu, D., Yifan, D., Ronghua, Z., Li, R. & Jiangcheng, H. (2023). Responses of soil water-holding capacity to environmental changes in alpine ecosystems across the southern Tibetan Plateau in the past 35–40 years. *Catena*, 222,106840. https://doi.org/10.1016/j.catena.2022.106840**.**
- Soil Quality Test Kit Guide. USDA Natural Resources Conservation Service. 1999. https://efotg.sc.egov.usda.gov/references/public/WI/Soil_Quality_Test_Kit_Guide.pdf
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7.1.2 Biodiversity Indicators

7.1.2.1 Aboveground Carbon Stored (Trees)

- **Code:** Alentejo_Bio01
- **Environmental Sector**: Forest Ecosystem Service
- **Units:** Tons C Ha^{-1}

Meaning and importance of the indicator

Above ground carbon stored in trees refers to the CO_2 sequestered from the atmosphere over time as a result of the tree accumulated growth. Carbon that is stored in the form of wood, bark, leaves, etc. is not returned to the atmosphere, contributing to climate change mitigation. When a tree dies or is cut down, the process is reversed, and carbon is re-emitted into the atmosphere as CO_2. The rate of this process depends on the rate of decomposition of wood. If the tree dies and remains in the forest, or if it is cut, the fate of the wood determines the CO_2 emission: it will be instantaneous if used as fuel or long-lasting if it is turned into furniture or any other long-lasting product. A tree can sequester carbon at a good rate for over a hundred years and can keep that carbon sequestered for centuries until its death.

Expected evolution of the indicator

The amount of carbon stored at the stand level increases over time as the trees grow, but eventually stabilizes. In the short and medium term, the rate of accumulation is rapid, but it slows down with age and reduced resources due to competition from neighbouring trees. The rate of carbon accumulation mainly depends on the species, the number of available resources (light, water, and nutrients), and the climate.

Data obtention

Required data:

Field sampling plots where different tree attributes are measured.

Sampling plan:

- Riparian corridor: Linear transects will be established with a width of 10 to 20 meters and a length sufficient to measure between 20 and 30 trees. The start and end of the transect will be marked with GPS and with a wooden or metal stake at each end. Within the sampling band, all trees with a diameter at breast height (DBH, hereafter) of at least 7.5 cm will be measured. For each living or dead tree, the species, diameter, and height will be recorded. The distance from the tree to the transect line and the distance from the start of the transect perpendicular to the tree will be measured. The location of the two ends of the transect, along with the position of each tree, will allow the plot to be located and the sampling to be repeated tree by tree.
- *Montado:* see Teruel_Bio02 from DEMO6.1.

Sampling calendar

Teruel_Bio02 from DEMO6.1.

Equipment

Teruel_Bio02 from DEMO6.1.

Calculation formula

Based on the species, DBH, and height, the aboveground carbon (kg dry weight) of each tree will be estimated using one of the following equations:

$$ABGC = a \cdot DBH^b \cdot H^c \cdot [C]$$

$$ABGC = a \cdot DBH^b \cdot [C]$$

Where:

- *ABGC,* is the tree aboveground biomass (kg dry weight)
- *DBH,* is the diameter at breast height (cm)
- *H,* is the tree height (m)
- *a*, *b* and *c,* are the parameters of the equation
- *[C],* is the carbon concentration (g C/g OM, Organic Matter)

It can be assumed that the concentration of C ([C]) is 0.5 g C/g OM. The parameters of the equation vary depending on the species. There is a repository of biomass equations by species in https://laboratoriforestal.creaf.cat/allometrapp/.

Finally, the aboveground carbon stored per hectare is calculated by summing the aboveground carbon (ABGC) of all trees and then multiplying by the factor that converts the area of the plot to a hectare.

References

- Pardé, J. 1988. Dendrométrie. par J. Pardé, J. Bouchon, 2e édition refondue. Nancy: École nationale du génie rural, des eaux et des forêts, 1988.
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7.1.2.2 Tree Regeneration

- **Code:** Alentejo_Bio02
- **Environmental Sector**: Forest Ecosystem Service
- **Units:** Trees Ha^{-1}

Meaning and importance of the indicator

After any restoration action in which invasive vegetation (riparian habitat) or shrub vegetation (montados) is removed, space is freed up that, despite the planting of native species, will likely allow vegetation to recover relatively easily. Monitoring the number of shoots, from seeds or resprouts, that appear—whether invasive or native—is crucial for determining the success or failure of the restoration effort in the medium and long term. This monitoring will help decide if additional reinforcement planting will be necessary in the future.

Expected evolution of the indicator

It is difficult for native species to recover the space previously occupied by invasive species such as giant reed and shrub species, as most of these are resprouting species. Natural regeneration of native species is expected to be very low, and survival is also likely to be low unless periodic control actions are taken against invasive or shrub vegetation. The subsequent survival of native seedlings and their likelihood of becoming adult trees will depend on the competition exerted by invasive or shrub species.

Possible relationship with other forest ecosystem service analyses

See Aboveground Carbon Stored Trees (Alentejo_Bio01).

Data obtention

Required data:

Field sampling plots where different tree attributes are measured.

Sampling plan:

In the same sampling plots (see Alentejo_Bio01)., a count of the number of individuals by size class by species, whether native or invasive, will be conducted. The classes will be: i) seedlings less than 50 cm in height; ii) seedlings between 50 and 100 cm in height; iii) individuals over 100 cm in height. If regeneration is very abundant, smaller-sized plots may be established.

Sampling calendar

Monitoring will be conducted just before the treatment, then at the beginning of each year for two years, and subsequently at 5 and 10 years. Sampling should be carried out during the autumn, following the summer, which is one of the most critical periods for the survival of individuals.

Calculation formula

The ratio between one hectare and the plot area will be used as the factor to multiply by the number of stems measured in the plot for each of the four size classes.

References

Pardé, J. 1988. Dendrométrie. par J. Pardé, J. Bouchon, 2e édition refondue. Nancy: École nationale du génie rural, des eaux et des forêts, 1988.

7.1.2.3 Overall Conservation Status of Habitats Under the EU Habitats Directive

- **Code:** Alentejo_Bio03
- **Environmental Sector**: Plant / Plant Biodiversity
- **Units:** A Multi-Component Indicator with Four Parameters: Natural Range, Area, Structure and Functions, And Future Prospects. The Overall Conservation Status Is Assessed in Four Categories: Favourable, Unfavourable-Inadequate, Unfavourable-Bad and Unknown.

Meaning and importance of the indicator

The European Habitats Directive protects 233 natural and semi-natural habitat types included in the Annex I (habitats of community interest) that are in danger of disappearing, have a small range or are outstanding examples of biogeographical regions of the European Union. These habitats require protection, sustainable use and restoration measures to achieve a favourable conservation status. Recently, the EU Nature restoration law calls to ensure no deterioration in the conservation trends and status of all protected habitats by 2030, especially those that improve river connectivity (e.g. 92A0), and forest and agricultural ecosystems (e.g. 6310). Article 17 of the Habitats Directive requires each EU Member to report every 6 years the conservation status and trends of all habitats of European interest at national biogeographic level, and Article 11 of the Directive requires to monitor the status of the habitats. The conservation status of a habitat is derived from four parameters: range; area covered by the habitat within its range; structure and functions, including the status of typical species; and future prospects. Restoration efforts must address all these four parameters.

Expected evolution of the indicator

The conservation status of the habitats of community interest is expected to improve, at least at small scale in the Demo zone, in particular for the habitats of community interest 6310 Dehesas with evergreen *Quercus* spp. and 92A0 *Salix alba* and *Populus alba* galleries. This improvement could be in the overall conservation status value, or only achieved in some of the four parameters analysed: range, area covered by the habitat, structure and functions, and future prospects.

Possible relationship with other biodiversity analyses

Area Of Habitats Restored (Alentejo_Bio11), Area of Habitats Under the EU Habitats Directive (Alentejo_Bio12), Area Covered by Invasive Species (Alentejo_Bio09), Linear Metres of Linear Landscape Elements Affected by Invasive Species (Alentejo_Bio10).

Data obtention

Required data:

- The conservation status of a habitat is defined when a habitat type or species is prospering (both in terms of quality and extent/population) and has good prospects of continuing to do so in the future. The methodology used to determine the conservation status of a habitat depends on the data available, and several criteria and thresholds for individual parameters and the overall conservation status. A detailed description of the methodology and data requirements can be found in Röschel et al. (2020) and DG Environment (2023). Conservation status is derived by individually assessing four parameters: natural range, area, structure and functions, and future prospects. The status of the range broadly reflects past and present changes in the natural distribution of the habitat. The status

of the area reflects past and present declines in its surface area. Structure and functions are based on the condition of specific structural features and habitat functions. Habitat structure is considered to be the physical components of a habitat while habitat functions are the ecological processes that occur at a number of temporal and spatial scales. Future prospects focus on the need for long-term maintenance of structure and functions and the need for area and range to be and to remain stable or increase in the foreseeable future.

Parameter	Conservation Status			
	Favourable ('green')	Unfavourable – Inadequate ('amber')	Unfavourable – Bad ('red')	*Unknown (insufficient information to make an assessment)*
Range (within the biogeographical/marine region concerned)	Stable (loss and expansion in balance) or increasing AND not smaller than the 'favourable reference range'	Any other combination	Large decrease: Equivalent to a loss of more than 1% per year within period specified by MS OR More than 10% below 'favourable reference range'	*No or insufficient reliable information available*
Area covered by habitat type within range[2]	Stable (loss and expansion in balance) or increasing AND not smaller than the 'favourable reference area' AND without significant changes in distribution pattern within range (if data available)	Any other combination	Large decrease in surface area: Equivalent to a loss of more than 1% per year (indicative value MS may deviate from if duly justified) within period specified by MS OR With major losses in distribution pattern within range OR More than 10% below 'favourable reference area'	*No or insufficient reliable information available*
Specific structure and functions (including typical species[3]**)**	Structures and functions (including typical species) in good condition and no significant deteriorations / pressures	Any other combination	More than 25% of the area is unfavourable as regards its specific structures and functions (including typical species)[4]	*No or insufficient reliable information available*
Future prospects (as regards range, area covered and specific structures and functions)	The habitats prospects for its future are excellent / good, no significant impact from threats expected; long-term viability assured	Any other combination	The habitats prospects are bad, severe impact from threats expected; long-term viability not assured.	*No or insufficient reliable information available*
Overall assessment of CS	All 'green' OR three 'green' and one 'unknown'	One or more 'amber' but no 'red'	One or more 'red'	Two or more 'unknown' combined with green or all 'unknown'

Sampling plan:

Field sampling and aerial images. Conservation status will be assessed according Röschel et al. (2020) and DG Environment (2023). In order to determine the overall conservation status of each habitat, it is necessary to assess several criteria and thresholds for the natural range, area, structure and functions, and future prospects. However, not all of this information is always available, and in most cases, the

assessment has to be made with scarce data, so the specific methodology for obtaining these four parameters and the overall conservation status cannot be specified in this document and should be assessed following Röschel et al. (2020) and DG Environment (2023).

Sampling calendar

The conservation status will be assessed almost before and after the restoration work and should be repeated every 3-6 years.

Equipment

The equipment required will depend on the selected variables and criteria chosen to assess the conservation status of a habitat. The current and available information and the ease with which certain information can be obtained for each habitat depends on several factors including the specific characteristics and idiosyncrasies of the habitat. It is therefore not possible to provide a list of the equipment required in this document.

Data sources

Copernicus, Direção-Geral do Território.

Calculation formula

See Röschel et al. (2020) and DG Environment (2023).

References

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- Dumitru, A., & Wendling, L. (2021). Evaluating the impact of nature-based solutions: Appendix of Methods. European Commission. 373 pg. Brussels. doi:10.2777/11361
- Official Journal of the European Union (1992). Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. https://eur-lex.europa.eu/eli/dir/1992/43/oj
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- Reference portal for reporting under Article 17 of the Habitats Directive: https://cdr.eionet.europa.eu/help/habitats_art17

7.1.2.4 Number Of Habitats Under the EU Habitats Directive

- **Code:** Alentejo_Bio04
- **Environmental Sector**: Plant / Plant Biodiversity
- **Units:** Ordinal Number

Meaning and importance of the indicator

The European Habitats Directive protects 233 natural and semi-natural habitat types listed in the Annex I (habitats of community interest) that are in danger of disappearing, have a small range or are outstanding examples of biogeographical regions of the European Union. These habitats require protection, sustainable use and restoration measures to achieve a favourable conservation status. In addition, the EU's Nature restoration law call for no deterioration in the conservation trends and status of all protected habitats by 2030, especially those that enhance river connectivity and forest and agricultural ecosystems, and the EU Biodiversity Strategy for 2030 calls for increased efforts to restore freshwater ecosystems and the natural functions of rivers, including the natural connectivity of rivers and their riparian and floodplain areas, in order to achieve a favourable conservation status for rivers, lakes and alluvial habitats and the species living in these habitats that are protected by European Directives.

Expected evolution of the indicator

The number of habitats under the EU Habitats Directive is expected to increase, in particular those that occurred in the past in the selected degraded zones (e.g. 6310, 92A0), and those that are somewhat related to the target habitats (e.g. 91E0, 92D0, 6430, 6420…).

Possible relationship with other biodiversity analyses

Area Of Habitats Restored (Alentejo_Plant1), Area Covered by Invasive Species (Alentejo_Plant9), Linear Metres of Linear Landscape Elements Affected by Invasive Species (Alentejo_Plant10).

Data obtention

Required data:

- Number of all habitats of community interest before and after the restoration works.

Sampling plan:

Field sampling. Field surveys will be carried out before and after restoration work begins to determine the number of habitats of community interest.

Sampling calendar

The number of habitats under the EU Habitats Directive will be assessed almost before and after the restoration work and should be repeated every 3-6 years.

References

- Alves, J., Santo, M. D. E., Costa, J. C., Gonçalves, J. H. C., & Lousa, M. F. (1998). Habitats naturais e seminaturais de Portugal Continental. Instituto da Conservação da Natureza, Lisboa.

- Dumitru, A., & Wendling, L. (2021). Evaluating the impact of nature-based solutions: A handbook for practitioners. European Commission. 552 pg. Brussels. doi:10.2777/244577
- Dumitru, A., & Wendling, L. (2021). Evaluating the impact of nature-based solutions: Appendix of Methods. European Commission. 373 pg. Brussels. doi:10.2777/11361
- Ichter, J. Evans, D. & Richard, D. (2014). Terrestrial habitat mapping in Europe: an overview. European Environment Agency, Luxembourg, 144 pg. doi:10.2800/11055
- Official Journal of the European Union (1992). Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. https://eur-lex.europa.eu/eli/dir/1992/43/oj
- Official Journal of the European Union (2024). Regulation (EU) 2024/1991 of the European Parliament and of the Council of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869 (Text with EEA relevance). https://eur-lex.europa.eu/eli/reg/2024/1991/oj
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7.1.2.5 Number Of Planted Trees

- **Code:** Alentejo_Bio05
- **Environmental Sector**: Plant / Plant Biodiversity
- **Units:** Ordinal Number

Meaning and importance of the indicator

The EU Biodiversity Strategy for 2030 calls for increased efforts to restore freshwater ecosystems and the natural functions of rivers. This restoration should focus on reestablishing the natural connectivity of rivers, their riparian zones, and floodplains. Such measures are essential to achieve a favourable conservation status for rivers and alluvial habitats, as well as the species and habitats of community interest. In addition, a key goal of the strategy is to restore at least 25,000 km of free-flowing rivers and to plant at least 3 billion additional trees in the Union by 2030, in full respect of ecological principles. The number of trees planted is an important indicator of restoration progress.

Expected evolution of the indicator

The expected trend in the number of trees planted (total, per hectare or linear meter) is an increase over the restoration actions.

Possible relationship with other biodiversity analyses

Area Of Habitats Restored (Alentejo_Bio01), Tax of Planted Trees Surviving Per Year (Alentejo_Bio07), Area Covered by Invasive Species (Alentejo_Bio09), Linear Metres of Linear Landscape Elements Affected by Invasive Species (Alentejo_Bio10).

Data obtention

Required data:

- Number of trees planted per day for the duration of the restoration works.

Sampling plan:

Field sampling. The trees planted should be counted every day to determine the total number of trees planted (or total trees planted per hectare or linear meter).

Sampling calendar

Over the restoration actions the trees planted should be counted every day to determine the total number of trees planted (or total trees planted per hectare or linear meter).

References

- Dumitru, A., & Wendling, L. (2021). Evaluating the impact of nature-based solutions: A handbook for practitioners. European Commission. 552 pg. Brussels. doi:10.2777/244577
- Dumitru, A., & Wendling, L. (2021). Evaluating the impact of nature-based solutions: Appendix of Methods. European Commission. 373 pg. Brussels. doi:10.2777/11361
- Official Journal of the European Union (2024). Regulation (EU) 2024/1991 of the European Parliament and of the Council of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869 (Text with EEA relevance). https://eur-lex.europa.eu/eli/reg/2024/1991/oj

7.1.2.6 Number Of Planted Shrubs

- **Code:** Alentejo_Bio06
- **Environmental Sector**: Plant / Plant Biodiversity
- **Units:** Ordinal Number

Meaning and importance of the indicator

The EU Biodiversity Strategy for 2030 calls for increased efforts to restore freshwater ecosystems and the natural functions of rivers. This restoration should focus on reestablishing the natural connectivity of rivers, their riparian zones, and floodplains. Such measures are essential to achieve a favourable conservation status for rivers and alluvial habitats, as well as the species and habitats of community interest. In addition, a key goal of the strategy is to restore at least 25,000 km of free-flowing rivers and to plant at least 3 billion additional trees in the Union by 2030, in full respect of ecological principles. The number of shrubs planted is an important indicator of restoration progress.

Expected evolution of the indicator

The expected trend in the number of shrubs planted (total, per hectare or linear meter) is an increase over the restoration actions.

Possible relationship with other biodiversity analyses

Area Of Habitats Restored (Alentejo_Bio11), Tax of Planted Shrubs Surviving Per Year (Alentejo_Bio08), Area Covered by Invasive Species (Alentejo_Bio09), Linear Metres of Linear Landscape Elements Affected by Invasive Species (Alentejo_Bio10).

Data obtention

Required data:

- Number of shrubs planted per day for the duration of the restoration works.

Sampling plan:

Field sampling. The shrubs planted should be counted every day to determine the total number of shrubs planted (or total shrubs planted per hectare or linear meter).

Sampling calendar

Over the restoration actions the shrubs planted should be counted every day to determine the total number of trees planted (or total trees planted per hectare or linear meter).

References

- Dumitru, A., & Wendling, L. (2021). Evaluating the impact of nature-based solutions: A handbook for practitioners. European Commission. 552 pg. Brussels. doi:10.2777/244577
- Dumitru, A., & Wendling, L. (2021). Evaluating the impact of nature-based solutions: Appendix of Methods. European Commission. 373 pg. Brussels. doi:10.2777/11361
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7.1.2.7 Tax of Planted Trees Survival rate

- **Code:** Alentejo_Bio07
- **Environmental Sector**: Plant / Plant Biodiversity
- **Units:** Percentage

Meaning and importance of the indicator

The number of trees planted is an important indicator to be applied over the restoration process, but once the restoration is complete, a key indicator to evaluate the success and effectiveness of the plantations is to determine the survival rate of planted trees over time. Tree survival rate refers to the percentage of trees that remain alive after a specific period of time following planting.

Expected evolution of the indicator

Survival rates of planted trees is expected to decrease over time, with higher rate of decrease in the first year, followed by a gradual stabilization with lower decrease. Survival rates differed significantly between territories, species, habitat types, elevation, soil types, climatology, planting methods, pre- and post-treatments, plant densities, etc. Therefore, expected or optimal values of tree survival cannot be specified. However, if the mortality rate is high, it is essential to identify the underlying causes and plant more plants but implementing measures to avoid any potential errors that may have contributed to the plant mortality.

Possible relationship with other biodiversity analyses

Area Of Habitats Restored (Alentejo_Bio11), Number of Planted trees (Alentejo_Bio05), Area Covered by Invasive Species (Alentejo_Bio09), Linear Metres of Linear Landscape Elements Affected by Invasive Species (Alentejo_Bio10).

Data obtention

Required data:

- Number of planted trees that die each year after the restoration works.

Sampling plan:

Field sampling followed. The number of plants that die each year after plantation is complete, will always be counted at the same time of the year, preferably after the dry season, and avoiding winter for deciduous species to avoid confusion between dead and dormant individuals. Ten permanent transects of 100 linear meters each will be randomly distributed along the planted zone and delimited with permanent markers at the beginning and the end. All planted trees within the transect will be counted and classified as live or dead, indicating the species if more than one species is present.

Sampling calendar

The proposed sampling plan will be conducted every year for 10 years, prior to the implementation of restoration actions and subsequently in years following the completion of restoration.

Equipment

Some small field materials to mark the limits of the permanent transects.

Calculation formula

Survival rate (SR) is the number of living trees (NLT) at the time of data collection, divided by the total number of planted trees (NTPT):

$$SR = NLT/ NTPT * 100$$

The overall survival rate is calculated as the mean value of the 10 transects.

References

- Sutherland, W. J. (Ed.). (2006). Ecological census techniques: a handbook. Cambridge university press.
- Southwood, T. R. E., & Henderson, P. A. (2009). Ecological methods. John Wiley & Sons.
- Wheater, C. P., Bell, J. R., & Cook, P. A. (2020). Practical field ecology: a project guide. John Wiley & Sons.

7.1.2.8 Tax of Planted Shrubs Survival rate

- **Code:** Alentejo_Bio08
- **Environmental Sector**: Plant / Plant Biodiversity
- **Units:** Percentage

Meaning and importance of the indicator

The number of shrubs planted is an important indicator to be applied over the restoration process, but once the restoration is complete, a key indicator to evaluate the success and effectiveness of the plantations is to determine the survival rate of planted shrubs over time. Shrub survival rate refers to the percentage of shrubs that remain alive after a specific period of time following planting.

Expected evolution of the indicator

Survival rates of planted shrubs is expected to decrease over time, with higher rate of decrease in the first year, followed by a gradual stabilization with lower decrease. Survival rates differed significantly between territories, species, habitat types, elevation, soil types, climatology, planting methods, pre- and post-treatments, plant densities, etc. Therefore, expected or optimal values of shrub survival cannot be specified. However, if the mortality rate is high, it is essential to identify the underlying causes and plant more plants but implementing measures to avoid any potential errors that may have contributed to the plant mortality.

Possible relationship with other biodiversity analyses

Area Of Habitats Restored (Alentejo_Bio11), Number of planted Shrubs (Alentejo_Bio6), Area Covered by Invasive Species (Alentejo_Bio09), Linear Metres of Linear Landscape Elements Affected by Invasive Species (Alentejo_Bio10).

Data obtention

Required data:

- Number of planted shrubs that die each year after the restoration works.

Sampling plan:

Field sampling followed. The number of plants that die each year after plantation is complete, will always be counted at the same time of the year, preferably after the dry season, and avoiding winter for deciduous species to avoid confusion between dead and dormant individuals. Ten permanent transects of 100 linear meters each will be randomly distributed along the planted zone and delimited with permanent markers at the beginning and the end. All planted shrubs within the transect will be counted and classified as live or dead, indicating the species if more than one species is present.

Sampling calendar

The proposed sampling plan will be conducted every year for 10 years, prior to the implementation of restoration actions and subsequently in years following the completion of restoration.

Equipment

Some small field materials to mark the limits of the permanent transects.

Calculation formula

Survival rate (SR) is the number of living shrubs (NLT) at the time of data collection, divided by the total number of planted shrubs (NTPT):

$$SR = NLT/ NTPT * 100$$

The overall survival rate is calculated as the mean value of the 10 transects.

References

- Sutherland, W. J. (Ed.). (2006). Ecological census techniques: a handbook. Cambridge university press.
- Southwood, T. R. E., & Henderson, P. A. (2009). Ecological methods. John Wiley & Sons.
- Wheater, C. P., Bell, J. R., & Cook, P. A. (2020). Practical field ecology: a project guide. John Wiley & Sons.

7.1.2.9 Area Covered by Invasive Species

- **Code:** Alentejo_Bio09
- **Environmental Sector**: Plant / Plant Biodiversity
- **Units:** Hectares (Ha)

Meaning and importance of the indicator

Invasive species are alien species whose introduction or spread has been shown to threaten or adversely affect biodiversity and related ecosystem services, as well as having other social and economic impacts that should be prevented. Invasive alien species are one of the major threats to biodiversity and related ecosystem services, including severe impacts on native species and ecosystem structure and function because they can cause habitat alteration, predation, competition, disease transmission, replacement of native species, or cause genetic effects through hybridisation. Furthermore, invasive alien species can also have a significant negative impact on human health and the economy. The area covered by invasive species is one of the most important indicators for monitoring the spread of an invasive species, for conducting surveillance or management of invasive species, for assessing the cost-area relationships of management actions, or for evaluating the success and effectiveness of eradication actions.

Expected evolution of the indicator

The area covered by invasive species is expected to decrease over time, with high decrease in the first year (with an optimal value of 0% or close to 0%), but in the following years this value may increase slightly (due to seed bank germination, the loss of some roots, rhizomes, or seedlings in the soil, or to a recolonization from neighbouring areas), and a new eradication measures should be carried out to have optimal values of area covered by invasive species of 0% or close to 0%.

Possible relationship with other biodiversity analyses

Area Of Habitats Restored (Alentejo_Bio11), Number of Planted trees (Alentejo_Bio05), Number of planted Shrubs (Alentejo_Bio06), Tax of Planted Trees Surviving Per Year (Alentejo_Bio07), Tax of Planted Shrubs Surviving Per Year (Alentejo_Bio08), Linear Metres of Linear Landscape Elements Affected by Invasive Species (Alentejo_Bio10).

Data obtention

Required data:

- Area covered by invasive species every year.

Sampling plan:

Field sampling followed by lab analyses. The area covered by invasive species will always be counted at the same time of the year, preferably after the dry season and avoiding winter for deciduous species to avoid confusion between dead and dormant individuals. We propose two methods for estimating the area covered by invasive species:

- A visual inspection of the entire restored area and mapping the zones with the presence of invasive species using a GPS and GIS.

- Ten permanent transects will be randomly distributed along the invaded zone and delimited with permanent markers at the beginning and the end. Each transect will include 100 linear meters of the river course (including both river margins). The area covered by invasive species within each transect will be recorded, indicating the species if there are more than one invasive species is present.

Sampling calendar

The proposed sampling plan will be carried out annually for 10 years prior to the implementation of restoration measures and then in the years following the completion of restoration.

Equipment

The most recent aerial photographs will be obtained from repositories at a high resolution (preferably at 1:2.500 to 1:10.000 scale). A standard GPS or smartphone with GPS. A GIS program (ArcGIS, QGIS, ...). Some small field materials to mark the limits of the permanent transects.

Data sources

Copernicus, Direção-Geral do Território.

Calculation formula

In the case of transects, the total area covered by invasive species is calculated as the mean value of the 10 transects.

References

- Marchante H, Morais M, Freitas H, Marchante E (2014). Guia prático para a identificação de Plantas Invasoras em Portugal. Coimbra. Imprensa da Universidade de Coimbra. 207 pp.
- Official Journal of the European Union (2014). Regulation (EU) No 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species. https://eur-lex.europa.eu/eli/reg/2014/1143/oj
- Official Journal of the European Union (2022). Commission Implementing Regulation (EU) 2022/1203 of 12 July 2022 amending Implementing Regulation (EU) 2016/1141 to update the list of invasive alien species of Union concern. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32022R1203
- Official Journal of the European Union (2024). Regulation (EU) 2024/1991 of the European Parliament and of the Council of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869 (Text with EEA relevance). https://eur-lex.europa.eu/eli/reg/2024/1991/oj
- Presidência do Conselho de Ministros. Decreto-Lei n.º 92/2019, de 10 de julho. Diário da República n.º 130/2019, Série I de 2019-07-10, páginas 3428 - 3442
- For invasive species in Portugal: Plantas invasoras em Portugal (http://invasoras.pt). Accessed 7/09/2024.
- For invasive species in Europe: Invasive alien species (https://environment.ec.europa.eu/topics/nature-and-biodiversity/invasive-alien-species_en). Accessed 7/09/2024.

7.1.2.10 Linear Metres of Linear Landscape Elements Affected by Invasive Species

- **Code:** Alentejo_Bio10
- **Environmental Sector**: Plant / Plant Biodiversity
- **Units:** Metres (M)

Meaning and importance of the indicator

Invasive species are alien species whose introduction or spread has been shown to threaten or adversely affect biodiversity and related ecosystem services, as well as having other social and economic impacts that should be prevented. Invasive alien species are one of the major threats to biodiversity and related ecosystem services, including severe impacts on native species and ecosystem structure and function because they can cause habitat alteration, predation, competition, disease transmission, replacement of native species, or cause genetic effects through hybridisation. Furthermore, invasive alien species can also have a significant negative impact on human health and the economy. Rivers and their associated vegetation are one of the most invaded habitats by alien species. These habitats appear as linear elements in the landscape. Therefore, the linear metres of linear landscape elements affected by invasive species is a good indicator for monitoring the spread of an invasive species, for implementing surveillance or management of invasive species, for assessing the cost-area relationships of the management actions, or for evaluating the success and effectiveness of eradication actions.

Expected evolution of the indicator

The linear metres of linear landscape elements affected by invasive species is expected to decrease over time, with high a decrease in the first year (with an optimal value of 0 m or close to 0 m), but in the following years this value may increase slightly (due to seed bank germination, the loss of some roots, rhizomes, or seedlings in the soil, or recolonization from neighbouring areas), and a new eradication measures should be carried out to have optimal values of the area covered by invasive species of 0 m (or close to 0%).

Possible relationship with other biodiversity analyses

Area Of Habitats Restored (Alentejo_Bio11), Number of Planted trees (Alentejo_Bio05), Number of planted Shrubs (Alentejo_Bio06), Tax of Planted Trees Surviving Per Year (Alentejo_Bio07), Tax of Planted Shrubs Surviving Per Year (Alentejo_Bio08); Area Covered by Invasive Species (Alentejo_Bio09).

Data obtention

Required data:

- Linear metres of linear landscape elements affected by invasive species every year.

Sampling plan:

Field sampling followed by lab analyses. the linear metres of linear landscape elements affected by invasive species will always be sampled at the same time of the year, preferably after the dry season and avoiding winter for deciduous species to avoid confusion between dead and dormant individuals. A visual inspection of all restored rivers will be carried out, and the zones with the presence of invasive species will be recorded with the aid of a GPS, with each species of invasive species being identified

separately. This data will then be mapped in a GIS to determine the linear metres of linear landscape elements affected by invasive species.

Sampling calendar

The proposed sampling plan will be carried out annually for 10 years prior to the implementation of restoration measures and then in the years following the completion of restoration.

Equipment

The most recent aerial photographs will be obtained from repositories at a high resolution (preferably at 1:2.500 to 1:10.000 scale). A standard GPS or smartphone with GPS. A GIS program (ArcGIS, QGIS, ...).

Data sources

Copernicus, Direção-Geral do Território.

References

- Marchante H, Morais M, Freitas H, Marchante E (2014). Guia prático para a identificação de Plantas Invasoras em Portugal. Coimbra. Imprensa da Universidade de Coimbra. 207 pp.
- Official Journal of the European Union (2014). Regulation (EU) No 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species. https://eur-lex.europa.eu/eli/reg/2014/1143/oj
- Official Journal of the European Union (2022). Commission Implementing Regulation (EU) 2022/1203 of 12 July 2022 amending Implementing Regulation (EU) 2016/1141 to update the list of invasive alien species of Union concern. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32022R1203
- Official Journal of the European Union (2024). Regulation (EU) 2024/1991 of the European Parliament and of the Council of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869 (Text with EEA relevance). https://eur-lex.europa.eu/eli/reg/2024/1991/oj
- Presidência do Conselho de Ministros. Decreto-Lei n.º 92/2019, de 10 de julho. Diário da República n.º 130/2019, Série I de 2019-07-10, páginas 3428 - 3442
- For invasive species in Portugal: Plantas invasoras em Portugal (http://invasoras.pt). Accessed 7/09/2024.
- For invasive species in Europe: Invasive alien species (https://environment.ec.europa.eu/topics/nature-and-biodiversity/invasive-alien-species_en). Accessed 7/09/2024.

7.1.2.11 **Area Of Habitats Restored**

- **Code:** Alentejo_Bio11
- **Environmental Sector**: Plant / Plant Biodiversity
- **Units:** Hectares (Ha) Or Percentage (%)

Meaning and importance of the indicator

The EU Nature restoration law urges to restore degraded habitats, especially those that improve river connectivity and forest and agricultural ecosystems. The area of habitats restored is a simple and effective indicator to assess the success, evolution and extent of planned restoration actions of target habitats. It is calculated as the extent (in hectares) of restored focal habitat area, or as a proportion of the total restored area of the planned restoration area of a given habitat type.

Expected evolution of the indicator

For each of the habitat types to be restored, the indicator values should reach the area of declared objectives (or KPIs): 10 km of riparian corridor restored (KPI1) and 1 ha of Montado (KPI1), or the 100% of restored area.

Possible relationship with other biodiversity analyses

Overall Conservation Status of Habitats Under the EU Habitats Directive (Alentejo_Bio3), Number of Habitats Under the EU Habitats Directive (Alentejo_Bio04), Number of Planted trees (Alentejo_Bio05), Number of planted Shrubs (Alentejo_Bio06), Area Covered by Invasive Species (Alentejo_Bio09), Linear Metres of Linear Landscape Elements Affected by Invasive Species (Alentejo_Bio10).

Data obtention

Required data:

- Area (in hectares or km^2) of the restored habitat types.

Sampling plan:

Field sampling and aerial images. Once the restoration work begins, the area of restored focal habitats will be determined through fieldwork and aerial images, and the extent of the restored area will be mapped using a Geographic Information System (GIS). Field data will be incorporated into a GIS to calculate the restored area.

Sampling calendar

The restored focal habitats area will be determined every month/trimester, depending on the progress of the restoration work.

Equipment

The most recent aerial photographs will be obtained from repositories at a high resolution (preferably at 1:2.500 to 1:10.000 scale). A standard GPS or smartphone with GPS. A GIS program (ArcGIS, QGIS, ...).

Data sources

Copernicus, Direção-Geral do Território.

References

- Alves, J., Santo, M. D. E., Costa, J. C., Gonçalves, J. H. C., & Lousa, M. F. (1998). Habitats naturais e seminaturais de Portugal Continental. Instituto da Conservação da Natureza, Lisboa.
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- Dumitru, A., & Wendling, L. (2021). Evaluating the impact of nature-based solutions: Appendix of Methods. European Commission. 373 pg. Brussels. doi:10.2777/11361
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- Official Journal of the European Union (2024). Regulation (EU) 2024/1991 of the European Parliament and of the Council of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869 (Text with EEA relevance). https://eur-lex.europa.eu/eli/reg/2024/1991/oj

7.1.2.12 **Area Of Habitats Under the EU Habitats Directive**

- **Code:** Alentejo_Bio12
- **Environmental Sector**: Plant / Plant Biodiversity
- **Units:** Hectares (Ha)

Meaning and importance of the indicator

The European Habitats Directive protects 233 natural and semi-natural habitat types included in the Annex I (habitats of community interest) that are in danger of disappearing, have a small range or are outstanding examples of biogeographical regions of the European Union. These habitats require protection, sustainable use and restoration measures to achieve a favourable conservation status. Recently, the EU Nature restoration law called for the restoration of degraded habitats, especially those that improve river connectivity (e.g. 92A0), and forest and agricultural ecosystems (e.g. 6310). Article 17 of the Habitats Directive requires each EU Member to report every 6 years the conservation status and trends of all habitats of European interest at national biogeographic level. One of the most commonly used and useful criteria for assessing the conservations status of habitats is the area covered by each habitat of community interest. The area of habitats under the European Habitats Directive is therefore a basic indicator for assessing the extent, conservation status, trends and success of restoration measures, and the implementation of EU biodiversity strategies and goals.

Expected evolution of the indicator

It is expected an increase int the area and conservation status of the habitats of community interest, in particular:
- In the Montados: 6310 Dehesas with evergreen *Quercus* spp.
- In the Riparian corridor: 92A0 *Salix alba* and *Populus alba* galleries.

Possible relationship with other biodiversity analyses

Area Of Habitats Restored (Alentejo_Plant1), Number of Habitats Under the EU Habitats Directive (Alentejo_Plant4).

Data obtention

Required data:

- Area (in hectares or km^2) of all habitats of community interest (especially 6310 and 92A0).

Sampling plan:

Field sampling and aerial images. Once the restoration work begins, the area of all habitats of community interest (with particular emphasis on habitat types 6310 and 92A0) will be determined by fieldwork and the aid of aerial images and GPS. The field data will be incorporated into a Geographic Information System (GIS) to calculate the area of each habitat of community interest.

Sampling calendar

The cartography of all habitats of community interest and their area will be determined every month/trimester, depending on the progress of the restoration work.

Equipment

The most recent aerial photographs will be obtained from repositories at a high resolution (preferably at 1:2.500 to 1:10.000 scale). A standard GPS or smartphone with GPS. GIS program (ArcGIS, QGIS, ...).

Data sources

Copernicus, Direção-Geral do Território.

References

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7.1.3 Energy Indicators

7.1.3.1 Energy use in agriculture

- **Code**: Alentejo_Energy01
- **Environmental Sector**: Energy
- **Units**: kWh/m^2 land

Meaning and importance of the indicator

"Energy use in agriculture" measures the amount of electrical, fuel and heat energy consumed in agricultural activities, including irrigation, lighting, heating, cooling, and operating machinery and equipment. This indicator is crucial for assessing the energy efficiency and environmental impact of agricultural practices. High energy consumption can indicate inefficiencies, leading to increased operational costs and higher carbon emissions. Conversely, optimizing energy use enhances sustainability by reducing greenhouse gas emissions and lowering production costs, which is vital for the economic viability of farming. Monitoring this indicator helps identify opportunities for implementing energy-saving technologies and practices, such as precision agriculture, renewable energy integration, and efficient irrigation systems. Ultimately, reducing energy use in agriculture supports broader sustainability goals, including resource conservation, climate change mitigation, and the promotion of eco-friendly farming practices.

Expected evolution of the indicator

The expected evolution of the indicator "Energy use in agriculture" is towards greater efficiency and sustainability, driven by technological advancements, economic considerations, and environmental regulations.

Data obtention method

Field measurement or assessment based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

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ANNEX H: DEMO8

DEMO8: Gediz Delta

Soil contamination by saline intrusion from the sea is a paramount issue in the Gediz Delta in Izmir (Türkiye). DEMO 8 presents a comprehensive plan for coastal wetland restoration, integrating various NBS to address environmental and social challenges. The initiative begins with the deployment of riparian buffer areas, primarily aimed at diversifying habitats and enhancing native vegetation. The riparian buffers provide additional protection to water quality as a secondary pollution removal mechanism. Next, diversion channels branching from the main open diversion channel are constructed to facilitate the inflow of freshwater into the existing wetlands. This measure aims to reduce salinity levels and promote a healthier habitat for indigenous flora and fauna. Additionally, green corridors will be developed within these diversion channels to enhance ecological connectivity. Invasive alien species control will be prioritised, targeting species that consume excessive water and degrade habitats along with techniques for fauna refuge and nesting (artificial nests for bird species on the roofs of shelters, bird perches), restoring native vegetation and reintroduction of native fauna, such as buffaloes, to enhance biodiversity and ecosystem resilience within the delta region. Sustainable communal grazing practices will be introduced to regulate animal husbandry, alleviating ecological pressures on the delta ecosystem.

DEMO8: Gediz Delta	Sector	Code
Soil Physical and Chemical Fertility	Soil	Gediz_Soil01
Soil Organic Carbon Content	Soil	Gediz_Soil02
Soil Bulk Density (ρ)	Soil	Gediz_Soil03
The Maturity Index of Bongers (Mi)	Soil	Gediz_Soil04
Soil Pollution by Arsenic (As)	Soil	Gediz_Soil05
Arsenic (As) Concentration in Pastures	Soil	Gediz_Soil06
Water Holding Capacity	Soil	Gediz_Soil07
Effective Wastewater Treatment (WWTeff)	Water	Gediz_Water01
Reclaimed Water Production (RWP)	Water	Gediz_Water02
Water Provision by the Ecosystem (Wavailable)	Water	Gediz_Water03
Water Availability (WA)	Water	Gediz_Water04
Effluent Pollutant Removal (EPR)	Water	Gediz_Water05
Aquifer Surface Ratio with Excessive Nitrate (ASREN)	Water	Gediz_Water06
Aquifer Surface Ratio with Excessive Arsenic (ASREA)	Water	Gediz_Water07
Increased Groundwater Recharge (GWR)	Water	Gediz_Water08
Infiltration Rate (IR)	Water	Gediz_Water09
Average Groundwater Electrical Conductivity (GWEC)	Water	Gediz_Water10
Area Of Habitats Restored	Biodiversity	Gediz_Bio01
Number Of Focal Habitat Specialist Species	Biodiversity	Gediz_Bio02
Focus Or Key Habitat(S) Area	Biodiversity	Gediz_Bio03
Tree Biomass Removed	Biodiversity	Gediz_Bio04
Biogas Generation Due to Wastewater Treatment	Energy	Gediz_Energy01
Energy Consumption of Biogas Production System	Energy	Gediz_Energy02
PV Electricity Generation and Total Land Used	Energy	Gediz_Energy03

8.1.1 Soil Indicators

8.1.1.1 Soil Physical and Chemical Fertility

- **Code:** Gediz_Soil01
- **Environmental Sector**: Soil / Soil Health
- **Units:** A Multi-Component Indicator. Diverse Units for Specific Components

Meaning and importance of the indicator

Soil productive capacity (a key soil ecosystem service) is the result of complex interactions between biological, chemical and physical properties. Achieving and maintaining appropriate levels of physical

and chemical soil fertility is of paramount importance for sustainable cropland management and, at large scale, for food security. Nutrients naturally arrive to soil from geological materials, from water, form atmospheric deposition and from decomposition of plant and animal residues. Nutrient availability to crops is significantly affected by soil acidity (pH), and nutrient presence in the soil solution is highly dependent on soil texture and soil cation exchange capacity; water provision to plants is notably improved by soil organic matter. Soil electrical conductivity warns about soil salinity, a serious risk for crops under Mediterranean conditions. Soil analysis is the basic tool to evaluate soil fertility and to guide farmers towards sustainable management.

Expected evolution of the indicator

There are recommended ranges and critical values for most of the soil properties to be analysed. For agricultural soils, together with the results of analyses, agricultural laboratories provide an evaluation of the level of each analysed parameter (deficient – correct – excessive or similar). The value of each parameter should evolve towards these reference values and will guide gardeners in designing fertilization or any other correction. Special attention will be paid in this case to the evolution of soil salinity and electrical conductivity. An approach to tolerable conductivity levels in soil, depending on soil texture (provided in the analyses) can be found in https://www.agric.wa.gov.au/soil-salinity/measuring-soil-salinity. A more extensive report to help the interpretation of soil salinity analyses can be found at: https://extension.uga.edu/publications/detail.html?number=C1019&title=soil-salinity-testing-data-interpretation-and-recommendations

Data obtention

Required data:

To be analysed at each soil sampling campaign: Stoniness and soil texture (% sand; % clay; % silt); textural class; pH; Electrical conductivity (CEC); cations (Ca, Mg, Na), Chloride (Cl^-), Total Soluble Salts (TSS), Sodium Adsorption Ratio (SAR), Nitrate-nitrogen (NO_3-N), Sulphate (SO_4^{2-}), Total organic carbon (%, dry soil basis); Carbonates; Total nitrogen (Kjeldahl); Available phosphorus (Olsen); Cation exchange capacity; Interchangeable); Micronutrients (Fe, Zn, Mn)

Sampling plan:

Field sampling followed by lab analysis. Soil will always be sampled at the same moment of the year, preferably in the month when the groundwater table is expected to be at its lowest level (set your favourite month).

Since the main objective of the action is reducing groundwater salinity and recovering pastures for grazing, soils will be sampled in the central area of the plain that will be affected by the provision of fresh water for desalination.

The work zone spans a surface area of about 500 ha. In this field and, using a virtual regular square mesh (50 x 50 m) that can be projected on the field map, randomly choose 50 squares and sample each square in the centre. Put each soil sample in a closed plastic zip bag duly labelled with the date and coordinates of the point.
The resulting soil samples will be sent to an expert lab for analysis as soon as possible. The soil lab must have been previously consulted for instructions about the preparation of the samples before shipping.

Sampling calendar

The area will be sampled in the proposed dates every two years for 10 years (5 times).

Equipment

Samples will be extracted from soil with soil borers of known and constant (the same for all samples at each sampling campaign) depth and diameter. The borer should be 15 cm long and the recommended diameter is 5 cm.
Some providers of these soil borers are: https://www.ams-samplers.com/soil-augers/; https://www.vanwalt.com/equipment/telescoping-augers/. Any other equivalent sampler of these dimensions is acceptable (but try to respect the 15 cm depth)
You will also need a small gardening spade and zip bags

External subcontracting

Yes. A trustable lab delivering soil fertility analyses must be hired.

References

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- For soil fertility in crops: https://www.agromatica.es/referencia-de-un-analisis-de-suelo/; https://www.fbn.com/community/blog/how-to-read-a-soil-analysis-report; https://pubs.nmsu.edu/_circulars/CR676/

8.1.1.2 Soil Organic Carbon Content

- **Code:** Gediz_Soil02
- **Environmental Sector**: Soil / Soil Health
- **Units:** %C

Meaning and importance of the indicator

Soil organic carbon (SOC) constitutes about 58% of soil organic matter (SOM) and is a chief indicator of soil health. SOC enters the soil through the decomposition of plant and animal residues, root exudates and living and dead soil biota (including microorganisms). Plant carbon comes from the C that plants remove from the atmosphere (photosynthesis), and animals obtain C from plant ingestion; therefore, the final origin of SOC is atmospheric CO_2. The stable fraction of SOC (the soil fraction that stays in soil for longtime periods and resists microbial attack) is considered "sequestered carbon" and contributes to climate change mitigation.

Expected evolution of the indicator

Increasing % C over time until reaching the highest values reported for this indicator in the pastures of the Gediz Delta.

Data obtention

Sampling plan:

Soil organic carbon analysis is included in the analyses of soil physical and chemical fertility (Gediz_Soil01)

Sampling calendar

This indicator will be produced every two years for a total of 10 years, coinciding with the evaluation of soil physical and chemical fertility (Gediz_Soil01).

Equipment

See Gediz_Soil01.

External subcontracting

No. Analysis included in general analyses of soil physical and chemical fertility (Gediz_Soil01).

References

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8.1.1.3 Soil Bulk Density (ρ)

- **Code:** Gediz_Soil03
- **Environmental Sector**: Soil / Soil Health
- **Units:** G Cm^{-3}

Meaning and importance of the indicator

Bulk density indicates the degree of soil compaction. Bulk density is inversely related to soil porosity which allows air and water to move through the soil and facilitates plant root penetration through the soil.

Expected evolution of the indicator

Bulk density is affected by soil texture (sand, silt, and clay proportion) and organic matter content. Fine-textured soils (such as silt and clay loams) with good structure have lower bulk density compared to sandy soils. According to data from the EU Joint Research Centre, mean European values for soil bulk density are 1.26 g cm^{-3} for arable lands, 1.23 g cm^{-3} for permanent crops, and 1.14 cm^{-3} for heterogeneous agricultural areas. Bulk density should increase as soil organic carbon increases.

Data obtention

Sampling plan:

Field sampling followed by very a very simple analysis. Soil will always be sampled at the same moment of the year, preferably when the underground water table is expected to be at its lowest level (set your favourite month). Try to match the bulk density sampling date with the fertility sampling date (Gediz_Soil01).

For soil bulk density assessment, you will follow the sampling pattern proposed for soil fertility, which will result in 50 sampling points, that will be established in the vicinity of the points that you have already sampled for fertility

A detailed explanation of the sampling method is provided in the USDA Soil Quality Test Kit Guide (1999), pg. 9 (see references).

In short for each sample, drive the metal cylinder all the way into the ground until its upper edge is level with the surface of the ground (using a mallet and a block of wood). Remove the ring taking great care not to lose soil. To do so, dig around the ring and with a trowel underneath it, carefully lift it out. Remove excess soil from the sample with a flat-bladed knife. The top and bottom of the soil sample should be flat and even with the edges of the ring. Using the flat-bladed knife, push out the entire soil sample into a plastic zip bag. Label the bag correctly.

Take the samples to the lab (or any other place where there is a scale - two decimal places of accuracy- and a drying oven). Transfer each sample individually from the plastic bag to a foil or paper tray duly labelled. Let the samples to dry at 100 degrees until constant weight (usually 4 days is enough). Weight the dry soil (in g) and register it in your soil data worksheet. If a drying oven is not available, you can use a microwave (see the method in the USDA Soil Quality Test Kit Guide (in references).

Sampling calendar

Bulk density will be measured together with soil fertility (Gediz_Soil01), every two years for ten years.

Equipment

Bulk density is the ratio between soil dry weight and soil volume. Therefore, soil samples will be taken with a stainless-steel cylinder of perfectly know volume. The recommended dimensions for this case are 10 cm deep and 8 cm in diameter.
Additional field materials: a mallet, a block of wood, a trowel, a knife and zip-bags.

External subcontracting

If a reliable scale and a microwave are available, bulk density can be obtained very simply without the need of an expert lab.

Calculation formula

$$\rho = M / V$$

- Where:
  ρ is estimated as g $cm^{-3,}$
- M is the dry weight of the sample in g,
- V the volume of the soil cylinder (in cm^3).

For each plot, calculate the average of the two estimates of density

References

- Soil Quality Indicators. Bulk Density. USDA Natural Resources Conservation Service https://www.nrcs.usda.gov/sites/default/files/2022-10/nrcs142p2_051591.pdf
- Soil Quality Test Kit Guide. USDA Natural Resources Conservation Service. 1999. https://efotg.sc.egov.usda.gov/references/public/WI/Soil_Quality_Test_Kit_Guide.pdf
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8.1.1.4 The Maturity Index of Bongers (Mi)

- **Code:** Gediz_Soil04
- **Environmental Sector** : Soil / Soil Health
- **Units:** Number

Meaning and importance of the indicator

Nematodes are one of the soil invertebrates' groups that have been studied for their high ecological relevance with attributes that make them useful tools as environmental indicators, due to their contribution against pest regulation and diseases, and maintenance of nitrogen cycle and mineralization on the soil. The use of indicators to evaluate the quality of the ecosystems are used globally as this gives us an idea of the structure, function and composition of the ecosystems. Furthermore, the maturity index from Bongers (MI) is used to determine the diversity and distribution of the species, as nematodes are considered valuable indicators of soil ecosystem health.

Expected evolution of the indicator

The maturity index can be found between a range from 1-5. Low values (< 2) indicate a high level of disturbance with low soil food web structure, while intermediate values (2.5–3) indicate some soil food web maturity. High values (>3) indicate a well-structured and complex soil food web likely with connectivity and energy flow between trophic levels. The forest, which is an unaltered system, has the highest index, while perennial cultivation systems have higher rates than annual crops. Also, those organically managed systems had higher values than the respective conventional crops.

Data obtention

Required data:

It needs to be analysed only the first time (See Gediz_Soil01).

Sampling plan:

Field sampling can be carried out using different tools and it will depend on the purpose of sampling. To avoid dehydration, the samples are stored in plastic bags. Samples must be handled with care because nematodes may day from shock and friction. Finally, samples must be processed soon, because storage may cause changes in nematode numbers and composition (See Gediz_Soil01).

Sampling calendar

This indicator will be produced every two years for a total of 10 years, coinciding with the evaluation of soil physical and chemical fertility (See Gediz_Soil01).

Required equipment

Additional field materials: A soil cylinder/core, zip bags, filter papers, a spatula and a balance (See Gediz_Soil01).

External subcontracting

Yes. A trustable lab delivering analyses must be hired (See Gediz_Soil01).

Calculation formula

$$MI = S\, v_i\, p_i,$$

Where:

- v_i is the value c-p of the taxon i,
- p_i is the proportion of the taxon from the sample.

References

- Du Preez, G., Daneel, M., De Goede, R., Du Toitl, M.J., Ferris, H., Fourie, H., Geinsen, S., Kakouli-Duarte, T., Korthals, G., Sanchez-Moreno, S., Shmidt, J.H. 2022. Nematode-based indices in soil ecology: Application, utility, and future directions. *Soil Biology and Biochemistry*. 169, 108640. https://doi.org/10.1016/j.soilbio.2022.108640.
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8.1.1.5 Soil Pollution by Arsenic (As)

- **Code:** Gediz_Soil05
- **Environmental Sector**: Soil Health
- **Units:** Mg Kg^{-1}

Meaning and importance of the indicator

Arsenic (As) is known for its carcinogenic, neurotoxic, mutagenic properties and for its oxidative stressor, endocrine system disruption and inflammatory action. Negative impact of As, especially in its trivalent form, on plant, animal and human health depends on the level and duration of exposure and on the metabolism of the receptor but, for humans, several cancers have been associated to low-level exposure to inorganic arsenic.

Inorganic arsenic (As) is naturally present in the environment, with base concentration in soil that range from 0.2 to 40 mg kg^{-1} in areas where there is no evidence of anthropogenic sources of contamination. Contaminated groundwater is a main source of animal and human exposure to arsenic by direct consumption (mainly in children and animals) or by arsenic accumulation in plants grown in polluted soils.

Expected evolution of the indicator

In uncontaminated agricultural soils as concentration ranges from 1 to 20 mg kg^{-1} but As rich groundwater can lead to dangerous As concentrations in soils. In this sense, very dangerous levels of As have been reported in the underground water of the Gediz Delta, that are well above the threshold of 10 μ g L^{-1} recommended for drinking water by the World Health Organization. Such high concentration of arsenic in groundwater directly in contact with the soils of the study area raises concerns that soil is itself contaminated.

There are no globally accepted regulations or guidelines for arsenic in agricultural soil. The FAO, and the Italian and Norwegian regulations impose a threshold of 20 mg kg^{-1}, and the Australian Ecological Investigation Limit (EIL) is set at the same level for As in urban soils. Some studies propose a soil standard limit for As of 40 mg kg^{-1} above which an As risk study should be conducted.

Therefore, if As concentration in soil is found to exceed 20 mg kg^{-1}, an in-deep risk assessment study should be conducted previous to any kind of agricultural use of the area.

Possible relationship with other soil analyses

This As analysis must be coordinated with an analysis of As concentration in plants.

Data obtention

Sampling plan:

Field sampling followed by lab analysis. Soil sampling for arsenic in soil will be done together with sampling for soil fertility (Gediz_Soil01). 50 sampling points will be established 1 m away from each of the soil fertility sampling points.

At each sampling point, the soil profile will be sampled at least at two levels: 0-15 cm and 15-30 cm with a soil borer of 3 cm of recommended diameter (see equipment below). To sample the two proposed soil levels, a 30 cm long soil borer can be useful. If you are using a 15 cm borer, excavate to be sure that you are sampling the 15-30 cm soil layer.

Put each sample in a closed plastic zip bag duly labelled with date, soil depth, and coordinates of the sampling point. Send the samples to an expert lab for analysis as soon as possible. The soil lab must have been previously consulted for instructions about the preparation of the samples before shipping.

Sampling calendar

The area will be sampled for arsenic content in soil prior to the inauguration of the planned channel. In case that the concentration of As in soil allows agricultural uses (grazing), soil sampling will be repeated together with soil fertility sampling (Gediz_Soil01) every two years for 10 years (5 times).

Equipment

Samples will be extracted from soil with soil borers of known and constant (the same for all samples at each sampling campaign) depth and diameter.
The borer should be 30 cm long and the recommended diameter is 3-5 cm. In order to sample exact soil levels, split soil core samplers can be useful.
Some providers of these soil borers are: https://www.ams-samplers.com/soil-augers/; https://www.vanwalt.com/equipment/telescoping-augers/.

External subcontracting

Yes. A trustable lab delivering soil analyses must be hired.

References

- Abad-Valle, P., Álvarez-Ayuso, E., Murciego, A., Muñoz-Centeno, L. M. et al. (2018). Arsenic distribution in a pasture area impacted by past mining activities. *Ecotoxicology and Environmental Safety*, *147*, 228-237.
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8.1.1.6 Arsenic (As) Concentration in Pastures

- **Code:** Gediz_Soil06
- **Environmental Sector**: Human Health
- **Units:** Mg Kg^{-1}

Meaning and importance of the indicator

Arsenic (As) is known for its carcinogenic, neurotoxic, mutagenic properties and for its oxidative stressor, endocrine system disruption and inflammatory action. Negative impact of As on plant, animal and human health depends on the level and duration of exposure and on the metabolism of the receptor but, for humans, several cancers have been associated with low-level exposure to inorganic arsenic.
Contaminated groundwater is a main source of animal and human exposure to arsenic by direct consumption), dust inhalation, direct skin contact and vegetable consumption. Arsenic is taken primarily by plants via root absorption and then allocated to the plant in different proportions according to species. The amount of arsenic contained in the edible part of plants grown into polluted water depends on plant species. Therefore, from an agricultural perspective, areas flooded with enriched arsenic waters may pose health problems, because pastures may contain sufficient arsenic levels to make them dangerous, both for grazers and human consumers, via food web.

Expected evolution of the indicator

According to the Directive 2002/32/EC on undesirable substances in animal feed, the concentration of arsenic in the above-ground part of the pasture species of our study area should not exceeded 2.3 mg kg^{-1} (dry weight) that is the limit for most animal feed for avoiding risks in higher levels of food chain.

Possible relationship with other soil analyses

This As analysis in forage crops must be coordinated with a [As] analysis in soil.

Data obtention

Sampling plan:

Field sampling followed by lab analysis. Sampling for arsenic concentration in pasture species will be done together with sampling for soil fertility (Gediz_Soil01), and As concentration in soil (Gediz_Soil05). Please, use in this case the same soil sampling squares (number= 50) used for soil fertility sampling.
Select the four most abundant forage species present in the area. At each sampling square and for each of these four selected species, collect the aerial part of 20 plants, and combine them in a unique composite sample per species. Put each sample in a plastic zip bag duly labelled with species name, collection date, and the central coordinates of the sampling square. In the lab, wash the plants three times vigorously in distilled water and let them dry for 48 h at 80 ºC. Dry plants, finely ground, must be sent to an expert lab for determination of arsenic content.

Sampling calendar

The area will be sampled for arsenic content in plants before the inauguration of the planned channel. Then, and in case that the As concentration, both in plants and soils, allows grazing (see Gediz_Soil05), plant sampling will be followed together with soil arsenic concentrations (Gediz_Soil05) according to soil sampling calendar, so every two years for 10 years (5 times).

Equipment

Gardening scissors, zip bags, lab drying oven

External subcontracting

Yes. A trustable lab delivering soil analyses must be hired.

References

- Abad-Valle, P., Álvarez-Ayuso, E., Murciego, A., Muñoz-Centeno, L. M. et al. (2018). Arsenic distribution in a pasture area impacted by past mining activities. *Ecotoxicology and Environmental Safety*, *147*, 228-237.
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8.1.1.7 Water Holding Capacity

- **Code:** Gediz_Soil07
- **Environmental Sector** : Soil / Soil Health
- **Units:** %

Meaning and importance of the indicator

The water holding capacity (WHC) is an important agronomic characteristic. The WHC of a soil is the maximum amount of water a soil can hold under standard conditions. Water holding capacity is affected by soil texture (sand, silt, and clay proportion) and soil structure (pore size, porosity, pores connectivity distribution and characteristics are essential determinants).

A soil with a limited WHC reaches sooner the saturation than a soil with a higher WHC, especially between sandy soils as they tend to have low water storage capacity.

Expected evolution of the indicator

Soil structure can be improved by adding organic matter content to stimulate the soil porosity, which increases the water holding capacity. Also, a better water holding capacity of the soil can be accomplished by increasing soil organic carbon. However, deforestation and farming activities may decrease soil water holding capacity.

Data obtention

Required data:

It needs to be analysed the first time and every two years for 10 years (5 times) (See Gediz_Soil01).

Sampling plan:

Field sampling followed by lab analyses Field sampling followed by lab analyses (See Gediz_Soil01). Collect the sample using a soil core, air dry it, break the aggregates and pass through a 2.0 mm sieve. Place the core containing soil in a water tray for saturation overnight and then place the sample in an oven at 105º C for 24-48 h. Finally, weigh the core sample. For further instructions go to the Practical manual on measurement of soil physical properties, on page 34.

Sampling calendar

This indicator will be produced every two years for a total of 10 years, coinciding with the evaluation of soil physical and chemical fertility (See Gediz_Soil01).

Equipment

Additional field materials: A soil cylinder /core, a tray, filter papers, a spatula, a sieve, water try, a balance and a drying oven (See Gediz_Soil01).

External subcontracting

If a reliable scale and an oven are available, WHC can be obtained very simply without the need of an expert lab. If not, a trustable lab delivering soil fertility analyses must be hired (See Gediz_Soil01).

Calculation formula

$$WHC\% = (Vw/Vt) * 100$$

Where:

- Vw is volume of water,
- Vt is total volume of saturated soil.

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8.1.2 Water Indicators

8.1.2.1 Water Monitoring Plan

Sampling points

Indigenous production landscapes in Izmir. .

Sampling point	Location	Purpose
SP-01	Inlet of the WWTP (with advanced biological treatment)	Monitor wastewater to be treated (efficiency of the whole treatment)
SP-02	Outlet of the WWTP (with advanced biological treatment)	Monitor reclaimed water production, availability (volume), and the quality of the effluent
SP-03	Outlet of the capillary channels	Monitor water provision and quality (volume and nutrient content)
SP-04	Well (piezometer/injection well)	Monitor water quality, availability, and recharge (nutrient content and volume)
SP-05	Prairies with high salinity	Monitor infiltration rate (volume)

Parameters to be analyzed

Parameter	Applicable Sampling Point	Related indicators	Type
Volume of treated wastewater (WW)	SP-01, SP-02	WWTeff; RWP	water flow measurements [volume/time]
Volume of reclaimed water produced (water suitable for its discharge in the channel)	SP-02	RWP; WA	water flow measurements [volume/time]
Volume of water availability	SP-01, SP-02, SP-03	WA;	water flow measurements [volume/time]
Water quality parameters: temperature, pH, conductivity, major anions (Cl^-, NO_3^-, NO_2^-, SO_4^{-2}, CO_3^{-2}, HCO_3^-), cations (Ca^{+2}, Mg^{+2}, Na^+, K^+), heavy metals, nitrate content (NO_3), arsenic (As),	SP-01, SP-02, SP-03, SP-04	EPR; ASREN; ASREA; GW_{EC}	water quality parameters
Volume of water for groundwater recharge	SP-04	GWR	water flow measurements [volume/time] or groundwater level measurements
Water infiltration velocity through the aquifer	SP-05	IR	water flow measurements [volume/time] and infiltration rate

Sampling method

Water flow measurements:

Direct measurement of volume provided during a time period or water flow with flow meters and/or water level sensors.

a) Automatic method

Automatic flow meters can be installed at the recommended sampling points (SP). For the automatisation process, it is recommended to register the measurements with a datalogger/digital control system in the DEMO. It is recommended to measure the flow at the recommended sampling points (SP).

Data should be stored in a datalogger/digital control system and then be able to be exported in a spreadsheet to calculate the associated indicators. When this is not possible, manual readings of the flow meters can be done instead.

b) Manual method

This could be applied as the last option if there is no possibility to apply the automatic method.

- Periodic manual measurements.
- If no devices are available to measure, correct and reliable estimates must be made to assess the indicator.
- Measure the volume at the point of reuse or approximate the value based on the amount of water demand met by prairie for reuse.

Water quality parameters:

Automatic measurement methods (a) or manual sampling campaigns (water sampling + laboratory analysis) (b) can be employed, with specific requirements for different types of pollutants.

a) Automatic method

Advanced sensors of water quality can be installed in the recommended sampling points (SP) to continuously monitor and measure various water quality parameters, such as temperature, pH, turbidity, dissolved oxygen, NO_3, etc. These sensors collect data in real-time, providing continuous and accurate information about water quality. The data is often transmitted wirelessly to a central database, or sensors can be also connected to a datalogger. The data is often transmitted wirelessly to a central database, or sensors can be also connected to a datalogger.

b) Manual method

As the DEMO has not been implemented yet, sampling campaigns will be carried out periodically to control the operation and performance of the treatment system. Samples will be collected at the recommended sampling points (SP).

Two types of water quality analysis have been defined: basic and complete. Different sampling and analysis periodicities will be suggested during the start-up phase, stabilization phase and mature operation.

Basic analysis will include all water quality parameters that are required to be monitored by legislation for reclaimed water reuse for aquifer recharge: conductivity, pH, arsenic (AS) (other if required by legislation).

Complete analysis includes other water quality parameters for general monitoring and indicators' assessment: temperature, major anions (Cl^-, NO_3^-, NO_2^-, SO_4^{-2}, CO_3^{-2}, HCO_3^-), cations (Ca^{+2}, Mg^{+2}, Na^+, K^+), heavy metals, nitrate content (NO_3).

Samples can be obtained manually or using automatic sampling equipment. An automatic sampler is a device that can be refrigerated or non-refrigerated and include automatic sampling pumps and upward stage samplers. The process involves collecting water samples intended for laboratory analysis of water quality parameters. However, there are limitations associated with automatic sampling, such as intermediate sampling containers, sampling from a fixed point, and sample storage and preservation, which must be considered and documented. Personnel using these methods should have training and prior experience in the use and calibration of automatic sampling equipment.

The laboratory analysis is done following current ISO laboratory protocols for each different parameter.

Groundwater level measurements:

The variation in the water level of the aquifer can be done manually or through automatic methods.

a) Automatic method

For the groundwater recharge of the aquifer, water level sensors or remote sensing through hydrological models can be used.

b) Manual method

For the groundwater recharge of the aquifer, direct water level measurements in a period of time can be done. Measure water depth of the aquifer at the initial time and after a period of time (e.g. minutes, hours, days, etc.).

Infiltration rate:

The infiltration rate is a type of water flow measurement, very related to the soil. Also, as other indicators, there are automatic and manual methods:

a) Automatic method

To measure infiltration rate automatically in the aquifer, a tensiometer-based system or automated infiltrometer can be employed. These systems consist of soil moisture sensors or pressure transducers installed in the ground at various depths to continuously measure changes in soil moisture content or water pressure. The automated system periodically adds a controlled amount of water to the surface, imitating rainfall or irrigation. The sensors monitor how quickly the water infiltrates and how the moisture levels change over time. Data is collected in real-time and transmitted to a central data logger or computer for analysis, calculating the infiltration rate without manual intervention.

b) Manual method

To manually sample the infiltration rate, it's needed to use a ring infiltrometer. An example of this process is the following. First, hammer a 30 cm diameter ring about 15 cm into the soil, and place a measuring rod inside. Then, hammer a 60 cm diameter ring around the first one (or build an earthen bund) to prevent lateral water movement. Pour water into both rings to a depth of 70-100 mm and record the time. Measure the drop in water level at regular intervals, adding water to maintain the initial level. Continue until the water drop rate stabilizes, which represents the basic infiltration rate. Repeat the test at least twice for accuracy.

Sampling calendar

Water flow measurements, groundwater level measurements and infiltration rate:

Data should be collected frequently for a relevant time period (e.g., daily, weekly, monthly) to allow for accumulation over the entire reporting period (yearly). This high frequency is also relevant to study seasonal variations.

Water quality parameters:

As the DEMO has not been implemented yet, different sampling and analysis periodicities will be suggested during the start-up phase, stabilization phase and mature operation:

- Start-up phase: the first 3 months of operation of the DEMO it is recommended to increase the frequency of the analysis to 2 basic analysis per week and 1 complete analysis per week.
- Stabilization phase: from month 4 to month 12 of operation it is recommended to do 1 basic analysis per week and 2-3 complete analysis per month.
- Mature operation: from month 13, the recommended frequency of water quality analysis is 1 basic analysis per week and 1 complete analysis per month.

Equipment

a) Water flow measurements:

Water flow meters are essential tools for monitoring and assessing the efficiency of these systems, as they provide real-time data on water movement and usage through the treatment processes and the different pipes, helping to determine the volume of water at those particular locations.
Some indicative providers of these water flow meters are:

- Endress+Hauser
- Systec Controls
- Aobo instrument

Any equivalent water flow meter is acceptable, these are given as examples.

b) Water quality parameters:

The automatic sampling method requires simple or multiparametric sensors for water quality and data loggers or digital control systems for data recording. It also requires personnel for data collection and treatment.
The manual sampling campaign requires laboratory and field personnel for manual sampling and analysis and also reagents and laboratory material depending on the current ISO laboratory protocols for each parameter.
Some indicative providers for water quality parameters are:

- ANISE sensor (NH_4 and NO_3) - Hach
- Conductivity meter - METTLER TOLEDO
- pH meter - METTLER TOLEDO
- Arsenic field tests - ALFA Chemistry
- Multi-parameter analyser and sensor measure groundwater quality (DO, turbidity, conductivity, pH, salinity, temperature) - BOQU instruments
- Multi-parameter water quality analyser (temperature, pH, conductivity, DO, turbidity, BOD, COD, ammonia nitrogen, NO_3, colour, chloride, depth, etc.) - BOQU instruments

Any equivalent water level sensor is acceptable, this is given as an example.

c) Groundwater level measurements:

One indicative provider of a water level sensor is:

- Sensor - OTT PLS-C
- Staff gauge - Fondriest

Any equivalent water level sensor is acceptable, this is given as an example.

d) Infiltration rate:

Some indicative providers are:

- Manual infiltrometer - Eijkelkamp
- Manual infiltrometer - ELE International
- Automated infiltrometer - SATURO

*For manual infiltrometers, take into account that you may need a hammer, a watch or clock, a bucket, a timber, or any other instrument to work together.
Any equivalent water flow meter is acceptable, these are given as examples.

External subcontracting

Yes. A trustable laboratory delivering water quality analyses must be hired if not available internally.

8.1.2.2 Effective Wastewater Treatment (WWTeff)

- **Code**: Gediz_Water01
- **Environmental Sector:** Water / Safeguarded water ecosystems
- **Units:** %

Meaning and importance of the indicator

The indicator measures the percentage of wastewater that is treated in compliance with legal and regulatory standards out of the total volume of wastewater treated. Includes the wastewater treatment coverage and volumetric efficiency. The concept is based on having an overview of the share of customers that is connected to the public wastewater system or is having a local legal treatment system in place. Based on population data, the share of total generated wastewater that is being treated can then be estimated. This indicator is used to have an overview of how much wastewater is generated in an area and it's important because untreated wastewater or not complying treated wastewater will have a negative impact on ecosystems in all kinds of water bodies.

Expected evolution of the indicator

The range is from 0 to 100%, the optimal value for the WWTeff indicator is ideally 100%, indicating that all treated wastewater meets or exceeds legal standards. However, achieving and maintaining values above 90-95% is considered very good and indicative of a highly effective wastewater treatment system.

Possible relationship with other indicators

Water quality compliance: biological, physical and chemical parameters, Reclaimed Water in non-potable Uses.

Data obtention

Sampling plan:

- Volume of treated wastewater complying with legal requirements (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO. Only data that complies with legal requirements will be selected.
- Volume of wastewater generated and treated in the DEMO (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.

Calculation formula

$$WWTeff = \frac{V_{Treatment}}{WW} \cdot 100$$

Where:

- WWTeff: Effective wastewater treatment (%),
- $V_{Treatment}$: Volume of treated wastewater complying with legal requirements (m^3/year),
- WW: Volume of treated wastewater (m^3/year).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- European Commission, Directorate-General for Research and Innovation (2021). Evaluating the impact of nature-based solutions: A handbook for practitioners. Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577
- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

8.1.2.3 Reclaimed Water Production (RWP)

- **Code**: Gediz_Water02
- **Environmental Sector:** Water / Water resource recovery and use
- **Units:** %

Meaning and importance of the indicator

The indicator measures the volume of reclaimed water produced, either for internal use or transfer to third parties, as a percentage of the total volume of treated wastewater, etc. This indicator aims to assess the level of environmental sustainability of the service in terms of circularity and the resources recovery, regarding the production of reclaimed water, obtained from the wastewater treatment. Reclaimed water means urban wastewater that has been treated in compliance with the requirements set out in Directive 91/271/EEC and which results from further treatment in a reclamation facility (EU Regulation 2020/741). However, based on further assessments, the approach to reclaimed water may need adjustment, particularly if the indicator for reclaimed water also includes treated rainwater or water from other sources. So, in this context, reclaimed water can also be considered treated water from other sources (i.e. rainwater/stormwater, greywater, etc.) which is suitable for its reuse.

Expected evolution of the indicator

The optimal value for the RWP indicator is as high as possible, ideally close to 100%, which would indicate that almost all treated wastewater (or other treated water sources) is further processed to produce reclaimed water. This contributes to more sustainable water management practices and to reduce the dependency on freshwater sources.

Possible relationship with other water indicators

Compliant reclaimed water, Water availability, Reclaimed water in non-potable uses, Effluent pollutant removal, Water footprint.

Data obtention

Sampling plan:

- Volume of reclaimed water produced under the responsibility of the utility, and which is transferred to other entities for use or for its own uses (exclude the recirculation or recycling of water, when it occurs in a closed circuit within one or more processes) (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO. Only data that complies with reclaimed water suitable for its reuse will be selected.
- Volume of wastewater treated or treated water from other sources (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.

Calculation formula

$$RWP = \frac{V_{reclaimed}}{TWW} \cdot 100$$

Where:

- RWP: Reclaimed Water Production (%),
- $V_{reclaimed}$: Volume of reclaimed water produced under the responsibility of the utility, and which is transferred to other entities for use or for its own uses (exclude the recirculation or recycling of water, when it occurs in a closed circuit within one or more processes) (m^3/year),
- TWW: Volume of wastewater treated or treated water from other sources (m^3/year).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

8.1.2.4 Water Provision by the Ecosystem (Wavailable)

- **Code**: Gediz_Water03
- **Environmental Sector:** Water / Freshwater supply / Resource efficiency
- **Units:** %

Meaning and importance of the indicator

The indicator measures the percentage of water available in the ecosystem for abstraction in the current year compared to the previous one. This indicator is important for understanding the sustainability of water resources over time and the ecosystem's ability to replenish and maintain water availability. This is a context indicator. Ecosystem is understood as a natural unit comprising living organisms and their physical environment, interacting as a system. In this way, it can include several scales related to the water sector. For example, hydrological basin, aquatic ecosystem, influencing area of the DEMO, municipality, riparian zone, wetland ecosystem, etc.)

The indicator measures the development of water provision by the ecosystem. The underlying concept is the ecosystem service theory, manifested in specific ecosystem services selectable from CICES (EEA, 2018). Here, so-called provisioning ecosystem services are beneficial for human well-being. For water related regulating ecosystem services especially the ecosystem service from water provisioning for several usages is important (water for potable and non-potable uses, water for hydroelectricity, etc.).

Expected evolution of the indicator

The baseline for this indicator is the initial water available capacity, which may be 0% if there is no initial water availability in the ecosystem. A stable or increasing percentage would indicate a healthy ecosystem with sustainable water resources, while a decreasing value may signal over-extraction or ecosystem degradation.

Possible relationship with other water indicators

Water availability, Water footprint.

Data obtention

Sampling plan:

- Volume of water available for abstraction from the ecosystem during the current year (m^3/year) Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data.
- Volume of water available for abstraction from the ecosystem in the previous year (m^3/year) Cumulative values during the previous year to the current one will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data.

Data obtention method

Existing data, satellite images.

Data sources

Existing information on water use and abstraction per year, local GIS data or estimations/simulations with relation to ecosystem related protection (water retention in the area, water sources and volumes, etc.)

Calculation formula

$$W_{Available} = \left(\frac{W_t}{W_{t-1}}\right) \cdot 100$$

Where:

- $W_{Available}$: Water provision by the ecosystem (%),
- W_t: Water available for abstraction from the ecosystem in the year (m^3/year),
- W_{t-1}: Water available for abstraction from the ecosystem in the previous year (m^3/year).

Note: A scope for the "ecosystem" must be defined previously. The ecosystem can be the same hydrological basin or aquatic ecosystem where the DEMO activity takes place, the influencing area of the DEMO, the municipality, etc.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/
- EEA (2018). CICES V5.1, 18/03/2018. https://cices.eu/resources/
- Net surface water availability: European Commission, Directorate-General for Research and Innovation (2021). Evaluating the impact of nature-based solutions: a handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577

8.1.2.5 Water Availability (WA)

- **Code**: Gediz_Water04
- **Environmental Sector:** Water / Freshwater supply / Resource efficiency
- **Units:** m^3/year

Meaning and importance of the indicator

The indicator refers to the volume of water available provided by the DEMO for its reuse in various applications (e.g. aquifer recharge, ecosystem restoration, on site reuse, irrigation, industrial activities, etc.). The water available should comply with quality standards required for different reuses as per current legislation.

Expected evolution of the indicator

The baseline for this indicator is the initial water availability capacity, which may start at 0 m^3/year. It is expected to increase over time once the DEMO is operating and optimized, reflecting an improvement in water availability for reuse and ecosystem services. Ensure that 100% of the water provided by the DEMO is available for reuse.

Possible relationship with other water indicators

Water footprint, Water provision by the ecosystem.

Data obtention

Sampling plan:

- Direct annual flow of the effluent or annual volume provided by the DEMO for specific purposes (e.g., aquifer recharge, ecosystem restoration, etc.) (m^3/year).
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total volume water available in the DEMO (WA) (m^3/year).

Calculation formula

$$WA = Water\ inflows\ (WI) - Water\ losses\ (WL)$$

Where:

- WI: Total water entering the DEMO system (e.g., precipitation, surface water, groundwater recharge, recycled water) (m^3)
- WL: Total water lost (due to evaporation (m^3)

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

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8.1.2.6 Effluent Pollutant Removal (EPR)

- **Code**: Gediz_Water05
- **Environmental Sector:** Water / Water treatment / Water quality
- **Units:** %

Meaning and importance of the indicator

The indicator measures the average removal ratio between incoming and outgoing pollution load of the NBS. It can be evaluated for any pollutant. It is used to assess the effectiveness of water treatment processes in reducing pollution before discharge into the environment or wastewater treatment plant or its reuse.

*If there are additional water treatments in combination with the NBS, we recommend sampling before and after each treatment to have a better understanding of the role of each one in the treatment process.

Expected evolution of the indicator

The target can be determined based on design requirements (e.g., why the NBS is necessary, which pollutant needs to be addressed, and the desired removal efficiency) or according to local regulations and guidelines that define water quality standards depending on its intended use (such as for consumption, discharge, or reuse). For reclaimed water (as per Water Directive 2020/741), the goals would be: 95% removal of microbiological and emerging contaminants, 60-95% removal of nutrient pollutants, and 95% removal of physico-chemical parameters (such as turbidity). For treated wastewater (under RD 509/1996 and RD 11/1995), the objectives would include 70-80% reduction of nutrient pollutants and 90% removal of physico-chemical parameters (such as turbidity). For drinking water (in line with RD 3/2023), the goals would involve: 99-100% elimination of microbiological contaminants, 80-99% reduction of chemical pollutants, and 95% removal of physico-chemical parameters (such as turbidity) and nutrients.

Possible relationship with other water indicators

Reclaimed water production, Environmental flow requirement compliance rate, Safe drinking water, Water quality compliance: biological, physical and chemical parameters.

Data obtention

Sampling plan:

- Average influent concentration (mg/L).
- Average effluent concentration (mg/L).

Water quality parameters:

- Physical-chemical properties data:
  - - pH (unitless)
  - - Temperature (ºC)
  - - Electrical Conductivity (EC) (µS/cm)
  - - Turbidity (NTU)
  - - TSS (Total Suspended Solids) (mg/L)
- Biological data:
  - - DO (Dissolved Oxygen) (mg/L O_2)

- - BOD (Biochemical Oxygen Demand) (mg/L O_2)
- - COD (Chemical Oxygen Demand) (mg/L O_2)
- - TOC (Total Organic Carbon) (mg/L O_2)

- Chemical pollutant data:
  - - Heavy metals (µg/L)

  - Total hydrocarbons (µg/L)
  - Total pesticides (µg/L)
- Nutrients data:
  - - TN (Total Nitrogen) (mg/L N)
  - - NO_3 (Nitrates) (mg/L)
  - - TP (Total Phosphorus) (mg/L P)
  - - PO_4 (Phosphates) (mg/L)
- Microbiological data:
  - - E. Coli (CFU/100 mL)
- Other specific pollutants data:
  - - Contaminants of emerging concern
  - - Pollutants from industrial effluents will be added if necessary.

Calculation formula

$$\%Re = \frac{(Ci - Ce)}{Ci} \cdot 100$$

Where:

- %Re: average effluent pollutant removal (%)
- Ci: average influent concentration (mg/L)
- Ce: average effluent concentration (mg/L)

*To be evaluated for each pollutant.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: A handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577
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8.1.2.7 Aquifer Surface Ratio with Excessive Nitrate (ASREN)

- **Code**: Gediz_Water06
- **Environmental Sector:** Water / Water Quality
- **Units:** %

Meaning and importance of the indicator

This indicator measures the proportion of an aquifer's surface area that contains nitrates levels exceeding safe or regulatory limits. This ratio helps assess the extent of groundwater contamination by nitrate, which is important for public health and water resource management. To be compared to a baseline.

Expected evolution of the indicator

Baseline: Initial water available capacity, that may be 0 m^3/year. The limit value for nitrate in water is 50 mg/l, so any amount greater than this number will be considered as an excessive level. It takes into account total nitrate levels, including organic and inorganic. This maximum value is set by the WHO (World Health Organization) and the Turkish Standards (applied to one DEMO). For this reason, the optimal target for the ASREN indicator is 0%, representing that there are no areas with excessive nitrate, meeting the required quality standards.

Possible relationship with other water indicators

Aquifer surface ratio with excessive arsenic, Average groundwater electrical conductivity, Safe drinking water, and Water quality compliance: biological, physical and chemical parameters.

Data obtention

Sampling plan:

- Surface area of aquifer with nitrate levels above safe limits (m^2)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total surface area of the aquifer (m^2)

Calculation formula

$$ASREN = \left(\frac{SA_{NO3>safe}}{SA_{Total}}\right) x\ 100$$

Where:

- ASREN: Aquifer surface with excessive nitrate (%)
- $SA_{NO3>safe}$: Surface area of the aquifer with nitrate levels above safe limits (m^2)
- SA_{Total}: Total surface area of the aquifer (m^2)

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: a handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577
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8.1.2.8 Aquifer Surface Ratio with Excessive Arsenic (ASREA)

- **Code**: Gediz_Water07
- **Environmental Sector:** Water / Water Quality
- **Units:** %

Meaning and importance of the indicator

This indicator measures the proportion of an aquifer's surface area that contains arsenic levels exceeding safe or regulatory limits. This ratio helps assess the extent of groundwater contamination by arsenic, which is important for public health and water resource management. To be compared to a baseline.

Expected evolution of the indicator

The limit value for arsenic in water is 10 µg/l, so any amount greater than this number will be considered as an excessive level. It takes into account total arsenic levels, including organic and inorganic. This maximum value is set by the WHO (World Health Organization) and the Turkish Standards. For this reason, the optimal target for the ASREA indicator is 0%, representing that there are no areas with excessive arsenic, meeting the required quality standards.

Possible relationship with other water indicators

Aquifer surface ratio with excessive nitrate, Average groundwater electrical conductivity, Safe drinking water, and Water quality compliance: biological, physical and chemical parameters.

Data obtention

Sampling plan:

- Surface area of aquifer with arsenic levels above safe limits (m^2)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total surface area of the aquifer (m^2)

Calculation formula

$$ASREA = \left(\frac{SA_{AS>safe}}{SA_{Total}}\right) x\ 100$$

Where:

- ASREA: Aquifer surface with excessive arsenic (%)
- $SA_{AS>safe}$: Surface area of the aquifer with arsenic levels above safe limits (m^2)
- SA_{Total}: Total surface area of the aquifer (m^2)

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: a handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577
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- WHO. (2017). Guidelines for Drinking-water Quality: FOURTH EDITION INCORPORATING THE FIRST ADDENDUM. https://iris.who.int/bitstream/handle/10665/254637/9789241549950-eng.pdf?sequence=1

8.1.2.9 Increased Groundwater Recharge (GWR)

- **Code**: Gediz_Water08
- **Environmental Sector:** Water / Water management
- **UNITS:** m^3

Meaning and importance of the indicator

The indicator provides information about the water volume available for groundwater recharge in comparison to the recharge without the solution, over a year. It shows how the NBS contributes to groundwater recharge.

Expected evolution of the indicator

Baseline: Initial recharge capacity.
Target: An increased recharge volume compared to the scenario without the NBS, demonstrating the effectiveness and positive impact of the NBS on groundwater recharge.

Possible relationship with other water indicators

Rainfall interception of NBS and Rainfall storage/absorption capacity of NBS, and Infiltration rate.

Data obtention

Sampling plan:

- Water captured available for recharge (m^3)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Water level in aquifer (m)
- Aquifer incoming water flow (m^3/s)

Calculation formula

If not possible and if the source is rainwater, apply "capture and infiltration method" based on annual rainfall and catchment runoff coefficient to estimate water captured for recharge.
The indicator is the sum of all volumes captured by the aquifer over the year:

$$GWR = \sum V_c$$

Where:

- V_c can be determined in 2 ways:

b) From NBS water level

V_c is a function of aquifer water level. It should be determined from the aquifer design relationship between water level (WL) and volume, during the entire recharge event. WL is monitored with a water level sensor:

$V_c = \sum f(WL)$ for all time steps of recharge event

b) From available water supply
Another way to proceed is to evaluate the water flow incoming (Q_{in}) to the aquifer throughout the year:

$V_c = \sum Q_{in}$ for all time steps of recharge event

And:

- GWR: Increased Groundwater Recharge (m^3),
- V_c: Water captured available for recharge (m^3),
- WL: Water level in aquifer (m),
- Q_{in}: Aquifer incoming water flow (m^3/s).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- EEA (2018): CICES V5.1, 18/03/2018. https://cices.eu/resources/
- Brill, Gregg, Tien Shiao, Cora Kammeyer, Sarah Diringer, Kari Vigerstol, Naabia Ofosu-Amaah, Michael Matosich, Carla Müller-Zantop, Wendy Larson and Tim Dekker (2021). Benefit Accounting of Nature-Based Solutions for Watersheds: Guide United Nations CEO Water Mandate and Pacific Institute. Oakland, California. www.ceowatermandate.org/nbs/guide
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8.1.2.10 Infiltration Rate (IR)

- **Code**: Gediz_Water09
- **Environmental Sector:** Water / Water management
- **Units:** m/d or mm/h

Meaning and importance of the indicator

The indicator reflects the speed at which water penetrates the soil or a porous surface, typically measured in units of depth per time (e.g., m/d or mm/h). It is influenced by factors such as soil texture, moisture content, and the presence of vegetation or surface structures.

Expected evolution of the indicator

Baseline: Initial recharge capacity based on the natural soil or site specifications. An increase in infiltration rate is expected over time with DEMO implementation, leading to higher recharge volumes compared to areas without the solution. Dependent on the specific NBS and local soil conditions; typically, higher infiltration rates indicate more effective water management, although very high rates could lead to groundwater contamination if not managed properly. The following table shows the basic infiltration rate for various soil types:

Soil type	Basic infiltration rate (mm/hour)
sand	less than 30
sandy loam	20 - 30
loam	10 - 20
clay loam	5 - 10
clay	1 - 5

Note: FAO (n.d.)

Possible relationship with other water indicators

Increased groundwater recharge.

Data obtention

Sampling plan:

- Infiltration rate: Direct measurement of the amount of water that penetrates the ground surface over time (m/d or mm/h).
  Cumulative values during a period will be needed, measuring in terms of time, such as days or hours. If this is not possible, average values can be obtained. The average can be done from daily average data obtained from sampling at the DEMO.
- Area of the infiltration surface (m^2).
- Darcy velocity: Hydraulic conductivity of the material, infiltration area, and difference in water level between the inlet and outlet points.

Calculation formula

$$q_{boundary} = \frac{Q_{out}}{S_b}$$

$$Q_{out} = -K \cdot \frac{dh}{dl} \cdot A$$

or

$$q = \frac{K \cdot A \cdot \Delta h}{L}$$

Where:

- $q_{boundary}$ and q: is the infiltration rate (in units of volume per area and time, such as $m^3/s \cdot m^2$ or m/d or mm/h),
- Q_{out} is the total infiltrated flow (m^3/s), calculated as the integration of the Darcy velocity over the entire infiltration surface,
- K is the hydraulic conductivity of the material (m/s), which depends on the properties of the porous medium,
- A is the infiltration area, which in this case is the cross-sectional area of the material through which the water flows (m^2),
- Δh is the hydraulic head difference (or difference in water level) between the inlet and outlet points (m),
- L is the length of the water flow path through the porous medium (m),
- Sb is the area of the infiltration surface (m^2).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- Bouwer, H. (2017). Water infiltration in an aquifer recharge basin affected by temperature and air entrapment. ResearchGate. https://www.researchgate.net/publication/318655137_Water_infiltration_in_an_aquifer_recharge_basin_affected_by_temperature_and_air_entrapment
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8.1.2.11 Average Groundwater Electrical Conductivity (GW_{EC})

- **Code**: Gediz_Water10
- **Environmental Sector:** Water / Water quality
- **Units:** µS/cm

Meaning and importance of the indicator

This indicator provides the average groundwater electrical conductivity (EC). In general terms, EC reflects the water's ability to conduct electricity, which correlates with the concentration of dissolved ions, including salts and minerals. Shifts in groundwater EC would be a sign of degradation and contamination of groundwater quality due to factors such as salinization, pollution, or mineral dissolution. To be compared to a baseline. To be compared without the implementation of the NBS (or to equivalent grey infrastructure).

Expected evolution of the indicator

Baseline: Initial groundwater conductivity measurements used for comparison.
Target: Compliance with regulatory standards. According to EC Drinking Water Directive the suggested EC value should not exceed 2500 µS/cm.

Possible relationship with other water indicators

Aquifer surface ratio with excessive nitrate, Aquifer surface ratio with excessive arsenic, Safe drinking water, and Water quality compliance: biological, physical and chemical parameters.

Data obtention

Sampling plan:

- Electrical conductivity measurements of groundwater (µS/cm)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total number of EC measurements (nº)
  Number of EC measurements to do the average of the values.

Calculation formula

$$GW_{EC} = \frac{\Sigma EC_i}{n}$$

Where:

- GW_{EC}: Average of the groundwater electrical conductivity (µS/cm),
- ΣEC_i: Individual EC measurements (µS/cm),
- n: Total number of measurements (nº).

References

- Bozdag A., Göçmez G. (2012). Evaluation of groundwater quality in the Cihanbeyli basin, Konya, Central Anatolia, Turkey. Available from: https://www.researchgate.net/figure/Groundwater-classification-based-on-electrical-conductivity_tbl1_257794237

8.1.3 Biodiversity Indicators

8.1.3.1 Area Of Habitats Restored

- **Code:** Gediz_Bio01
- **Environmental Sector**: Plant / Plant Biodiversity
- **Units:** Hectares (Ha) Or Percentage (%)

Meaning and importance of the indicator

The area of habitats restored is a simple and effective indicator to assess the success, evolution and extent of planned restoration actions of target habitats. It is calculated as the extent (in hectares) of restored focal habitat area, or as a proportion of the total restored area of the planned restoration area of a given habitat type.

Expected evolution of the indicator

For each of the habitat types to be restored (eucalyptus plantation, temporary wetlands, prairie, etc.), the indicator values should reach the area of the declared objectives or the 100% of the declared area to be restored.

Possible relationship with other biodiversity analyses

Gediz_Bio03

Data obtention

Required data:

- Area of the restored habitat types.

Sampling data:

Field sampling and aerial images. Once the restoration work begins, the area of restored focal habitats will be determined through fieldwork and aerial images, and the extent of the restored area mapped using a Geographic Information System (GIS). Field data should be incorporated into a GIS to calculate the restored area.

Sampling calendar

The area of the restored focal habitats will be determined every month/trimester, depending on the progress of the restoration work.

Equipment

The most recent aerial photographs will be obtained from repositories at a high resolution (preferably at 1:2.500 to 1:10.000 scale). A standard GPS or smartphone with GPS. A GIS program (ArcGIS, QGIS, ...).

Data sources

Copernicus, Turkey National Geographic Information Systems

References

- Dumitru, A., & Wendling, L. (2021). Evaluating the impact of nature-based solutions: A handbook for practitioners. European Commission. 552 pg. Brussels. doi:10.2777/244577
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8.1.3.2 Number Of Focal Habitat Specialist Species

- **Code:** Gediz_Bio02
- **Environmental Sector**: Plant / Plant Biodiversity
- **Units:** Hectares (Ha)

Meaning and importance of the indicator

The number of focal habitat specialist species is an effective indicator to assess the progress and success of the objectives of the planned restoration actions. The input of fresh water into the delta will gradually desalinate the shallow waters and soils of some areas of the delta and sometimes creating temporal lagoons or temporary wetlands. These changes, will also gradually be reflected in the vegetation, causing changes in the plant composition, changing the number of specialist species of focal habitat such as saltmarshes, wetlands, riverine or riparian, dune, halophyte, macrophyte, etc. The number of focal habitat specialist species is an important indicator to assess the evolution of the objectives of the actions.

Expected evolution of the indicator

The expected evolution is an increase in specialist plant species associated with inland surface waters habitats with fresh or more or less brackish waterbodies, such as flooded *Phragmites australis* beds, temporary waterbodies (lakes, ponds, pools), or East Mediterranean tamarisk thickets, and a decrease in habitat specialist species of the following habitats: Mediterranean saltmarsh scrubs, *Juncus maritimus* communities, sea-lavender communities, *Alhagi pseudoalhagi* communities, or Annual *Salicornia*, *Suaeda* and *Puccinellia maritima* saltmarshes. Any continued decline in focal habitat specialist species associated with inland surface water habitats, or an increase in ruderal or invasive species, should be an early warning of any failure to achieve the planned objectives.

Possible relationship with other biodiversity analyses

Gediz_Bio01, Gediz_Bio03

Data obtention

Required data:

- Number of focal habitat specialist species.

Sampling plan:

Field sampling and aerial images. 5-10 permanent plots (delimited with permanent markers) of 25 m^2 each one, will be randomly distributed per habitat type in the zone with the freshwater input. 5-10 more plots per habitat type will be selected away from the influence of the water input and will be used as a control. All vascular plants will be sampled in each plot, or at least all focal habitat specialist species.

Sampling calendar

All plots will be sampled before any intervention and every 2-3 years thereafter. Fieldwork will always be carried out at the same time of the year, preferably at the phenological optimum of vegetation, to avoid plant misidentifications or confusions.

Equipment

A vegetation/habitats map at a scale between 1:5.000 to 1:25.000. The most recent aerial photographs will be obtained from repositories at a high resolution (preferably at 1:2.500 to 1:10.000 scale). A standard GPS or smartphone with GPS. A GIS program (ArcGIS, QGIS, ...). Some small field materials to mark the limits of the permanent transects.

Data sources

Copernicus, Turkey National Geographic Information Systems

References

- Dumitru, A., & Wendling, L. (2021). Evaluating the impact of nature-based solutions: A handbook for practitioners. European Commission. 552 pg. Brussels. doi:10.2777/244577
- Dumitru, A., & Wendling, L. (2021). Evaluating the impact of nature-based solutions: Appendix of Methods. European Commission. 373 pg. Brussels. doi:10.2777/11361
- Ichter, J. Evans, D. & Richard, D. (2014). Terrestrial habitat mapping in Europe: an overview. European Environment Agency, Luxembourg, 144 pg. doi:10.2800/11055
- Iban, M. C., & Aksu, O. (2020). A model for big spatial rural data infrastructure in Turkey: Sensor-driven and integrative approach. Land Use Policy, *91*, 104376
- Yalcin, G. 2016. Orthophoto Information System in Turkey in the View of Spatial Data Infrastructure. The International Arab Journal of Information Technology (IAJIT), 13(5): 25-31.

8.1.3.3 Focus Or Key Habitat(S) Area

- **Code:** Gediz_Bio03
- **Environmental Sector**: Plant / Plant Biodiversity
- **Units:** Hectares (Ha)

Meaning and importance of the indicator

The area of focus or key habitats is a simple and effective indicator to assess the success of the objectives of the planned restoration actions. The input of fresh water into the delta will gradually desalinate the shallow waters and soils of some areas of the delta and sometimes creating temporal lagoons or temporary wetlands. These changes will also gradually be reflected in the vegetation, leading to changes in plant composition and, ultimately, on habitats. Changes in key habitats will imply changes in ecosystem services and in the composition and distribution of the fauna in the Gediz delta, therefore the area of the key habitats is an important indicator of the planned interventions. It is calculated as the area (in hectares) of a key habitat type.

Expected evolution of the indicator

The expected evolution of the focus or key habitat area in the freshwater input zones is an increase in habitats related associated with inland surface waters with fresh or more or less brackish waterbodies, such as flooded *Phragmites australis* beds, temporary waterbodies (lakes, ponds, pools), or East Mediterranean tamarisk thickets, and a decrease in Mediterranean saltmarsh scrubs, *Juncus maritimus* communities, sea-lavender communities, *Alhagi pseudoalhagi* communities, or Annual *Salicornia*, *Suaeda* and *Puccinellia maritima* saltmarshes.

Possible relationship with other biodiversity analyses

Gediz_Bio01.

Data obtention

Required data:

- Area of focus or key habitats.

Sampling plan:

Field sampling and aerial images. Once the freshwater input begins, the focus or key habitat area will be determined through fieldwork and the aid of aerial images and mapped using a Geographic Information System (GIS) to calculate the area of each focus or key habitat.

Sampling calendar

The focus or key habitat area will be determined before any intervention and every 2-3 years thereafter. Fieldwork will always be carried out at the same time of the year, preferably during the phenological vegetation optimum period, to avoid misidentification or confusion of habitat types.

Equipment

The most recent aerial photographs will be obtained from repositories at a high resolution (preferably at 1:2.500 to 1:10.000 scale). A standard GPS or smartphone with GPS. A GIS program (ArcGIS, QGIS, ...).

Data sources

Copernicus, Turkey National Geographic Information Systems

References

- Dumitru, A., & Wendling, L. (2021). Evaluating the impact of nature-based solutions: A handbook for practitioners. European Commission. 552 pg. Brussels. doi:10.2777/244577
- Dumitru, A., & Wendling, L. (2021). Evaluating the impact of nature-based solutions: Appendix of Methods. European Commission. 373 pg. Brussels. doi:10.2777/11361
- Ichter, J. Evans, D. & Richard, D. (2014). Terrestrial habitat mapping in Europe: an overview. European Environment Agency, Luxembourg, 144 pg. doi:10.2800/11055
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- Yalcin, G. 2016. Orthophoto Information System in Turkey in the View of Spatial Data Infrastructure. The International Arab Journal of Information Technology (IAJIT), 13(5): 25-31.

8.1.3.4 Tree Biomass Removed

- **Code:** Gediz_Bio04
- **Environmental Sector**: Forest Ecosystem Service
- **Units:** T C Ha^{-1}

Meaning and importance of the indicator

Biomass stored in trees can be converted to CO_2 sequestered from atmosphere over time by trees as a of the trees' accumulated growth. The time that carbon remains sequestered in the form of wood, bark, leaves, etc., is carbon that is not returned to the atmosphere, contributing to climate change mitigation. When a tree is cut down, this process is reversed, and the carbon is re-emitted as CO2 into the atmosphere. This process can be more or less rapid depending on the fate of the wood: CO2 emissions will be immediate if it is used as fuel, or long-lasting if it is transformed, for example, into furniture or any other long-lasting product. A tree can sequester carbon at a good rate for over a hundred years and can keep that carbon sequestered for centuries until its death. It is important to quantify the aboveground carbon removed because, depending on the destination, the carbon will be released instantaneously to the atmosphere.

Expected evolution of the indicator

The expected evolution of biomass after the intervention will be zero tons because, in addition to cutting down the eucalyptus, it is also planned to remove the stumps and roots, ensuring that there is no possibility of regrowth.

Possible relationship with other forest ecosystem service analyses

DEMO 6.1. Aboveground Carbon Removed (Trees)

Data obtention

Required data:

Field sampling plots where different tree attributes are measured.

Sampling plan:

Circular plots with a fixed radius will be established, with a size sufficient to measure between 20 and 30 trees. Within the sampling radius, for each living or dead eucalyptus, the diameter at breast height (DBH, hereafter) and height will be measured.

Sampling calendar

This field sampling will be conducted twice. The first sampling campaign will take place before the implementation of the forest treatment. The second campaign will be carried out immediately after the forest intervention to quantify the effects of the treatments.

Equipment

A digital rangefinder, such as a Vertex Haglöf, will be used to measure the distance to the center of the plot. Alternatively, a clinometer can be used to measure the height of each tree. A diameter tape or a forestry caliper can be used to measure the DBH.

Calculation formula

Based on the DBH and height, the aboveground biomass (AGB) and belowground biomass (BGB) of each tree will be estimated using the following equations:

$$AGB = a \cdot DBH^b \cdot H^c \text{ or alternatively, } AGB = a \cdot DBH^b$$
$$BGB = a \cdot DBH^b$$
$$B = AGB + BGB$$

Where:

- *AGB,* is the tree aboveground biomass (kg dry weight)
- *BGB,* is the tree belowground biomass (kg dry weight)
- *B,* is the total tree biomass (kg dry weight)
- *DBH,* is the diameter at breast height (cm)
- *H,* is the tree height (m)
- *a*, *b* and *c,* are the parameters of the equation

The parameters of the equation can be found in the biomass equation repository by species: https://laboratoriforestal.creaf.cat/allometrapp/.
Finally, the biomass removed per hectare is calculated by summing the biomass (B) of all trees and then multiplying by the factor that converts the area of the plot to a hectare.

References

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- Whittaker R. H. i Woodwell G. M., 1969. Structure, production and diversity of the oak-pine forest at Brookhaven, New York. Journ. of Ecol. 57: 157-174.

8.1.4 Energy Indicators

8.1.4.1 Biogas Generation Due to Wastewater Treatment

- **Code**: Gediz_Energy01
- **Environmental Sector:** Energy
- **Units**: m^3 biogas/m^3 wastewater

Meaning and importance of the indicator

"Biogas generation due to wastewater treatment" measures the amount of biogas (a biofuel) produced as a byproduct of treating wastewater. This biogas, primarily composed of methane and carbon dioxide, is generated during the anaerobic digestion process where microorganisms break down organic matter in the absence of oxygen. The importance of this indicator lies in its dual environmental and economic benefits. Environmentally, biogas production reduces greenhouse gas emissions by capturing methane that would otherwise be released into the atmosphere, contributing to climate change mitigation. Economically, biogas serves as a renewable energy source that can be used for heating, electricity generation, or as a vehicle fuel, thereby reducing reliance on fossil fuels and promoting energy sustainability. Additionally, the process supports waste management by treating wastewater efficiently and reducing the volume of sludge. Overall, this indicator is vital for assessing the sustainability and effectiveness of wastewater treatment processes and their contributions to renewable energy production and environmental protection.

Expected evolution of the indicator

The expected evolution of the indicator "Biogas generation due to wastewater treatment" is towards increasing biogas production efficiency and capacity. The tendency is driven by advancements in anaerobic digestion technology, improvements in the operational management of wastewater treatment plants, and increased regulatory and policy support for renewable energy and waste-to-energy initiatives.

Data obtention

Online measurement of amounts of biogas production and wastewater treated.

Frequency

Continuous.

8.1.4.2 Energy Consumption of Biogas Production System

- **Code**: Gediz_Energy02
- **Environmental Sector:** Energy
- **Units**: kWh/m^3 wastewater

Meaning and importance of the indicator

"Energy Consumption of biogas production system" measures the amount of energy (mainly electricity) used in the processes involved in biogas production to make it safe for discharge or reuse. This indicator is crucial for evaluating the sustainability and efficiency of biogas production facilities. High energy consumption can indicate inefficiencies and result in increased operational costs and higher carbon emissions, which are detrimental to both economic and environmental goals. Conversely, optimizing energy use in biogas production can lead to significant cost savings, lower greenhouse gas emissions, and a reduced environmental footprint. Monitoring this indicator helps in identifying opportunities for implementing energy-saving technologies and practices, such as using more efficient equipment, improving process controls, and integrating renewable energy sources. Ultimately, reducing energy consumption in biogas production supports broader sustainability objectives by minimizing resource use and contributing to climate change mitigation.

Expected evolution of the indicator

The expected evolution of the indicator "Energy Consumption in biogas production system" is towards decreasing energy use per unit of biogas, reflecting improvements in efficiency and sustainability of biogas production processes. This evolution is driven by technological advancements, better operational practices, and increased regulatory and policy pressures to reduce environmental impact.

Data obtention

Field measurement or assessment based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

8.1.4.3 PV Electricity Generation and Total Land Used

- **Code**: Gediz_Energy03
- **Environmental Sector:** Energy
- **Units**: kWh/m^2 land

Meaning and importance of the indicator

"PV electricity generation and total land used" measures the amount of electricity generated by photovoltaic (PV) solar panels in relation to the total land area occupied by these installations. This indicator is crucial for evaluating the efficiency and land-use impact of solar energy projects. By assessing the ratio of electricity output to land use, stakeholders can determine the productivity and spatial efficiency of PV systems, which is important for optimizing land resources, especially in areas where land is scarce or valuable for other uses. Monitoring this indicator helps in planning and decision-making processes, ensuring that solar energy projects are both effective in terms of energy generation and sustainable in terms of land utilization. It also supports the broader goals of increasing renewable energy capacity, reducing carbon emissions, and promoting sustainable development practices.

Expected evolution of the indicator

The expected evolution of the indicator "PV electricity generation and total land used" is towards increasing efficiency, meaning more electricity generation per unit of land used. This trend is driven by advancements in photovoltaic technology and improved installation practices.

Data obtention

Online measurement.

Frequency

Continuous.

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DEMONSTRATED IN THE MEDITERRANEAN REGION

Deliverable 2.2

ANNEX I: DEMO9

DEMO9: Nikosia

To address the heat island effect, the lack of freshwater resources, and support the disadvantaged communities through food production and community engagement, three coordinated actions of different scales in different public parks of Nikosia (Cyprus) will be implemented. The actions consist in the creation of a rainwater harvesting system (filter drain) in the Polykratous Park, a halophyte-based water treatment (photobioreactor) in Kaimakli Park, and a vertical hydroponic wall system (green facade) located in the Gardens of the Future. These actions will help to improve the microclimate, to expand the green and natural spaces around the city, and to enhance quality of life of its residents.

DEMO 9.1: Nikosia - Kaimakli Park	Sector	Code
Soil Physical and Chemical Fertility	Soil	Nikosia-1_Soil01
Soil Bulk Density (ρ)	Soil	Nikosia-1_Soil02
Effective Groundwater Treatment (GWTeff)	Water	Nikosia-1_Water01
Reclaimed Water in Non-Potable Uses (RWnpU)	Water	Nikosia-1_Water02
Water-Related Materials' Recovery (WR)	Water	Nikosia-1_Water03
Water Storage Capacity (WSC)	Water	Nikosia-1_Water04
Effluent Pollutant Removal (EPR)	Water	Nikosia-1_Water05
Water Quality Compliance (WQC)	Water	Nikosia-1_Water06
Aquifer Surface Ratio with Excessive Nitrate (ASREN)	Water	Nikosia-1_Water07
Physico-Chemical Status of Groundwater/Surface Water (Wstatus)	Water	Nikosia-1_Water08
Bird Species Richness	Biodiversity	Nikosia-1_Bio01
New Fauna Habitat Area	Biodiversity	Nikosia-1_Bio02
Energy Consumption for Groundwater Treatment	Energy	Nikosia-1_Energy01
DEMO9.2: Nikosia - Polykratous Park		
Soil Physical and Chemical Fertility	Soil	Nikosia-2_Soil01
Soil Bulk Density (ρ)	Soil	Nikosia-2_Soil02
Reclaimed Water in Non-Potable Uses (RWnpU)	Water	Nikosia-2_Water01
Water Storage Capacity (WSC)	Water	Nikosia-2_Water02
Water Quality Compliance (WQC)	Water	Nikosia-2_Water03
Rainfall Interception of NBS (RI)	Water	Nikosia-2_Water04
Bird Species Richness	Biodiversity	Nikosia-2_Bio01
New Fauna Habitat Area	Biodiversity	Nikosia-2_Bio02
Energy Indicators	Biodiversity	Nikosia-2_Bio03
Air Temperature Measurement (Weather Station)	Energy	Nikosia-2_Energy01
Air Humidity Measurement (Weather Station)	Energy	Nikosia-2_Energy02
Energy consumption of Water Storage and Irrigation in green areas	Energy	Nikosia-2_Energy03
DEMO9.3: Nikosia - Gardens of the Future		
Water Footprint (WFP)	Water	Nikosia-3_Water01
Tap Water Consumption (TWC)	Water	Nikosia-3_Water02
Number of Individuals Producing Edible Fruits	Biodiversity	Nikosia-3_Bio01
Fruit Production Per Species	Biodiversity	Nikosia-3_Bio02
Flying Insect Sampling	Biodiversity	Nikosia-3_Bio03
Electricity Use in Agriculture	Energy	Nikosia-3_Energy01
Food production (yield in terms of weight for energy footprint)	Energy	Nikosia-3_Energy02
Renewable Energy Sources (RES) units integrated and capacity	Energy	Nikosia-3_Energy03
Gross Renewable consumption relative to total gross final consumption	Energy	Nikosia-3_Energy04
Increase In Renewable Energy Use in The Area	Energy	Nikosia-3_Energy05

DEMO 9.1: Nikosia - Kaimakli Park

9.1.1 Soil Indicators

9.1.1.1 Soil Physical and Chemical Fertility

- **Code:** Nikosia-1_Soil01
- **Environmental Sector**: Soil / Soil Health

- **Units:** A Multi-Component Indicator. Diverse Units for Specific Components

Meaning and importance of the indicator

Soil fertility, its capacity to sustain plant growth, depends on complex interactions between biological, chemical and physical properties. Achieving and maintaining appropriate levels of physical and chemical fertility is of paramount importance to support urban green. In natural soils, nutrients come from minerals, water, atmospheric deposition, and recycling of plant and animal residues but their availability to plants is significantly affected by soil acidity (pH), and nutrient presence in the soil solution is highly dependent on soil texture and soil cation exchange capacity. Water retention in soils and progressive release to plants is notably improved by soil organic matter, which is particularly important in Mediterranean regions under increasing aridity. Urban soils are highly heterogeneous and are frequently called “technosoils”. Soils are made of human-transported substrates, or are native soils highly transformed by anthropization. Urban soils are very often compacted and polluted, but they perform multiple unvaluable ecosystem services when returned to health, particularly in water and carbon cycles, and play a pivotal role in human wellbeing trough supporting healthy vegetation. Soil analysis is the basic tool to evaluate soil fertility and to guide city managers towards sustainable soil management.

Expected evolution of the indicator

There are recommended ranges and critical values for most of the soil properties to be analysed. For urban gardens, together with the results of soil analyses agricultural laboratories provide an evaluation of the level of each analyzed parameter (deficient – correct – excessive or similar). The value of each parameter should evolve towards these reference values and will guide gardeners in designing fertilization or any other correction. Special attention will be paid in this case to the evolution of soil salinity. An approach to tolerable salinity and electrical conductivity levels in soil, depending on soil texture (provided in the analyses) can be found in https://www.agric.wa.gov.au/soil-salinity/measuring-soil-salinity.

Data obtention

Required data:

To be analysed only the first time: soil texture (% sand; % clay; % silt); textural class.

To be analysed at each soil sampling campaign: pH; Electrical conductivity (CEC); Total organic carbon (%, dry soil basis); Carbonates; Total nitrogen (Kjeldahl); Available phosphorus (Olsen); Cation exchange capacity; Interchangeable bases (Ca, Mg, Na and K); Micronutrients (Fe, Zn, Mn)

Sampling plan:

Field sampling followed by lab analyses. The samples will always be taken at the same moment of the year (set a fixed spring month), preferably avoiding temporal proximity to gardening interventions (or any other type of actions affecting soil (tree pruning, plantation, grass sowing, fertilization, etc.)

In homogeneous landscapes, two samples per hectare may be a standard sampling density. We don’t have a clear estimate of the surface area to be irrigated with underground water treated to reduce its salinity (case 1), or with rainfall harvested the hydro park (case 3) and we don’t know the spatial distribution of this irrigated areas.

As a general approach, at each site divide the space to be monitored in homogeneous units (garden islands, different slopes, etc) and sample every unit of sufficient dimensions. Take at least two soil samples within each land unit, from two points randomly selected. The two samples will be mixed into a unique plastic zip bag duly labelled with the date and the location of the place. Soil must be sampled at 15 cm depth with soil samplers like those described in the "equipment" section.
The resulting composite soil samples will be sent to an expert lab for analysis as soon as possible. The soil lab must have been previously consulted for instructions about the preparation of the samples before shipping.

Sampling calendar

The gardens will be sampled in the proposed season every 2 years for 10 years (5 times).

Equipment

Samples will be taken with soil borers of similar and known (the same for all samples at each sampling campaign) depth and diameter. The borer should be 15 cm long and the recommended diameter is 5 cm. Some providers of these soil samplers are: https://www.ams-samplers.com/soil-augers/; https://www.vanwalt.com/equipment/telescoping-augers/. Any other equivalent sampler of these dimensions is acceptable (but try to respect the 15 cm depth)
You will need some small field materials, such as zip bags and outdoor knife (or small garden spade)

External subcontracting

Yes. A trustable lab delivering soil fertility analyses must be hired.

References

- Dondini, C., Úbeda, X., Certini, G., Francos, M. (2024). Soil quality in the urban gardens of Barcelona (Spain). *Journal of Soils and Sediments*, 1-13.
- Kortleve, A. J., Mogollón, J. M., Heimovaara, T. J., Gebert, J. (2023). Topsoil carbon stocks in urban greenspaces of The Hague, the Netherlands. *Urban Ecosystems*, *26*(3), 725-742.

- Dondini, C., Úbeda, X., Certini, G., Francos, M. (2024). Soil quality in the urban gardens of Barcelona (Spain). *Journal of Soils and Sediments*, 1-13.
- Kortleve, A. J., Mogollón, J. M., Heimovaara, T. J., Gebert, J. (2023). Topsoil carbon stocks in urban greenspaces of The Hague, the Netherlands. *Urban Ecosystems*, *26*(3), 725-742.

- For soil fertility in gardens: https://extension.umaine.edu/gardening/manual/soils/interpreting-soil-tests/

9.1.1.2 Soil Bulk Density (ρ)

- **Code:** Nikosia-1_Soil02
- **Environmental Sector**: Soil / Soil Health
- **Units:** G Cm^{-3}

Meaning and importance of the indicator

Bulk density indicates the degree of soil compaction. Bulk density is inversely related to soil porosity which allows air and water to move through the soil and facilitates plant root penetration through the soil. Compaction is the main feature of urban soils, very specially when they have been sealed beneath pavement, since sealing most often is preceded by removal of topsoil horizons and mechanic compaction that induces heavy alteration of the soil pore space and architecture. Other urban anthropogenic soils are made of human-transported materials and typically show heterogeneous granulometry and composition and unpredictable hydrological behavior depending on treatment. Compaction is among the main features of physical degradation of urban soils and is often accompanied by low water holding capacity, low biological activity and low chemical quality and capacity to sustain healthy plants.

Expected evolution of the indicator

In case of pre-existing natural soil, bulk density is affected by soil texture (sand, silt, and clay proportion) and organic matter content. Fine-textured soils (such as silt and clay loams) with good structure have lower bulk density compared to sandy soils. According to data from the EU Joint Research Centre, mean European values for soil bulk density are 1.26 g cm^{-3} for arable lands, 1.23 g cm^{-3} for permanent crops, and 1.14 for heterogeneous agricultural areas. In highly disturbed urban soils, bulk density can range from 1.5 g cm^{3} in lawns to densities that approach those of concrete in heavily trodden paths of sport yards (2.2 g cm^{3}). Bulk density should decrease as soil recovers its structure and gains organic matter.

Data obtention

Required data:

None. Measured from specific soil samples at each sampling campaign for soil fertility (Nikosia-1_Soil01).

Sampling plan:

Field sampling followed by very a simple analysis. Bulk density will be measures at the hydropark area. Samples will always be taken at the same moment of the year (make it match the soil fertility sampling date), preferably avoiding temporal proximity to gardening interventions (or any other type of interventions implying soil trampling or compaction)

We do not know the exact surface area or spatial distribution and heterogeneity of the soil to be monitored at the hydro park but, at each sampling date, you will sample soil for bulk density in the same land islands or homogeneous units that you have sampled for soil fertility (Nikosia_Soil1) and in the vicinity of the already sampled points (at least two sampling points per land unit).

A detailed explanation of the sampling method is provided in the USDA Soil Quality Test Kit Guide (1999), pg.9 (see references).

In short for each sample, drive the metal cylinder all the way into the ground until its upper edge is level with the surface of the ground (using a mallet and a block of wood). Remove the ring taking great care not

to lose soil. To do so, dig around the ring and with a trowel underneath it, carefully lift it out. Remove excess soil from the sample with a flat-bladed knife. The top and bottom of the soil sample should be flat and even with the edges of the ring. Using the flat-bladed knife, push out the entire soil sample into a plastic zip bag. Label the bag correctly.
Take the samples to the lab (or any other place where there is a scale - two decimal places of accuracy- and a drying oven). Transfer each sample individually from the plastic bag to a foil or paper tray duly labelled. Put the soil samples to dry at 100 ºC until constant weight (usually 4 days is enough). Weight the dry soil (in g) and register it in your soil data worksheet. If a drying oven is not available, you can use a microwave (see the method in the USDA Soil Quality Test Kit Guide (in references)

Sampling calendar

Bulk density will be measured together with soil fertility (Nikosia-1_Soil01), every two years for ten years.

Equipment

Bulk density is the ratio between soil dry weight and soil volume. Therefore, soil samples will be taken with a stainless-steel cylinder of perfectly know volume. The recommended dimensions for this case are 10 cm deep and 8 cm in diameter.
Additional field materials: a mallet, a block of wood, a trowel, a knife and zip-bags.

External subcontracting

If a reliable scale and a microwave are available, bulk density can be obtained very simply without the need of an expert lab.

Calculation formula

$$\rho = M / V$$

- Where:
  ρ is estimated as g cm^{-3}
- M is the dry weight of the sample in g
- V the volume of the soil cylinder (in cm^3)

For each island or homogeneous sampling unit, calculate the average of the two estimates of density.

References

- Can Urban Soil Compaction Be Reversed? Technical Note #108 from Watershed Protection Techniques. 1(4): 666-66. https://owl.cwp.org/mdocs-posts/elc_pwp37/
- Effect of Urban Soil Compaction on Infiltration Rate https://owl.cwp.org/mdocs-posts/effect-of-urban-soil-compaction-on-infiltration-rate/
- O'Riordan, R., Davies, J., Stevens, C., Quinton, J. N. (2021). The effects of sealing on urban soil carbon and nutrients. *Soil*, *7*(2), 661-675.
- Paradelo, R., Herbón, C., Barral, M. T. (2024). Physical properties of the urban soils of Santiago de Compostela (Spain). *Journal of Soils and Sediments*, 1-10.
- The Compaction of Urban Soils. Technical Note #107 from Watershed Protection Techniques. 3(2): 661-665. https://owl.cwp.org/mdocs-posts/elc_pwp36/

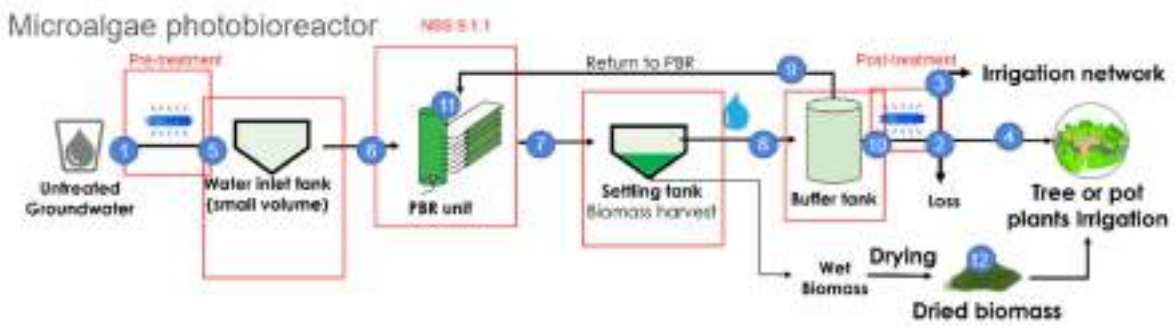
- Soil Quality Indicators. Bulk Density. USDA Natural Resources Conservation Service https://www.nrcs.usda.gov/sites/default/files/2022-10/nrcs142p2_051591.pdf
- Soil Quality Test Kit Guide. USDA Natural Resources Conservation Service. 1999. https://efotg.sc.egov.usda.gov/references/public/WI/Soil_Quality_Test_Kit_Guide.pdf

9.1.2 Water Indicators

9.1.2.1 Water Monitoring Plan

Sampling points

Improvement of groundwater quality using microalgae.



Sampling point	Location	Purpose
SP-01	Inlet of the pre-treatment of the untreated groundwater	Monitor groundwater to be treated (efficiency of the whole treatment)
SP-02	Outlet of the treatment system (after UV post-treatment)	Monitor groundwater treated and reclaimed water quality and availability (efficiency of the whole treatment, nutrient content and volume)
SP-03	Reclaimed water pipe to the irrigation network (after stream disposal and before the tank)	Monitor reclaimed water availability for irrigation (volume)
SP-04	Reclaimed water pipe to the trees or pot plants irrigation	Monitor reclaimed water for green areas irrigation
SP-05	Outlet of the UV pre-treatment (before the water inlet tank)	Monitor the efficiency of the pre-treatment and groundwater availability
SP-06 (Optional)	Inlet of the PBR unit	Monitor the efficiency of the PBR unit
SP-07 (Optional)	Outlet of the PBR unit	Monitor the efficiency of the PBR unit
SP-08	Outlet of the setting tank	Monitor the reclaimed water
SP-09	Outlet of the buffer tank to the PBR	Monitor the reclaimed water for the PBR

SP-10	Inlet of the UV treatment (after the buffer tank)	Monitor the reclaimed water
SP-11	Inside the PBR unit	Monitor water materials recovery
SP-12	In the dried biomass	Monitor water materials recovery

Parameters to be analyzed

Parameter	Applicable Sampling point	Related indicator/s	Type
Volume of treated groundwater (GW)	SP-01, SP-02	GWTeff; WR;	water flow measurements [volume/time]
Volume of reclaimed water produced	SP-09	RWnpU	water flow measurements [volume/time]
Volume of reclaimed water used for irrigation	SP-03, SP-04	RWnpU, WSC	water flow measurements [volume/time]
Water withdrawal for irrigation	SP-02	RWnpU, GWTeff	water flow measurements [volume/time]
Water quality parameters: -Nitrogen content (TN, NO3 or NH3) depending on the fertilizer it would replace and its N content. -Total phosphorus (TP) content	SP-01, SP-02, SP-07	ASREN; WR	water quality parameters
Water quality parameters: Conductivity, COD, BOD5, TSS, TN, TP, TOC, Temperature, turbidity, E. coli	SP-01, SP-02	EPR	water quality parameters

Sampling method

Water flow measurements:

Direct measurement of volume provided during a time period or water flow with flow meters and/or water level sensors.

a) Automatic method

Automatic flow meters can be installed at the recommended sampling points (SP). For the automatisation process, it is recommended to register the measurements with a datalogger/digital control system in the DEMO. It is recommended to measure the flow at the recommended sampling points (SP).

Data should be stored in a datalogger/digital control system and then be able to be exported in a spreadsheet to calculate the associated indicators. When this is not possible, manual readings of the flow meters can be done instead.

b) Manual method

This could be applied as the last option if there is no possibility to apply the automatic method.

- Periodic manual measurements
- If no devices are available to measure, correct and reliable estimates must be made to assess the indicator.
- Measure the volume at the point of reuse or approximate the value based on the amount of water demand met by tree or plot plants for reuse.

Water quality parameters:

Automatic measurement methods (a) or manual sampling campaigns (water sampling + laboratory analysis) (b) can be employed, with specific requirements for different types of pollutants.

a) Automatic method

Advanced sensors of water quality can be installed in the recommended sampling points (SP) to continuously monitor and measure various water quality parameters, such as temperature, pH, turbidity, dissolved oxygen, NO_3, etc. These sensors collect data in real-time, providing continuous and accurate information about water quality. The data is often transmitted wirelessly to a central database, or sensors can be also connected to a datalogger. The data is often transmitted wirelessly to a central database, or sensors can be also connected to a datalogger.

b) Manual method

As the DEMO has not been implemented yet, mature and operating, sampling campaigns will be carried out periodically to control the operation and performance of the treatment system. Samples will be collected at the recommended sampling points (SP). Two types of water quality analysis have been defined: basic and complete. Different sampling and analysis periodicities will be suggested during the start-up phase, stabilization phase and mature operation. Basic analysis will include all water quality parameters that are required to be monitored by legislation for reclaimed water reuse for irrigation: turbidity, COD/BOD_5, E. coli, TSS (other if required by legislation). Complete analysis includes other water quality parameters for general monitoring and indicators' assessment: conductivity, TN, TP, TOC, temperature, NO_3 and/or NH_3.

Samples can be obtained manually or using automatic sampling equipment. An automatic sampler is a device that can be refrigerated or non-refrigerated and include automatic sampling pumps and upward stage samplers. The process involves collecting water samples intended for laboratory analysis of water quality parameters. However, there are limitations associated with automatic sampling, such as intermediate sampling containers, sampling from a fixed point, and sample storage and preservation, which must be considered and documented. Personnel using these methods should have training and prior experience in the use and calibration of automatic sampling equipment. The laboratory analysis is done following current ISO laboratory protocols for each different parameter.

Sampling calendar

Water flow measurements and water depth variation:

Data should be collected frequently for a relevant time period (e.g., daily, weekly, monthly) to allow for accumulation over the entire reporting period (yearly). This high frequency is also relevant to study seasonal variations.

Water quality parameters:

As the DEMO has not been implemented yet, different sampling and analysis periodicities will be suggested during the start-up phase, stabilization phase and mature operation:

- Start-up phase: the first 3 months of operation of the DEMO it is recommended to increase the frequency of the analysis to 1 basic analysis per week and 1 complete analysis biweekly.
- Stabilization phase: from month 4 to month 12 of operation it is recommended to do 1 basic analysis per week and 1 complete analysis per month.
- Mature operation: from month 13, the recommended frequency of water quality analysis is 1 basic analysis per week and 1 complete analysis per month.

Equipment

Water flow measurements:

Water flow meters are essential tools for monitoring and assessing the efficiency of these systems, as they provide real-time data on water movement and usage through the treatment processes and the different pipes, helping to determine the volume of water at those particular locations. Some providers of these water flow meters are:

- Endress+Hauser
- Systec Controls
- Aobo instrument

Any equivalent water flow meter is acceptable, these are given as examples.

Water quality parameters:

The automatic sampling method requires simple or multiparametric sensors for water quality and data loggers or digital control systems for data recording. It also requires personnel for data collection and treatment.

The manual sampling campaign requires laboratory and field personnel for manual sampling and analysis and also reagents and laboratory material depending on the current ISO laboratory protocols for each parameter.

Some indicative providers for water quality parameters are:

- ANISE sensor (NH_4 and NO_3) - Hach
- Conductivity meter - METTLER TOLEDO
- pH meter - METTLER TOLEDO
- Multi-parameter analyser and sensor measure groundwater quality (DO, turbidity, conductivity, pH, salinity, temperature) - BOQU instruments
- Multi-parameter water quality analyser (temperature, pH, conductivity, DO, turbidity, BOD, COD, ammonia nitrogen, NO_3, colour, chloride, depth, etc.) - BOQU instruments

Any equivalent water level sensor is acceptable, this is given as an example.

External subcontracting

Yes. A trustable laboratory delivering water quality analyses must be hired if not available internally.

9.1.2.2 Effective Groundwater Treatment (GWTeff)

- **Code**: Nikosia-1_Water01
- **Environmental Sector:** Water / Safeguarded water ecosystems
- **Units:** %

Meaning and importance of the indicator

The indicator measures the effectiveness of groundwater treatment processes in removing pollutants to meet established quality and regulatory standards before the water is considered suitable for its intended use. This indicator evaluates the efficiency of treatment systems in mitigating pollutants such as chemicals, heavy metals, and pathogens from groundwater sources. This indicator also is used to have an overview of how much groundwater is not complying and will have a negative impact on ecosystems.

Expected evolution of the indicator

The GWTeff indicator ranges from 0 to 100%. A higher percentage indicates a more effective treatment process, ensuring that the groundwater is adequately treated and safe for consumption or other uses. The GWTeff indicator is necessary for assessing the reliability and performance of groundwater treatment facilities. The optimal value is 100%, which would indicate that all treated groundwater meets or exceeds the required quality standards. This level of effectiveness is critical for safeguarding both ecosystems and human health.

Possible relationship with other water indicators

Water quality compliance: biological, physical and chemical parameters, Water provision by the ecosystem, Aquifer surface ratio with excessive nitrate, Aquifer surface ratio with excessive arsenic, Increased groundwater recharge, Physico-chemical status of groundwater/surface waters.

Data obtention

Sampling plan:

- Volume of treated groundwater complying with quality or legal requirements (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO. Only data that complies with legal requirements will be selected.
- Volume of treated groundwater in the DEMO (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.

Calculation formula

$$GWTeff = \frac{V_{Treatment}}{GW} \cdot 100$$

Where:

- GWTeff: Effective groundwater treatment (%)
- $V_{Treatment}$: Volume of treated groundwater complying with quality or legal requirements (m^3/year)
- GW: Volume of treated groundwater (m^3/year)

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: a handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577
- Indicator adapted from Effective Wastewater treatment (WWTeff). B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

9.1.2.3 Reclaimed Water in Non-Potable Uses (RWnpU)

- **Code**: Nikosia-1_Water02
- **Environmental Sector:** Water / Water resource recovery and use
- **Units:** %

Meaning and importance of the indicator

The indicator measures the proportion of reclaimed water (from treated wastewater, rainwater, urban runoff, etc.) used in non-potable applications where previously drinking or freshwater was used. It is related to the total volume of water used for those purposes. This indicator provides valuable insight into the sustainable use of water resources by quantifying the extent to which reclaimed water is used for non-potable purposes.

Expected evolution of the indicator

The optimal value for the RWnpU indicator is as close to 100% as possible, indicating that the majority of non-potable water needs are met with reclaimed water, minimizing the demand for freshwater.

Possible relationship with other water indicators

Compliant reclaimed water, Water availability, Reclaimed water production, Water provision by the ecosystem.

Data obtention

Sampling plan:

- Volume of reclaimed water used for non-potable uses (e.g., irrigation, street cleaning, groundwater recharge) (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total volume of water used for non-potable uses, from all sources, including freshwater and reclaimed water (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.

Calculation formula

$$RWnpU = \frac{RW}{npW} \cdot 100$$

Where:

- RWnpU: Reclaimed Water in non-potable Uses (%)
- RW: Volume of reclaimed water used for non-potable uses (e.g., irrigation, street cleaning, groundwater recharge) (m^3/year)
- npW: Total volume of water used for non-potable uses, from all sources, including freshwater and reclaimed water (m^3/year)

Note: “used” may be “supplied” or “consumed”, but must be consistent in RW and npW.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

9.1.2.4 Water-Related Materials' Recovery (WR)

- **Code**: Nikosia-1_Water03
- **Environmental Sector:** Water / Water resource recovery and use
- **Units:** %

Meaning and importance of the indicator

The indicator is defined as the percentage of a by-product* material or waste that is recovered and suitable for reuse after a treatment process or activity* to improve other activities within the same DEMO or other external sites (i.e. drinking water plant, wastewater treatment plant, industry, agroforestry, etc).
**By-product*: a secondary product produced in the manufacturing, treatment or synthesis of something else. Some examples can be: nitrogen and phosphorus recovery for its reuse as biofertilizer, sludge recovery from wastewater as compost, harvested microalgal biomass as fertilizer, organic biomass from aquaculture as fertilizer and saturated filter media or adsorption materials for water filtration, purification of aqueous or gaseous mediums, retention of contaminants.
Treatment process or activity: the main infrastructure or technology where the DEMO or an external organization performs its main activities. If more than one waste stream is recovered, a weighting factor can be applied to obtain a single total indicator.

Expected evolution of the indicator

The optimal value is ideally close to 100%. A higher percentage indicates that more materials are being recovered, which suggests greater resource efficiency and reduced environmental impact.

Possible relationship with other water indicators

Reclaimed water production, Water footprint.

Data obtention

Sampling plan:

- Material recovered from the treatment process or activity and considered suitable for reuse (kg/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total potential recoverable material entering the treatment process or activity (kg/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.

Calculation formula

$$WR = \frac{W_{i,re}}{W_{i,in}} \cdot 100$$

Where:

- WR: Water-related materials' Recovery (%)
- $W_{i,re}$: Material recovered from the treatment process or activity and considered suitable for reuse (kg/year)

- $W_{i,in}$: Total potential recoverable material entering the treatment process or activity (including materials that are added and recovered during the process) (kg/year).

Note: some examples of recoverable material are nitrogen and phosphorus for its reuse as biofertilizer, sludge from wastewater as compost, harvested microalgal biomass as fertilizer, organic biomass from aquaculture as fertilizer.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/
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9.1.2.5 Water Storage Capacity (WSC)

- **Code:** Nikosia-1_Water04
- **Environmental Sector:** Water / Effectiveness of the adaptive change towards resilient infrastructure
- **Units:** Days

Meaning and importance of the indicator

The indicator assesses the resilience and efficiency of water supply systems. It is defined as the ratio between the total volume of available storage (e.g., water supply tanks, reservoirs for rainwater harvesting, and reclaimed water storage) and the average flow rate either provided to or demanded by the system. This flow rate encompasses all demands associated with distribution systems, rainwater harvesting infrastructure, and treatment facilities. The indicator provides insightful information about the number of days that the system can handle relying on the potential stored volume of water, not on the actual volume of stored water.

Expected evolution of the indicator

The WSC indicator will vary by region, depending on local water availability, climate conditions, and demand patterns in the DEMO. The optimal value is context-specific, but generally, a higher WSC indicates a more resilient water supply system capable of withstanding longer periods without external water inputs. However, as water supply systems integrate more non-conventional water sources (e.g., rainwater harvesting, reclaimed water, etc.), the WSC is expected to increase, improving the system's sustainability and resilience.

Possible relationship with other water indicators

Water availability, Captured runoff.

Data obtention

Sampling plan:

- Total operational volume of storage capacity, such as supply tanks, reservoirs, and reclaimed water storage (m^3)
  Fixed value of the operational volume of the storage capacity.
- Daily average inflow entering or being demanded to the DEMO system (m^3/day)
  The average can be done from data obtained from sampling at the DEMO.

Calculation formula

$$WSC = \frac{V_t}{Q_S}$$

Where:

- WSC: Water Storage Capacity (days)
- V_t: Total operational volume of storage capacity (m^3)
- Q_s: Daily average inflow entering or being demanded to the system (m^3/day)

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/
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9.1.2.6 Effluent Pollutant Removal (EPR)

- **Code**: Nikosia-1_Water05
- **Environmental Sector:** Water / Water treatment / Water quality
- **Units:** %

Meaning and importance of the indicator

The indicator measures the average removal ratio between incoming and outgoing pollution load of the NBS. It can be evaluated for any pollutant. It is used to assess the effectiveness of water treatment processes in reducing pollution before discharge into the environment or wastewater treatment plant or its reuse.

*If there are additional water treatments in combination with the NBS, we recommend sampling before and after each treatment to have a better understanding of the role of each one in the treatment process.

Expected evolution of the indicator

The target can be determined based on design requirements (e.g., why the NBS is necessary, which pollutant needs to be addressed, and the desired removal efficiency) or according to local regulations and guidelines that define water quality standards depending on its intended use (such as for consumption, discharge, or reuse). For reclaimed water (as per Water Directive 2020/741), the goals would be: 95% removal of microbiological and emerging contaminants, 60-95% removal of nutrient pollutants, and 95% removal of physico-chemical parameters (such as turbidity). For treated wastewater (under RD 509/1996 and RD 11/1995), the objectives would include 70-80% reduction of nutrient pollutants and 90% removal of physico-chemical parameters (such as turbidity). For drinking water (in line with RD 3/2023), the goals would involve: 99-100% elimination of microbiological contaminants, 80-99% reduction of chemical pollutants, and 95% removal of physico-chemical parameters (such as turbidity) and nutrients.

Possible relationship with other water indicators

Reclaimed water production, Environmental flow requirement compliance rate, Safe drinking water, Water quality compliance: biological, physical and chemical parameters.

Data obtention

Sampling plan:

- Average influent concentration (mg/L).
- Average effluent concentration (mg/L).

Water quality parameters:

- Physical-chemical properties data:
  - - pH (unitless)
  - - Temperature (ºC)
  - - Electrical Conductivity (EC) (µS/cm)
  - - Turbidity (NTU)
  - - TSS (Total Suspended Solids) (mg/L)
- Biological data:
  - - DO (Dissolved Oxygen) (mg/L O_2)

- - BOD (Biochemical Oxygen Demand) (mg/L O_2)
- - COD (Chemical Oxygen Demand) (mg/L O_2)

- Chemical pollutant data:
  - - Heavy metals (µg/L)

  - Total pesticides (µg/L)
- Nutrients data:
  - - TN (Total Nitrogen) (mg/L N)
  - - NO_3 (Nitrates) (mg/L)
  - - TP (Total Phosphorus) (mg/L P)
  - - PO_4 (Phosphates) (mg/L)
- Microbiological data:
  - - E. Coli (CFU/100 mL)
- Other specific pollutants data:
  - - Contaminants of emerging concern
  - - Pollutants from industrial effluents will be added if necessary.

Calculation formula

$$\%Re = \frac{(Ci - Ce)}{Ci} \cdot 100$$

Where:

- %Re: average effluent pollutant removal (%)
- Ci: average influent concentration (mg/L)
- Ce: average effluent concentration (mg/L)

*To be evaluated for each pollutantz

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: A handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577
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- Boletín Oficial del Estado (1996). Real Decreto 509/1996, de 15 de marzo, de desarrollo del Real Decreto-ley 11/1995, de 28 de diciembre, por el que se establecen las normas aplicables al tratamiento de las aguas residuales urbanas. https://www.boe.es/buscar/pdf/1996/BOE-A-1996-7159-consolidado.pdf

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9.1.2.7 Water Quality Compliance (WQC): Biological, Physical and Chemical Parameters

- **Code:** Nikosia-1_Water06
- **Environmental Sector:** Water / Water quality
- **Units:** [Compliant with regulatory standards: Yes/No]

Meaning and importance of the indicator

The indicator provides a simplified view of regulatory compliance regarding water quality, taking into account various parameters. It is especially important to validate quality standards required by current regulations. It can be evaluated for each water quality parameter: pH, temperature, DO, BOD, COD, electrical conductivity (EC), total suspended solids (TSS), total dissolved solids (TDS), nitrogen (N), ammonium (NH_4^+), phosphorus (P), metals (Cadmium (Cd) - Copper (Cu) - Lead (Pb) - Mercury (Hg) - Nickel (Ni) - Zinc (Zn), etc.), other ions (Chloride (Cl^-) - Sulphate (SO_4^{2-}) - Sodium (Na) - Potassium (K) - Calcium (Ca) - Magnesium (Mg)), total faecal coliform bacteria, PAH content, total organic carbon (TOC), Organic micropollutants such as pesticides and chemicals (polychlorinated bisphenols (PCBs) - Hexachlorocyclohexane (HCH) group compounds - Polycyclic aromatic hydrocarbons (PAHs)), other depending on legislation and needs.

Expected evolution of the indicator

The indicator should show that all measured parameters meet or exceed regulatory compliance standards over time. Optimal values vary depending on the specific parameter and local environmental regulations but should indicate no exceedance of legal thresholds for water quality. One example is:
The target could be assessed based on local policies and directives that establish the water quality limits depending on its use (water consumption, discharge, reuse, etc.).
For reclaimed water (Water Directive 2020/741), the targets would be: E. coli ≤ 10 CFU/100 m/L, BOD (Biochemical Oxygen Demand) ≤ 10 mg/L, TSS (Total Suspended Solids) ≤ 10 mg/L and Turbidity ≤ 5 NTU.
For treated wastewater (RD 509/1996 and RD 11/1995), the targets would be: TN (Total Nitrogen) 15 mg/L N (from 10,000 to 100,000 h-e) 10 mg/l N (more than 100,000 h-e), TP (Total Phosphorus) 2 mg/L P (from 10,000 to 100,000 h-e) 1 mg/L P (more than 100,000 h-e), BOD (Biochemical Oxygen Demand) 25 mg/L O_2, COD (Chemical Oxygen Demand) 125 mg/L O_2, TSS (Total Suspended Solids) 35 mg/L.
For drinking water (RD 3/2023), the targets would be: E. coli 0 CFU/100 mL, pH 6.5-9.5, Electrical Conductivity (EC) 2500 µS/cm at 20 ºC, Turbidity 4.0 NTU, Total Organic Carbon (TOC) 5.0 mg/L, Polycyclic Aromatic Hydrocarbons (PAHs) 0.10 µg/L, Arsenic 10 µg/L, Cadmium 5.0 µg/L, Chromium 25 µg/L, Mercury 1.0 µg/L, Nickel 20 µg/L, Lead 5.0 µg/L, Antimony 10 µg/L, Selenium 20 µg/L, Nitrate 50 mg/L, Nitrite 0.50 mg/L and individual pesticide 0.10 µg/L."

Possible relationship with other water indicators

Reclaimed water production, Compliant reclaimed water.

Data obtention

Sampling plan:
The quality parameters required by the current regulations or permits associated:

- Physical Parameters: pH, temperature, EC, TSS, turbidity, alkalinity, etc.

- Chemical Parameters: COD, BOD, nutrients (nitrogen, phosphorus), metals (Cd, Cu, Pb, Hg, Ni, Zn), and other ions (Cl^-, SO_4^{2-}, Na, K, Ca, Mg).
- Biological Parameters: DO, total coliform bacteria, E. coli, Legionella spp., etc.
- Organic Micropollutants: Pesticides, PCBs, polycyclic aromatic hydrocarbons (PAHs), etc.

See more information at the individual DEMO Monitoring Plan.

Calculation formula

Compare Ce to Creg:
If Ce < Creg, then WQC = Yes
If Ce > Creg, then WQC = No

Where:

- Ce: average effluent concentration in pollutant concentration units.
- Creg: regulated pollutant concentration for water use in pollutant concentration units.

*To be evaluated for each pollutant.
For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- Boletín Oficial del Estado (1995). Real Decreto 11/1995, de 28 de diciembre, por el que se establecen las normas aplicables al tratamiento de las aguas residuales urbanas. Boletín Oficial del Estado, núm. 312, 37517-37519. https://www.boe.es/boe/dias/1995/12/30/pdfs/A37517-37519.pdf
- Boletín Oficial del Estado (1996). Real Decreto 509/1996, de 15 de marzo, de desarrollo del Real Decreto-ley 11/1995, de 28 de diciembre, por el que se establecen las normas aplicables al tratamiento de las aguas residuales urbanas. Boletín Oficial del Estado, núm. 76, 12038-12041. https://www.boe.es/boe/dias/1996/03/29/pdfs/A12038-12041.pdf
- Boletín Oficial del Estado (2023). Real Decreto 3/2023, de 10 de enero, por el que se establecen los criterios técnico-sanitarios de la calidad del agua de consumo, su control y suministro. https://www.boe.es/buscar/pdf/2023/BOE-A-2023-628-consolidado.pdf
- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions : a handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577
- Regulation (EU) 2020/741 of the European Parliament and of the Council of 25 May 2020 on minimum requirements for water reuse. (2020). Official Journal of the European Union, L 177, 32-55. https://faolex.fao.org/docs/pdf/eur195719.pdf

9.1.2.8 Aquifer Surface Ratio with Excessive Nitrate (ASREN)

- **Code**: Nikosia-1_Water07
- **Environmental Sector:** Water / Water Quality
- **Units:** %

Meaning and importance of the indicator

This indicator measures the proportion of an aquifer's surface area that contains nitrates levels exceeding safe or regulatory limits. This ratio helps assess the extent of groundwater contamination by nitrate, which is important for public health and water resource management. To be compared to a baseline.

Expected evolution of the indicator

Baseline: Initial water available capacity, that may be 0 m^3/year. The limit value for nitrate in water is 50 mg/l, so any amount greater than this number will be considered as an excessive level. It takes into account total nitrate levels, including organic and inorganic. This maximum value is set by the WHO (World Health Organization) and the Turkish Standards (applied to one DEMO). For this reason, the optimal target for the ASREN indicator is 0%, representing that there are no areas with excessive nitrate, meeting the required quality standards.

Possible relationship with other water indicators

Aquifer surface ratio with excessive arsenic, Average groundwater electrical conductivity, Safe drinking water, and Water quality compliance: biological, physical and chemical parameters.

Data obtention

Sampling plan:

- Surface area of aquifer with nitrate levels above safe limits (m^2)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total surface area of the aquifer (m^2)

Calculation formula

$$ASREN = \left(\frac{SA_{NO3>safe}}{SA_{Total}}\right) x\ 100$$

Where:

- ASREN: Aquifer surface with excessive nitrate (%)
- $SA_{NO3>safe}$: Surface area of the aquifer with nitrate levels above safe limits (m^2)
- SA_{Total}: Total surface area of the aquifer (m^2)

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: a handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577
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9.1.2.9 Physico-Chemical Status of Groundwater/Surface Water (Wstatus)

- **Code**: Nikosia-1_Water08
- **Environmental Sector:** Water / Water quality
- **Units:** good or poor // high, good, moderate, poor, bad

Meaning and importance of the indicator

The Physico-Chemical Status of Groundwater/Surface Water indicator assesses the quality of the groundwater and surface water. The indicator is based on key physico-chemical parameters: pH, electrical conductivity (EC), dissolved oxygen (DO), temperature (T), turbidity, total suspended solids (TSS), ion concentrations (nitrates, phosphates, chlorides and sulfates), total nitrogen (TN), total phosphorus (TP), and E. coli. The goal of this metric is to provide a comprehensive assessment of water health, which is crucial for protecting aquatic ecosystems and ensuring the sustainable management of water resources.

Expected evolution of the indicator

This indicator categorizes the water quality into specific classifications based on regulatory and environmental standards, indicating whether the status of groundwater is "good" or "poor," and whether surface water is classified as "high," "good," "moderate," "poor," or "bad". Therefore, the higher the parameter is high or good, the better the water quality will be. The following table shows the values to consider the quality of the groundwater/surface water good or bad in a physico-chemical way, according to the DIRECTIVE 2000/60/EC, the DIRECTIVE 1998/83/EC and WHO (2008).

Parameter	Groundwater - Good	Groundwater - Poor	Surface Water - High	Surface Water - Good	Surface Water - Moderate	Surface Water - Poor	Surface Water - Bad
pH	6.5 - 8.5	< 6.5 or > 8.5	6.5 - 8.5	6.5 - 8.5	6.0 - 6.5 or 8.5 - 9.0	5.5 - 6.0 or 9.0 - 9.5	< 5.5 or > 9.5
Electrical Conductivity (EC)	< 400 µS/cm	> 1500 µS/cm	< 200 µS/cm	200 - 400 µS/cm	400 - 800 µS/cm	800 - 1500 µS/cm	> 1500 µS/cm
Dissolved Oxygen (DO)	> 6 mg/L	< 3 mg/L	> 8 mg/L	6 - 8 mg/L	4 - 6 mg/L	2 - 4 mg/L	< 2 mg/L
Temperature (T)	Within natural range	Significant deviation	Within natural range	Within natural range	Slight variation	Moderate variation	Extreme variation
Turbidity	< 1 NTU	> 5 NTU	< 1 NTU	1 - 2 NTU	2 - 5 NTU	5 - 10 NTU	> 10 NTU
Total Suspended Solids (TSS)	< 20 mg/L	> 100 mg/L	< 10 mg/L	10 - 20 mg/L	20 - 50 mg/L	50 - 100 mg/L	> 100 mg/L
Nitrates (NO_3^-)	< 10 mg/L	> 50 mg/L	< 1 mg/L	1 - 5 mg/L	5 - 10 mg/L	10 - 20 mg/L	> 20 mg/L
Phosphates (PO_4^{3-})	< 0.1 mg/L	> 0.5 mg/L	< 0.01 mg/L	0.01 - 0.05 mg/L	0.05 - 0.1 mg/L	0.1 - 0.2 mg/L	> 0.2 mg/L
Chlorides (Cl^-)	< 250 mg/L	> 600 mg/L	< 50 mg/L	50 - 250 mg/L	250 - 400 mg/L	400 - 600 mg/L	> 600 mg/L
Sulfates (SO_4^{2-})	< 250 mg/L	> 500 mg/L	< 100 mg/L	100 - 250 mg/L	250 - 400 mg/L	400 - 500 mg/L	> 500 mg/L
Total Nitrogen (TN)	< 1 mg/L	> 10 mg/L	< 0.5 mg/L	0.5 - 1 mg/L	1 - 2 mg/L	2 - 5 mg/L	> 5 mg/L
Total Phosphorus (TP)	< 0.1 mg/L	> 0.2 mg/L	< 0.01 mg/L	0.01 - 0.05 mg/L	0.05 - 0.1 mg/L	0.1 - 0.2 mg/L	> 0.2 mg/L
E. coli	0 CFU/100 mL	> 100 CFU/100 mL	0 CFU/100 mL	< 10 CFU/100 mL	10 - 100 CFU/100 mL	100 - 500 CFU/100 mL	> 500 CFU/100 mL

Note: DIRECTIVE 2000/60/EC; DIRECTIVE 1998/83/EC; WHO (2008).

Possible relationship with other water indicators

Effluent pollutant removal, Water quality compliance: biological, physical and chemical parameters, Average groundwater electrical conductivity.

Data obtention

Sampling plan:

pH, electrical conductivity, dissolved oxygen (DO), temperature (T), turbidity, total suspended solids (TSS), ion concentrations (nitrates, phosphates, chlorides and sulfates), total nitrogen (TN), total phosphorus (TP), and E. coli.

References

- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: a handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577
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- DIRECTIVE 1998/83/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 3 November 1998 On the quality of water intended for human consumption.
- World Health Organization. (2008). Guidelines for Drinking-water Quality: THIRD EDITION INCORPORATING THE FIRST AND SECOND ADDENDA. WHO, Volume 1. https://iris.who.int/bitstream/handle/10665/204411/9789241547611_eng.pdf?sequence=1

9.1.3 Biodiversity Indicators

9.1.3.1 Bird Species Richness

- **Code**: Nikosia-1_Bio01
- **Environmental sector:** Fauna biodiversity
- **Units:** Number of bird species – N

Meaning and importance of the indicator

This indicator measures the diversity of bird species within the new green areas (including fruit trees) created by the demo. Bird species richness is a key metric for assessing the ecological success of the habitat, as it reflects the ability of the new green areas to support a variety of avian species but also serves as a proxy for the presence and health of other fauna groups. High species richness indicates a well-functioning habitat that can provide necessary resources and shelter for different bird species and other faunal groups including invertebrates and small mammals, as these species often share and depend on similar habitat features and are a main food source for many bird species. Monitoring bird species richness helps in understanding the overall impact of the new green areas on local biodiversity and ecosystem health, especially in urban environments where habitat fragmentation often limits wildlife diversity.

Expected evolution of the indicator

Over time, as the green areas mature and the habitat conditions improve, an increase in bird species richness is expected. The goal is to reach a stable and diverse bird population that reflects the habitat's capacity to support a variety of fauna species.

Possible relationship with other analyses

The presence and diversity of bird species can be influenced by the area of fauna habitats, and other factors such as vegetation density, food and shelter availability, and the level of human disturbance.

Data obtention

Required data:

Number of bird species observed in the new green areas. The required data can be obtained through different methods, that can be selected based on practical limitations and resource availability:

- **Visual sampling:** Conduct bird surveys using trained observers to identify and count bird species present in the new green areas. For visual sampling, the observer should remain stationary at each sampling point for 15 minutes. During this time, they must record all bird species detected either visually or auditorily (songs or calls). Only birds present within the designated survey area (DEMO) should be considered for calculating the indicator. Birds observed outside the DEMO can be recorded separately, clearly marked as "Outside" to exclude them from the final calculations. At each sampling point, the observer must record the date, start and end times, geographical coordinates, and weather conditions (temperature, wind speed, cloud cover, and precipitation). The observer must record all the species detected. Optionally, number of individuals observed, bird behaviour (e.g., flying, feeding, singing, or stationary) and the type of habitat they are using (trees, grass, buildings, or other structures) also provide useful information.

- **Bioacoustics sampling:** Utilize audio recording equipment to capture bird calls and songs. This method helps identify species that may be difficult to observe visually and provides additional data on species presence. The recordings can be conducted by a non-trained person, but subsequent identification is needed to be conducted by an expert ornithologist to accurately determine species. For bioacoustics sampling, recorders must be places in high areas (trees for example) for 15 minutes. At each sampling point, the observer must record the date, start and end times, geographical coordinates, and weather conditions (temperature, wind speed, cloud cover, and precipitation). After sampling, recording must be processes by an expert in order to identify all the species.

If possible, it is recommended to conduct two replicates at each sampling point, separated by one week, to enhance data reliability. Both methods can be used complementarily to maximize the probability of detecting all species present in the habitat.

Sampling plan

- **Sampling points**: Visual or bioacoustic sampling points should be spaced at least 200 meters apart to avoid overlap in detections, due to the small size of the DEMO area, a single sampling point is needed.
- **Time of the day**: Surveys must be conducted in the early morning (typically within 3 hours after sunrise), when birds are most active. Avoid midday or late afternoon counts when bird activity decreases.
- **Season:** Surveys should be conducted between April and May to capture most breeding species when bird activity is at its peak.
  If a second sampling is conducted, it should take place in September or October to monitor migratory species and changes in bird populations after the breeding season.

Sampling calendar

Sampling should be conducted annually to assess changes in species richness.

Equipment

Binoculars, sheet for noting the results and GPs device of smartphone for recording coordinates. For bioacoustics sampling, a high-quality audio recorder with good sensitivity and low noise floor, including battery and memory card.

External subcontracting

An ornithologist is required for the project. If one is not available within the team or cannot be found among volunteers or recreational bird watchers, it will be required to be subcontracted.

Data sources

For baseline information, online databases such as GBIF or APPS (eBird, iNaturalist, observation.org or other local platforms), ornithological organizations or local bird watching clubs can provide valuable data.

Calculation formula

S_{total}=Number of unique species observed across all replicates of both sampling points.

The species lists from all sampling points and replicates should be combined, and duplicates removed, to obtain the total number of unique species present.

References

- European Comission. 2021. Evaluating the Impact of Nature-based Solutions: A Handbook for Practitioners. Luxembourg. *Indicator 9.5 Number of species within a defined area* doi:10.2777/244577
- Fundación Biodiversidad. 2022. Guía para la medición y seguimiento de indicadores. Convocatoria de subvenciones de la Fundación Biodiversidad F.S.P., para el fomento de actuaciones dirigidas a la renaturalización y resiliencia en ciudades españolas, correspondiente al año 2022, en el marco del Plan de Recuperación, Transformación y Resiliencia. *Indicator BDU-009*. https://fundacion-biodiversidad.es/wp-content/uploads/2022/10/guia_indicadores_renaturb_2022_0.pdf

9.1.3.2 New Fauna Habitat Area

- **Code:** Nikosia-1_Bio02
- **Environmental sector**: Fauna habitats
- **Units:** Square meters (m^2)

Meaning and importance of the indicator

This indicator measures the establishment of new functional habitats for fauna created by the new green areas created for the improvement of groundwater quality using microalgae. This metric is critical for understanding the ecological value of the new green area in supporting biodiversity, especially in urban environments where such green areas can provide essential refuge for species that contribute to ecosystem services, such as pollination or seed dispersal, serving as a key indicator of the ecological performance of the new habitats created.

Possible relationship with other analyses

The quality of the newly created habitat can be influenced by several factors related to the soil and substrate. Key considerations include soil nutrient content, drainage, and moisture retention capacity. The quality of irrigation water and the choice of plant species also play a critical role in enhancing the habitat's ability to support fauna.

Expected evolution of the indicator

The total cover of new functional habitat is expected increase, until reaching the optimal scenario where the entire area intervened serves as functional habitat for fauna, implying that all available surface area contributes effectively to biodiversity enhancement and habitat provision.

Data obtention

Required data:

Total coverage of new fauna functional habitat created (m^2).

Sampling plan:

The required data can be obtained through different methods, that can be selected based on practical limitations and resource availability:

- Field Sampling: Measure the total area of new green space where trees and grass have been planted. This involves physically surveying the site to determine the coverage of functional habitats, including all areas covered by vegetation.
- Aerial Images: Utilize drone or satellite imagery to assess the extent of the newly created green areas. This method provides a broader view and helps verify the coverage.

For comprehensive data, combine field sampling and aerial images with existing data to ensure accuracy and reliability in measuring the new fauna habitat area.

Paths, seats, of other structures found in the area that do not provide functional habitats for fauna should be excluded of the measurements.

The measures should be done during the spring month (may or early June) to capture the plant cover at its peak development stage.

Sampling calendar

This indicator will be produced every year for a total of 10 years in case of field surveys or drone aerial images. If satellite imagery is used, assessments can be extended to every 5 years to ensure the availability of updated images.

Equipment

Tape measure and measuring wheel for manual measurements and sheet for noting the results, including the date, environmental conditions and observer's name. Camera, as it's recommended to document the visual state of the habitats trough images. Drone in case capturing high-resolution images of the green area. In case of using satellite imagery, GIS software is required to obtain the size of the green area.

Data sources

Satellite imagery platforms such as Google Earth, Copernicus, NASA's Earthdata, the European Space Agency's (ESA) Sentinel Hub, and other open-access geospatial data platforms for high-resolution and updated images of the green areas.

Calculation formula

New functional Habitat Area (A) = Total area covered by new fauna habitats.

References

- Connecting nature. 2020. Nature-based solution evaluation indicators: Environmental Indicators Review. *Indicator Env78. Targeted habitats and 93. Habitats restored. area*.https://connectingnature.eu/sites/default/files/images/inline/CN_Env_Indicators_Review_0.pdf
- European Comission. 2021. Evaluating the Impact of Nature-based Solutions: A Handbook for Practitioners. Luxembourg. *Indicator 10.2 Area of habitats restored* doi:10.2777/244577
- Fundación Biodiversidad. 2022. Guía para la medición y seguimiento de indicadores. Convocatoria de subvenciones de la Fundación Biodiversidad F.S.P., para el fomento de actuaciones dirigidas a la renaturalización y resiliencia en ciudades españolas, correspondiente al año 2022, en el marco del Plan de Recuperación, Transformación y Resiliencia. *Indicator CON-008*. https://fundacion-biodiversidad.es/wp-content/uploads/2022/10/guia_indicadores_renaturb_2022_0.pdf

9.1.4 Energy Indicators

9.1.4.1 Energy Consumption for Groundwater Treatment

- **Code:** Nikosia-1_Energy01
- **Environmental sector:** Energy
- **Units**: kWh/m^3 wastewater

Meaning and importance of the indicator

"Energy Consumption for Groundwater Treatment" measures the amount of energy (mainly electricity) used in the processes involved in treating groundwater to make it safe for discharge or reuse. This indicator is crucial for evaluating the sustainability and efficiency of wastewater treatment facilities. High energy consumption can indicate inefficiencies and result in increased operational costs and higher carbon emissions, which are detrimental to both economic and environmental goals. Conversely, optimizing energy use in groundwater treatment can lead to significant cost savings, lower greenhouse gas emissions, and a reduced environmental footprint. Monitoring this indicator helps in identifying opportunities for implementing energy-saving technologies and practices, such as using more efficient equipment, improving process controls, and integrating renewable energy sources. Ultimately, reducing energy consumption in groundwater treatment supports broader sustainability objectives by minimizing resource use and contributing to climate change mitigation.

Expected evolution of the indicator

The expected evolution of the indicator "Energy Consumption for groundwater Treatment" is towards decreasing energy use per unit of treated groundwater, reflecting improvements in efficiency and sustainability of treatment processes. This evolution is driven by technological advancements, better operational practices, and increased regulatory and policy pressures to reduce environmental impact.

Data obtention

Field measurement or assessment based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

DEMO9.2: Nikosia - Polykratous Park

9.2.1 Soil Indicators

9.2.1.1 Soil Physical and Chemical Fertility

- **Code:** Nikosia-2_Soil01
- **Environmental Sector:** Soil / Soil Health
- **Units**: A multi-component indicator. Diverse units for specific components

Meaning and importance of the indicator

Soil fertility, its capacity to sustain plant growth, depends on complex interactions between biological, chemical and physical properties. Achieving and maintaining appropriate levels of physical and chemical fertility is of paramount importance to support urban green. In natural soils, nutrients come from minerals, water, atmospheric deposition, and recycling of plant and animal residues but their availability to plants is significantly affected by soil acidity (pH), and nutrient presence in the soil solution is highly dependent on soil texture and soil cation exchange capacity. Water retention in soils and progressive release to plants is notably improved by soil organic matter, which is particularly important in Mediterranean regions under increasing aridity. Urban soils are highly heterogeneous and are frequently called “technosoils”. Soils are made of human-transported substrates, or are native soils highly transformed by anthropization. Urban soils are very often compacted and polluted, but they perform multiple unvaluable ecosystem services when returned to health, particularly in water and carbon cycles, and play a pivotal role in human wellbeing trough supporting healthy vegetation. Soil analysis is the basic tool to evaluate soil fertility and to guide city managers towards sustainable soil management.

Expected evolution of the indicator

There are recommended ranges and critical values for most of the soil properties to be analysed. For urban gardens, together with the results of soil analyses agricultural laboratories provide an evaluation of the level of each analysed parameter (deficient – correct – excessive or similar). The value of each parameter should evolve towards these reference values and will guide gardeners in designing fertilization or any other correction. Special attention will be paid in this case to the evolution of soil salinity. An approach to tolerable salinity and electrical conductivity levels in soil, depending on soil texture (provided in the analyses) can be found in https://www.agric.wa.gov.au/soil-salinity/measuring-soil-salinity.

Data obtention

Required data:

- To be analysed only the first time: soil texture (% sand; % clay; % silt); textural class.
- To be analysed at each soil sampling campaign: pH; Electrical conductivity (CEC); Total organic carbon (%, dry soil basis); Carbonates; Total nitrogen (Kjeldahl); Available phosphorus (Olsen); Cation exchange capacity; Interchangeable bases (Ca, Mg, Na and K); Micronutrients (Fe, Zn, Mn).

Sampling plan:

Field sampling followed by lab analyses. The samples will always be taken at the same moment of the year (set a fixed spring month), preferably avoiding temporal proximity to gardening interventions (or any other type of actions affecting soil (tree pruning, plantation, grass sowing, fertilization, etc.)
In homogeneous landscapes, two samples per hectare may be a standard sampling density. We don't have a clear estimate of the surface area to be irrigated with underground water treated to reduce its salinity (case 1), or with rainfall harvested the hydro park (case 3) and we don't know the spatial distribution of this irrigated areas.
As a general approach, at each site divide the space to be monitored in homogeneous units (garden islands, different slopes, etc) and sample every unit of sufficient dimensions. Take at least two soil samples within each land unit, from two points randomly selected. The two samples will be mixed into a unique plastic zip bag duly labelled with the date and the location of the place. Soil must be sampled at 15 cm depth with soil samplers like those described in the "equipment" section.
The resulting composite soil samples will be sent to an expert lab for analysis as soon as possible. The soil lab must have been previously consulted for instructions about the preparation of the samples before shipping.

Sampling calendar

The gardens will be sampled in the proposed season every 2 years for 10 years (5 times).

Equipment

Samples will be taken with soil borers of similar and known (the same for all samples at each sampling campaign) depth and diameter. The borer should be 15 cm long and the recommended diameter is 5 cm. Some providers of these soil samplers are: https://www.ams-samplers.com/soil-augers/; https://www.vanwalt.com/equipment/telescoping-augers/. Any other equivalent sampler of these dimensions is acceptable (but try to respect the 15 cm depth)
You will need some small field materials, such as zip bags and outdoor knife (or small garden spade)

External subcontracting

Yes. A trustable lab delivering soil fertility analyses must be hired.

References

- Dondini, C., Úbeda, X., Certini, G., Francos, M. (2024). Soil quality in the urban gardens of Barcelona (Spain). *Journal of Soils and Sediments*, 1-13.
- Kortleve, A. J., Mogollón, J. M., Heimovaara, T. J., Gebert, J. (2023). Topsoil carbon stocks in urban greenspaces of The Hague, the Netherlands. *Urban Ecosystems*, *26*(3), 725-742.

- Dondini, C., Úbeda, X., Certini, G., Francos, M. (2024). Soil quality in the urban gardens of Barcelona (Spain). *Journal of Soils and Sediments*, 1-13.
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- For soil fertility in gardens: https://extension.umaine.edu/gardening/manual/soils/interpreting-soil-tests/

9.2.1.2 Soil Bulk Density (ρ)

- **Code**: Nikosia-2_Soil03
- **Environmental Sector**: Soil / Soil Health / Soil Bulk Density
- **Units**: g cm^{-3}

Meaning and importance of the indicator

Bulk density indicates the degree of soil compaction. Bulk density is inversely related to soil porosity which allows air and water to move through the soil and facilitates plant root penetration through the soil. Compaction is the main feature of urban soils, very specially when they have been sealed beneath pavement, since sealing most often is preceded by removal of topsoil horizons and mechanic compaction that induces heavy alteration of the soil pore space and architecture. Other urban anthropogenic soils are made of human-transported materials and typically show heterogeneous granulometry and composition and unpredictable hydrological behaviour depending on treatment. Compaction is among the main features of physical degradation of urban soils and is often accompanied by low water holding capacity, low biological activity and low chemical quality and capacity to sustain healthy plants.

Expected evolution of the indicator

In case of pre-existing natural soil, bulk density is affected by soil texture (sand, silt, and clay proportion) and organic matter content. Fine-textured soils (such as silt and clay loams) with good structure have lower bulk density compared to sandy soils. According to data from the EU Joint Research Centre, mean European values for soil bulk density are 1.26 g cm^{-3} for arable lands, 1.23 g cm^{-3} for permanent crops, and 1.14 for heterogeneous agricultural areas. In highly disturbed urban soils, bulk density can range from 1.5 g cm^{3} in lawns to densities that approach those of concrete in heavily trodden paths of sport yards (2.2 g cm^{3}). Bulk density should decrease as soil recovers its structure and gains organic matter.

Data obtention

Required data:

None. Measured from specific soil samples at each sampling campaign for soil fertility (Nikosia-2_Soil01).

Sampling plan:

Field sampling followed by very a simple analysis. Bulk density will be measures at the hydro park area. Samples will always be taken at the same moment of the year (make it match the soil fertility sampling date), preferably avoiding temporal proximity to gardening interventions (or any other type of interventions implying soil trampling or compaction). We do not know the exact surface area or spatial distribution and heterogeneity of the soil to be monitored at the hydro park but, at each sampling date, you will sample soil for bulk density in the same land islands or homogeneous units that you have sampled for soil fertility (Nikosia-1_Soil01) and in the vicinity of the already sampled points (at least two sampling points per land unit). A detailed explanation of the sampling method is provided in the USDA Soil Quality Test Kit Guide (1999), pg.9 (see references). In short for each sample, drive the metal cylinder all the way into the ground until its upper edge is level with the surface of the ground (using a mallet and a block of wood). Remove the ring taking great care not to lose soil. To do so, dig around the ring and with a trowel underneath it, carefully lift it out. Remove excess soil from the sample with a flat-bladed knife.

The top and bottom of the soil sample should be flat and even with the edges of the ring. Using the flat-bladed knife, push out the entire soil sample into a plastic zip bag. Label the bag correctly.
Take the samples to the lab (or any other place where there is a scale - two decimal places of accuracy- and a drying oven). Transfer each sample individually from the plastic bag to a foil or paper tray duly labelled. Put the soil samples to dry at 100 ºC until constant weight (usually 4 days is enough). Weight the dry soil (in g) and register it in your soil data worksheet. If a drying oven is not available, you can use a microwave (see the method in the USDA Soil Quality Test Kit Guide (in references).

Sampling calendar

Bulk density will be measured together with soil fertility (Nikosia-2_Soil01), every two years for ten years.

Equipment

Bulk density is the ratio between soil dry weight and soil volume. Therefore, soil samples will be taken with a stainless-steel cylinder of perfectly know volume. The recommended dimensions for this case are 10 cm deep and 8 cm in diameter. Additional field materials: a mallet, a block of wood, a trowel, a knife and zip-bags.

External subcontracting

If a reliable scale and a microwave are available, bulk density can be obtained very simply without the need of an expert lab.

Calculation formula

$$\rho = M / V$$

Where:

- ρ is estimated as g cm^{-3}
- M is the dry weight of the sample in g
- V the volume of the soil cylinder (in cm^3)

For each island or homogeneous sampling unit, calculate the average of the two estimates of density.

References

- Can Urban Soil Compaction Be Reversed? Technical Note #108 from Watershed Protection Techniques. 1(4): 666-66. https://owl.cwp.org/mdocs-posts/elc_pwp37/
- Effect of Urban Soil Compaction on Infiltration Rate https://owl.cwp.org/mdocs-posts/effect-of-urban-soil-compaction-on-infiltration-rate/
- O'Riordan, R., Davies, J., Stevens, C., Quinton, J. N. (2021). The effects of sealing on urban soil carbon and nutrients. *Soil*, *7*(2), 661-675.
- Paradelo, R., Herbón, C., Barral, M. T. (2024). Physical properties of the urban soils of Santiago de Compostela (Spain). *Journal of Soils and Sediments*, 1-10.
- The Compaction of Urban Soils. Technical Note #107 from Watershed Protection Techniques. 3(2): 661-665. https://owl.cwp.org/mdocs-posts/elc_pwp36/

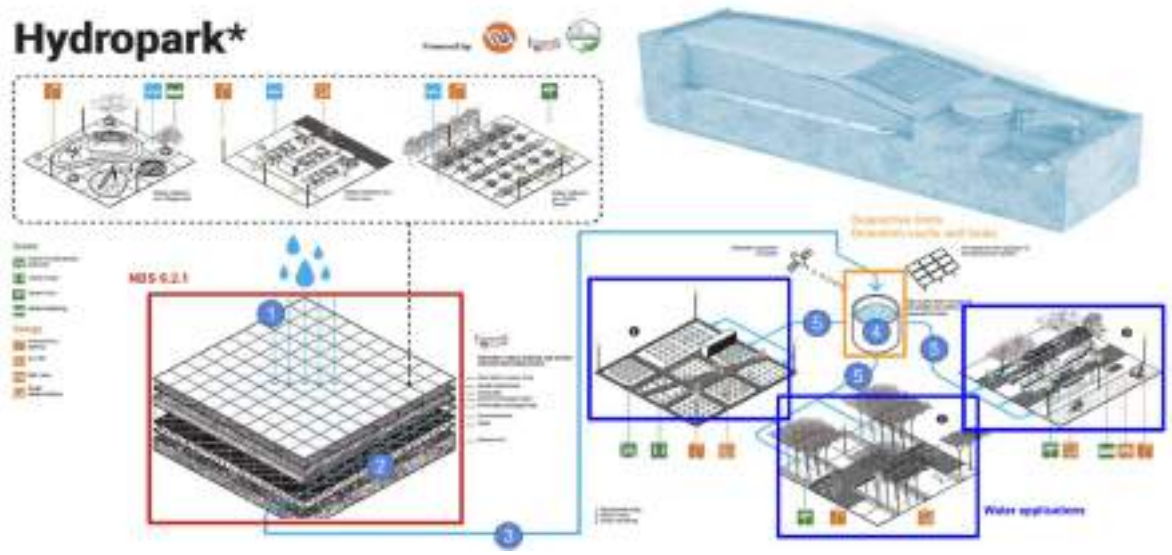
- Soil Quality Indicators. Bulk Density. USDA Natural Resources Conservation Service https://www.nrcs.usda.gov/sites/default/files/2022-10/nrcs142p2_051591.pdf
- Soil Quality Test Kit Guide. USDA Natural Resources Conservation Service. 1999. https://efotg.sc.egov.usda.gov/references/public/WI/Soil_Quality_Test_Kit_Guide.pdf

9.2.2 Water Indicators

9.2.2.1 Water Monitoring Plan

System diagram

The Rainwater Harvesting when Nature Inspires: An innovative filter drains for rainwater harvesting in the urban environment.



Sampling points

Sampling point	Location	Purpose
SP-01	Inlet and/or surface of the NBS 9.2.1	Monitor the rainfall/stormwater (volume)
SP-02	Filter drain	Monitor the infiltration rate
SP-03	Outlet of the NBS 9.2.1: hydraulic pipeline network to the storage unit	Monitor reclaimed water quality (efficiency of the treatment, nutrient content)
SP-04	Inlet of the detention vaults and tanks	Monitor reclaimed water storage for irrigation (volume)
SP-05	Outlet of the storage tanks (pipeline to water applications: educational crops, urban forest and urban gardening	Monitor total volume of reclaimed water used for irrigation (volume)

Parameters to be analyzed

Parameter	Applicable Sampling Point	Related indicators	Type
Volume of rainfall water	SP-01	RI	water flow measurements [volume/time]
Speed of the water penetration through the soil	SP-02	IR	water flow measurements [volume/time]
Volume of storage water	SP-04	WSC	water flow measurements [volume/time]
Volume of reclaimed water used for irrigation	SP-05	RWnpU, WSC	water flow measurements [volume/time]
Water quality parameters: Conductivity, pH, redox, COD, BOD_5, TSS, TN, TP, TOC, temperature, turbidity, *E. coli*, heavy metals, anions and cations	SP-03	QWC	water quality parameters

Sampling method

Water flow measurements:

Direct measurement of volume provided during a time period or water flow with flow meters and/or water level sensors.

a) Automatic method

Automatic flow meters can be installed at the recommended sampling points (SP). For the automatization process, it is recommended to register the measurements with a datalogger/digital control system in the DEMO. It is recommended to measure the flow at the recommended sampling points (SP).

Data should be stored in a datalogger/digital control system and then be able to be exported in a spreadsheet to calculate the associated indicators. When this is not possible, manual readings of the flow meters can be done instead.

b) Manual method

This could be applied as the last option if there is no possibility to apply the automatic method.

- Periodic manual measurements.
- If no devices are available to measure, correct and reliable estimates must be made to assess the indicator.

- Measure the volume at the point of reuse or approximate the value based on the amount of water demand met by urban gardens for reuse.

Rainwater/stormwater data:

For the registration of rainwater or stormwater data, it is more recommended to apply online and automatic methods.

a) Automatic method

Arduino-based cameras that can detect floods, drone-derived orthophotos or satellite data can be used. Also, information from nearby meteorological/weather stations.

b) Manual method

Manual simple measurements using rain gauges could be used as the last option. These methods can give less accurate data.

Water quality parameters:

Automatic measurement methods (a) or manual sampling campaigns (water sampling + laboratory analysis) (b) can be employed, with specific requirements for different types of pollutants.

a) Automatic method

Advanced sensors of water quality can be installed in the recommended sampling points (SP) to continuously monitor and measure various water quality parameters, such as temperature, pH, turbidity, dissolved oxygen, NO_3, etc. These sensors collect data in real-time, providing continuous and accurate information about water quality. The data is often transmitted wirelessly to a central database, or sensors can be also connected to a datalogger. The data is often transmitted wirelessly to a central database, or sensors can be also connected to a datalogger.

b) Manual method

As the DEMO has not been implemented yet, sampling campaigns will be carried out periodically to control the operation and performance of the treatment system. Samples will be collected at the recommended sampling points (SP).

Two types of water quality analysis have been defined: basic and complete. Different sampling and analysis periodicities will be suggested during the start-up phase, stabilization phase and mature operation. Basic analysis will include all water quality parameters that are required to be monitored by legislation for reclaimed water reuse for irrigation: turbidity, BOD_5, E. coli, TSS (other if required by legislation). Complete analysis includes other water quality parameters for general monitoring and indicators' assessment: conductivity, pH, redox, COD, TN, TP, TOC, temperature, heavy metals, anions and cations. Samples can be obtained manually or using automatic sampling equipment. An automatic sampler is a device that can be refrigerated or non-refrigerated and include automatic sampling pumps and upward stage samplers. The process involves collecting water samples intended for laboratory analysis of water quality parameters. However, there are limitations associated with automatic sampling, such as intermediate sampling containers, sampling from a fixed point, and sample storage and preservation, which must be considered and documented. Personnel using these methods should have training and prior experience in the use and calibration of automatic sampling equipment. The laboratory analysis is done following current ISO laboratory protocols for each different parameter.

Infiltration rate:

The infiltration rate is a type of water flow measurement, very related to the soil. Also, as other indicators, there are automatic and manual methods:

a) Automatic method

To measure infiltration rate automatically in a NBS, a tensiometer-based system or automated infiltrometer can be employed. These systems consist of soil moisture sensors or pressure transducers installed in the ground at various depths to continuously measure changes in soil moisture content or water pressure. The automated system periodically adds a controlled amount of water to the surface, imitating rainfall or irrigation. The sensors monitor how quickly the water infiltrates and how the moisture levels change over time. Data is collected in real-time and transmitted to a central data logger or computer for analysis, calculating the infiltration rate without manual intervention.

b) Manual method

To manually sample the infiltration rate, it's needed to use a ring infiltrometer. An example of this process is the following. First, hammer a 30 cm diameter ring about 15 cm into the soil, and place a measuring rod inside. Then, hammer a 60 cm diameter ring around the first one (or build an earthen bund) to prevent lateral water movement. Pour water into both rings to a depth of 70-100 mm and record the time. Measure the drop in water level at regular intervals, adding water to maintain the initial level. Continue until the water drop rate stabilizes, which represents the basic infiltration rate. Repeat the test at least twice for accuracy.

Sampling calendar

Water flow measurements and infiltration rate:

Data should be collected frequently for a relevant time period (e.g., daily, weekly, monthly) to allow for accumulation over the entire reporting period (yearly). This high frequency is also relevant to study seasonal variations.

Water quality parameters:

As the DEMO has not been implemented yet, different sampling and analysis periodicities will be suggested during the start-up phase, stabilization phase and mature operation:

- Start-up phase: the first 3 months of operation of the DEMO it is recommended to increase the frequency of the analysis to 1 basic analysis per week and 1 complete analysis biweekly.
- Stabilization phase: from month 4 to month 12 of operation it is recommended to do 1 basic analysis per week and 1 complete analysis per month.
- Mature operation: from month 13, the recommended frequency of water quality analysis is 1 basic analysis per week and 1 complete analysis per month.

Equipment

a) Water flow measurements:

Water flow meters are essential tools for monitoring and assessing the efficiency of these systems, as they provide real-time data on water movement and usage through the treatment processes and the different pipes, helping to determine the volume of water at those particular locations. Some indicative providers of these water flow meters are:

- Endress+Hauser
- Systec Controls
- Aobo instrument

Any equivalent water flow meter is acceptable, these are given as examples.

b) Water quality parameters:

The automatic sampling method requires simple or multiparametric sensors for water quality and data loggers or digital control systems for data recording. It also requires personnel for data collection and treatment.

The manual sampling campaign requires laboratory and field personnel for manual sampling and analysis and also reagents and laboratory material depending on the current ISO laboratory protocols for each parameter.

Some indicative providers for water quality parameters are:

- ANISE sensor (NH_4 and NO_3) - Hach
- Conductivity meter - METTLER TOLEDO
- pH meter - METTLER TOLEDO
- Multi-parameter water quality analyser (temperature, pH, conductivity, DO, turbidity, BOD, COD, ammonia nitrogen, NO_3, colour, chloride, depth, etc.) - BOQU instruments

Any equivalent water level sensor is acceptable, this is given as an example.

c) Infiltration rate:

Some indicative providers are:

- Manual infiltrometer - Eijkelkamp
- Manual infiltrometer - ELE International
- Automated infiltrometer - SATURO

*For manual infiltrometers, take into account that you may need a hammer, a watch or clock, a bucket, a timber, or any other instrument to work together.

Any equivalent water flow meter is acceptable, these are given as examples.

External subcontracting

Yes. A trustable laboratory delivering water quality analyses must be hired if not available internally.

9.2.2.2 Reclaimed Water in Non-Potable Uses (RWnpU)

- **Code**: Nikosia-2_Water01
- **Environmental Sector:** Water / Water resource recovery and use
- **Units:** %

Meaning and importance of the indicator

The indicator measures the proportion of reclaimed water (from treated wastewater, rainwater, urban runoff, etc.) used in non-potable applications where previously drinking or freshwater was used. It is related to the total volume of water used for those purposes. This indicator provides valuable insight into the sustainable use of water resources by quantifying the extent to which reclaimed water is used for non-potable purposes.

Expected evolution of the indicator

The optimal value for the RWnpU indicator is as close to 100% as possible, indicating that the majority of non-potable water needs are met with reclaimed water, minimizing the demand for freshwater.

Possible relationship with other water indicators

Compliant reclaimed water, Water availability, Reclaimed water production, Water provision by the ecosystem.

Data obtention

Sampling plan:

- Volume of reclaimed water used for non-potable uses (e.g., irrigation, street cleaning, groundwater recharge) (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Total volume of water used for non-potable uses, from all sources, including freshwater and reclaimed water (m^3/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.

Calculation formula

$$RWnpU = \frac{RW}{npW} \cdot 100$$

Where:

- RWnpU: Reclaimed Water in non-potable Uses (%)
- RW: Volume of reclaimed water used for non-potable uses (e.g., irrigation, street cleaning, groundwater recharge) (m^3/year)
- npW: Total volume of water used for non-potable uses, from all sources, including freshwater and reclaimed water (m^3/year)

Note: “used” may be “supplied” or “consumed” but must be consistent in RW and npW.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

9.2.2.3 Water Storage Capacity (WSC)

- **Code:** Nikosia-2_Water02
- **Environmental Sector:** Water / Effectiveness of the adaptive change towards resilient infrastructure
- **Units:** Days

Meaning and importance of the indicator

The indicator assesses the resilience and efficiency of water supply systems. It is defined as the ratio between the total volume of available storage (e.g., water supply tanks, reservoirs for rainwater harvesting, and reclaimed water storage) and the average flow rate either provided to or demanded by the system. This flow rate encompasses all demands associated with distribution systems, rainwater harvesting infrastructure, and treatment facilities. The indicator provides insightful information about the number of days that the system can handle relying on the potential stored volume of water, not on the actual volume of stored water.

Expected evolution of the indicator

The WSC indicator will vary by region, depending on local water availability, climate conditions, and demand patterns in the DEMO. The optimal value is context-specific, but generally, a higher WSC indicates a more resilient water supply system capable of withstanding longer periods without external water inputs. However, as water supply systems integrate more non-conventional water sources (e.g., rainwater harvesting, reclaimed water, etc.), the WSC is expected to increase, improving the system's sustainability and resilience.

Possible relationship with other water indicators

Water availability, Captured runoff.

Data obtention

Sampling plan:

- Total operational volume of storage capacity, such as supply tanks, reservoirs, and reclaimed water storage (m^3)
  Fixed value of the operational volume of the storage capacity.
- Daily average inflow entering or being demanded to the DEMO system (m^3/day)
  The average can be done from data obtained from sampling at the DEMO.

Calculation formula

$$WSC = \frac{V_t}{Q_S}$$

Where:

- WSC: Water Storage Capacity (days)
- V_t: Total operational volume of storage capacity (m^3)
- Q_s: Daily average inflow entering or being demanded to the system (m^3/day)

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/
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- Donatello S., Dodd N. & Cordella M. (2021). Level(s) indicator 3.1: Use stage water consumption user manual: introductory briefing, instructions and guidance (Publication version 1.1). JRC, European Commission.

9.2.2.4 Water Quality Compliance (WQC): Biological, Physical and Chemical Parameters

- **Code:** Nikosia-2_Water03
- **Environmental Sector:** Water / Water quality
- **Units:** [Compliant with regulatory standards: Yes/No]

Meaning and importance of the indicator

The indicator provides a simplified view of regulatory compliance regarding water quality, taking into account various parameters. It is especially important to validate quality standards required by current regulations. It can be evaluated for each water quality parameter: pH, temperature, DO, BOD, COD, electrical conductivity (EC), total suspended solids (TSS), total dissolved solids (TDS), nitrogen (N), ammonium (NH_4^+), phosphorus (P), metals (Cadmium (Cd) - Copper (Cu) - Lead (Pb) - Mercury (Hg) - Nickel (Ni) - Zinc (Zn), etc.), other ions (Chloride (Cl^-) - Sulphate (SO_4^{2-}) - Sodium (Na) - Potassium (K) - Calcium (Ca) - Magnesium (Mg)), total faecal coliform bacteria, PAH content, total organic carbon (TOC), Organic micropollutants such as pesticides and chemicals (polychlorinated bisphenols (PCBs) - Hexachlorocyclohexane (HCH) group compounds - Polycyclic aromatic hydrocarbons (PAHs)), other depending on legislation and needs.

Expected evolution of the indicator

The indicator should show that all measured parameters meet or exceed regulatory compliance standards over time. Optimal values vary depending on the specific parameter and local environmental regulations but should indicate no exceedance of legal thresholds for water quality. One example is:
The target could be assessed based on local policies and directives that establish the water quality limits depending on its use (water consumption, discharge, reuse, etc.).
For reclaimed water (Water Directive 2020/741), the targets would be: E. coli ≤ 10 CFU/100 m/L, BOD (Biochemical Oxygen Demand) ≤ 10 mg/L, TSS (Total Suspended Solids) ≤ 10 mg/L and Turbidity ≤ 5 NTU.
For treated wastewater (RD 509/1996 and RD 11/1995), the targets would be: TN (Total Nitrogen) 15 mg/L N (from 10,000 to 100,000 h-e) 10 mg/l N (more than 100,000 h-e), TP (Total Phosphorus) 2 mg/L P (from 10,000 to 100,000 h-e) 1 mg/L P (more than 100,000 h-e), BOD (Biochemical Oxygen Demand) 25 mg/L O_2, COD (Chemical Oxygen Demand) 125 mg/L O_2, TSS (Total Suspended Solids) 35 mg/L.
For drinking water (RD 3/2023), the targets would be: E. coli 0 CFU/100 mL, pH 6.5-9.5, Electrical Conductivity (EC) 2500 µS/cm at 20 ºC, Turbidity 4.0 NTU, Total Organic Carbon (TOC) 5.0 mg/L, Polycyclic Aromatic Hydrocarbons (PAHs) 0.10 µg/L, Arsenic 10 µg/L, Cadmium 5.0 µg/L, Chromium 25 µg/L, Mercury 1.0 µg/L, Nickel 20 µg/L, Lead 5.0 µg/L, Antimony 10 µg/L, Selenium 20 µg/L, Nitrate 50 mg/L, Nitrite 0.50 mg/L and individual pesticide 0.10 µg/L."

Possible relationship with other water indicators

Reclaimed water production, Compliant reclaimed water.

Data obtention

Sampling plan:
The quality parameters required by the current regulations or permits associated:

- Physical Parameters: pH, temperature, EC, TSS, turbidity, alkalinity, etc.

- Chemical Parameters: COD, BOD, nutrients (nitrogen, phosphorus), metals (Cd, Cu, Pb, Hg, Ni, Zn), and other ions (Cl^-, SO_4^{2-}, Na, K, Ca, Mg).
- Biological Parameters: DO, total coliform bacteria, E. coli, Legionella spp., etc.
- Organic Micropollutants: Pesticides, PCBs, polycyclic aromatic hydrocarbons (PAHs), etc.

See more information at the individual DEMO Monitoring Plan.

Calculation formula

Compare Ce to Creg:
If Ce < Creg, then WQC = Yes
If Ce > Creg, then WQC = No

Where:

- Ce: average effluent concentration in pollutant concentration units.
- Creg: regulated pollutant concentration for water use in pollutant concentration units.

*To be evaluated for each pollutant.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- Boletín Oficial del Estado (1995). Real Decreto 11/1995, de 28 de diciembre, por el que se establecen las normas aplicables al tratamiento de las aguas residuales urbanas. Boletín Oficial del Estado, núm. 312, 37517-37519. https://www.boe.es/boe/dias/1995/12/30/pdfs/A37517-37519.pdf
- Boletín Oficial del Estado (1996). Real Decreto 509/1996, de 15 de marzo, de desarrollo del Real Decreto-ley 11/1995, de 28 de diciembre, por el que se establecen las normas aplicables al tratamiento de las aguas residuales urbanas. Boletín Oficial del Estado, núm. 76, 12038-12041. https://www.boe.es/boe/dias/1996/03/29/pdfs/A12038-12041.pdf
- Boletín Oficial del Estado (2023). Real Decreto 3/2023, de 10 de enero, por el que se establecen los criterios técnico-sanitarios de la calidad del agua de consumo, su control y suministro. https://www.boe.es/buscar/pdf/2023/BOE-A-2023-628-consolidado.pdf
- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: a handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577
- Regulation (EU) 2020/741 of the European Parliament and of the Council of 25 May 2020 on minimum requirements for water reuse. (2020). Official Journal of the European Union, L 177, 32-55. https://faolex.fao.org/docs/pdf/eur195719.pdf

9.2.2.5 Rainfall Interception of NBS (RI)

- **Code**: Nikosia-2_Water04
- **Environmental Sector:** Water / Rainwater management and flood protection
- **Units:** mm/h

Meaning and importance of the indicator

The indicator measures the rate at which rainfall is intercepted by the NBS. This indicator is important for assessing the effectiveness of NBS in managing rainwater, reducing surface runoff, and mitigating flood risks. The interception capacity of NBS directly influences the hydrological balance and contributes to water retention in the ecosystem, thereby playing a vital role in flood prevention and sustainable water management.

Expected evolution of the indicator

Baseline: Initial interception capacity of the NBS.

Target: The optimal value would be a higher rate of rainfall interception compared to the baseline scenario and conventional infrastructure, leading to reduced surface runoff and enhanced groundwater recharge. This should ideally increase over time as the NBS matures and vegetation coverage expands.

Possible relationship with other water indicators

Captured runoff, Flood excess volume, Avoided floods.

Data obtention

Sampling plan:

- Volume of rainfall intercepted by the NBS (mm)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.
- Time duration of the rainfall event (h)

Calculation formula

$$RI = \frac{Vrainfall\ NBS}{t}$$

Where:

- RI: Rainfall Interception Rate (mm/h),
- Vrainfall NBS: The total volume of rainfall intercepted by the NBS during a given time period (mm),
- t: time duration of the rainfall event (h).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of nature-based solutions: a handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577

9.2.3 Biodiversity Indicators

9.2.3.1 Bird Species Richness

- **Code**: Nikosia-2_Bio 01
- **Environmental sector**: Fauna biodiversity
- **Units:** Number of bird species

Meaning and importance of the indicator

This indicator measures the diversity of bird species within the green areas of the demo (Cupressus, olive, bauhinia and schinus trees, also shrubs of pittosporum and Pistacia around the park). Bird species richness is a key metric for assessing the ecological success of the habitat, as it reflects the ability of the new green areas to support a variety of avian species but also serves as a proxy for the presence and health of other fauna groups. High species richness indicates a well-functioning habitat that can provide necessary resources and shelter for different bird species and other faunal groups including invertebrates and small mammals, as these species often share and depend on similar habitat features and are a main food source for many bird species. Monitoring bird species richness helps in understanding the overall impact of the new green areas on local biodiversity and ecosystem health, especially in urban environments.

Expected evolution of the indicator

Over time, as the green areas mature and the habitat conditions improve, an increase in bird species richness is expected. The goal is to reach a stable and diverse bird population that reflects the habitat's capacity to support a variety of fauna species.

Possible relationship with other analyses

The presence and diversity of bird species can be influenced by the area of fauna habitats, and other factors such as vegetation density, food and shelter availability, and the level of human disturbance.

Data obtention

Required data:

Number of bird species observed in the green areas. The required data can be obtained through different methods, that can be selected based on practical limitations and resource availability:

- **Visual sampling:** Conduct bird surveys using trained observers to identify and count bird species present in the new green areas. For visual sampling, the observer should remain stationary at each sampling point for 15 minutes. During this time, they must record all bird species detected either visually or auditorily (songs or calls). Only birds present within the designated survey area (DEMO) should be considered for calculating the indicator. Birds observed outside the DEMO can be recorded separately, clearly marked as "Outside" to exclude them from the final calculations. At each sampling point, the observer must record the date, start and end times, geographical coordinates, and weather conditions (temperature, wind speed, cloud cover, and precipitation). The observer must record all the species detected. Optionally, number of individuals observed, bird behaviour (e.g., flying, feeding, singing, or stationary) and the type of habitat they are using (trees, grass, buildings, or other structures) also provide useful information.

- **Bioacoustics sampling:** Utilize audio recording equipment to capture bird calls and songs. This method helps identify species that may be difficult to observe visually and provides additional data on species presence. The recordings can be conducted by a non-trained person, but subsequent identification is needed to be conducted by an expert ornithologist to accurately determine species. For bioacoustics sampling, recorders must be places in high areas (trees for example) for 15 minutes. At each sampling point, the observer must record the date, start and end times, geographical coordinates, and weather conditions (temperature, wind speed, cloud cover, and precipitation). After sampling, recording must be processes by an exert to identify all the species.

Both methods can be used complementarily to maximize the probability of detecting all species present in the habitat. If possible, it is recommended to conduct two replicates at each sampling point, separated by one week, to enhance data reliability.

Sampling plan:

- **Sampling points**: Visual or bioacoustic sampling points should be spaced at least 200 meters apart to avoid overlap in detections, due to the small size of the DEMO area, a single sampling point is needed.
- **Time of the day**: Surveys must be conducted in the early morning (typically within 3 hours after sunrise), when birds are most active. Avoid midday or late afternoon counts when bird activity decreases.
- **Season:** Surveys should be conducted between April and May to capture most breeding species when bird activity is at its peak.
  If a second sampling is conducted, it should take place in September or October to monitor migratory species and changes in bird populations after the breeding season.

Sampling calendar

Sampling should be conducted annually to assess changes in species richness.

Equipment

Binoculars, sheet for noting the results and GPs device of smartphone for recording coordinates. For bioacoustics sampling, a high-quality audio recorder with good sensitivity and low noise floor, including battery and memory card.

External subcontracting

An ornithologist is required for the project. If one is not available within the team or cannot be found among volunteers or recreational bird watchers, it will be required to be subcontracted.

Data sources

For baseline information, online databases such as GBIF or APPS (eBird, iNaturalist, observation.org or other local platforms), ornithological organizations or local bird watching clubs can provide valuable data.

Calculation formula

S_{total}=Number of unique species observed across all replicates of both sampling points.

The species lists from all sampling points and replicates should be combined, and duplicates removed, to obtain the total number of unique species present.

References

- European Comission. 2021. Evaluating the Impact of Nature-based Solutions: A Handbook for Practitioners. Luxembourg. *Indicator 9.5 Number of species within a defined area* doi:10.2777/244577
- Fundación Biodiversidad. 2022. Guía para la medición y seguimiento de indicadores. Convocatoria de subvenciones de la Fundación Biodiversidad F.S.P., para el fomento de actuaciones dirigidas a la renaturalización y resiliencia en ciudades españolas, correspondiente al año 2022, en el marco del Plan de Recuperación, Transformación y Resiliencia. *Indicator BDU-009*. https://fundacion-biodiversidad.es/wp-content/uploads/2022/10/guia_indicadores_renaturb_2022_0.pdf

9.2.3.2 New Fauna Habitat Area

- **Code**: Nikosia-2_Bio02
- **Environmental sector**: Fauna habitats
- **Units:** Square meters (m^2)

Meaning and importance of the indicator

This indicator measures the establishment of new functional habitats for fauna created by the new green areas created. This metric is critical for understanding the ecological value of the new green area in supporting biodiversity, especially in urban environments where such green areas can provide essential refuge for species that contribute to ecosystem services, such as pollination or seed dispersal, serving as a key indicator of the ecological performance of the new habitats created.

Expected evolution of the indicator

The total cover of new functional habitat is expected increase, until reaching the optimal scenario where the entire area intervened serves as functional habitat for fauna, implying that all available surface area contributes effectively to biodiversity enhancement and habitat provision.

Possible relationship with other analyses

The quality of the newly created habitat can be influenced by several factors related to the soil and substrate. Key considerations include soil nutrient content, drainage, and moisture retention capacity. The quality of irrigation water and the choice of plant species also play a critical role in enhancing the habitat's ability to support fauna.

Data obtention

Required data:

Total coverage of new fauna functional habitat created (m^2). The required data can be obtained through different methods, that can be selected based on practical limitations and resource availability:

- Field Sampling: Measure the total area of new green space where trees and grass have been planted. This involves physically surveying the site to determine the coverage of functional habitats, including all areas covered by vegetation.
- Aerial Images: Utilize drone or satellite imagery to assess the extent of the newly created green areas. This method provides a broader view and helps verify the coverage.

For comprehensive data, combine field sampling and aerial images with existing data to ensure accuracy and reliability in measuring the new fauna habitat area.

Paths, seats, of other structures found in the area that do not provide functional habitats for fauna should be excluded of the measurements.

Sampling plan:

The measures should be done during the spring month (may or early June) in order to capture the plant cover at its peak development stage.

Sampling calendar

This indicator will be produced every year for a total of 10 years in case of field surveys or drone aerial images. If satellite imagery is used, assessments can be extended to every 5 years to ensure the availability of updated images.

Equipment

Tape measure and measuring wheel for manual measurements and sheet for noting the results, including the date, environmental conditions and observer's name. Camera, as it's recommended to document the visual state of the habitats trough images. Drone in case capturing high-resolution images of the green area. In case of using satellite imagery, GIS software is required to obtain the size of the green area.

Data sources

Satellite imagery platforms such as Google Earth, Copernicus, NASA's Earthdata, the European Space Agency's (ESA) Sentinel Hub, and other open-access geospatial data platforms for high-resolution and updated images of the green areas.

Calculation formula

New functional Habitat Area (A) = Total area covered by new fauna habitats.

References

- Connecting nature. 2020. Nature-based solution evaluation indicators: Environmental Indicators Review. *Indicator Env78. Targeted habitats and 93. Habitats restored. area*.https://connectingnature.eu/sites/default/files/images/inline/CN_Env_Indicators_Review_0.pdf
- European Comission. 2021. Evaluating the Impact of Nature-based Solutions: A Handbook for Practitioners. Luxembourg. *Indicator 10.2 Area of habitats restored* doi:10.2777/244577
- Fundación Biodiversidad. 2022. Guía para la medición y seguimiento de indicadores. Convocatoria de subvenciones de la Fundación Biodiversidad F.S.P., para el fomento de actuaciones dirigidas a la renaturalización y resiliencia en ciudades españolas, correspondiente al año 2022, en el marco del Plan de Recuperación, Transformación y Resiliencia. *Indicator CON-008*. https://fundacion-biodiversidad.es/wp-content/uploads/2022/10/guia_indicadores_renaturb_2022_0.pdf

9.2.4 Energy Indicators

9.2.4.1 Air Temperature Measurement (Weather Station)

- **Code**: Nikosia-2_Energy01
- **Environmental Sector**: Energy
- **Units**: °C

Meaning and importance of the indicator

"Air temperature measurement" assesses the ambient temperature within hydro park areas compared to surrounding urban environments. This indicator is important for understanding the cooling benefits provided by green spaces in cities, which can mitigate the urban heat island (UHI) effect. Lower air temperatures in parks contribute to enhanced public comfort, reduced energy demand for air conditioning, and improved overall urban liveability. By monitoring air temperature in parks, urban planners and environmentalists can evaluate the effectiveness of green infrastructure in regulating microclimates, inform the design and maintenance of green spaces, and advocate for increased vegetation and sustainable urban development practices. Ultimately, this indicator supports efforts to create healthier, more resilient urban areas that can better withstand the impacts of climate change.

Expected evolution of the indicator

The expected evolution of the indicator "Air temperature measurement" in parks is towards a gradual decrease in air temperatures relative to surrounding urban areas, reflecting the cooling effects of green spaces and improved park management practices.

Data obtention

Measurement with weather station.

Frequency

Continuous.

9.2.4.2 Air Humidity Measurement (Weather Station)

- **Code**: Nikosia-2_Energy02
- **Environmental Sector:** Energy
- **Units**: °C

Meaning and importance of the indicator

" The indicator "Air humidity measurement" in parks assesses the level of moisture in the air within park areas, providing valuable data on the microclimate effects of green spaces in urban environments. This indicator is important because it helps to understand the role of parks in regulating humidity levels, which can influence thermal comfort, ecosystem health, and human well-being. Higher humidity levels in parks, compared to the drier urban surroundings, can enhance the cooling effect through evapotranspiration from plants and soil. Monitoring air humidity in parks allows urban planners and environmental managers to evaluate the effectiveness of green spaces in maintaining a balanced and comfortable urban climate. It also supports the design of parks that maximize their environmental benefits, contributing to improved air quality, reduced heat stress, and enhanced biodiversity. Ultimately, this indicator plays a crucial role in promoting sustainable urban development and enhancing the quality of life in cities.

Expected evolution of the indicator

The expected evolution of the indicator "Air humidity measurement" in park is towards maintaining or slightly increasing humidity levels relative to surrounding urban areas, reflecting the natural processes and ecological benefits of green spaces.

Data obtention

Field measurement with weather station.

Frequency

Continuous.

9.2.4.3 Energy consumption of Water Storage and Irrigation in green areas

- **Code**: Nikosia-2_Energy03
- **Environmental Sector:** Energy
- **Units**: kWh

Meaning and importance of the indicator

"Energy consumption of Water Storage and Irrigation in green areas" measures the amount of energy used to store and distribute water for the maintenance of parks, gardens, and other urban green spaces. This indicator is crucial for assessing the efficiency and sustainability of water management practices in these areas. High energy consumption can indicate inefficiencies and lead to increased operational costs and environmental impact due to higher greenhouse gas emissions. Conversely, optimizing energy use in water storage and irrigation systems can lead to significant cost savings, lower carbon footprints, and more sustainable urban environments. Monitoring this indicator helps identify opportunities for implementing energy-efficient technologies, such as solar-powered pumps and smart irrigation systems, which can enhance water distribution efficiency and reduce energy consumption. Ultimately, reducing the energy consumption for water storage and irrigation supports broader sustainability goals by conserving resources, reducing emissions, and promoting the health and resilience of urban green spaces.

Expected evolution of the indicator

The expected evolution of the indicator "Energy consumption of Water Storage and Irrigation in green areas" is towards a reduction in energy use, driven by advancements in technology, improved efficiency measures, and sustainable water management practices.

Data obtention

Field measurement or assessment based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

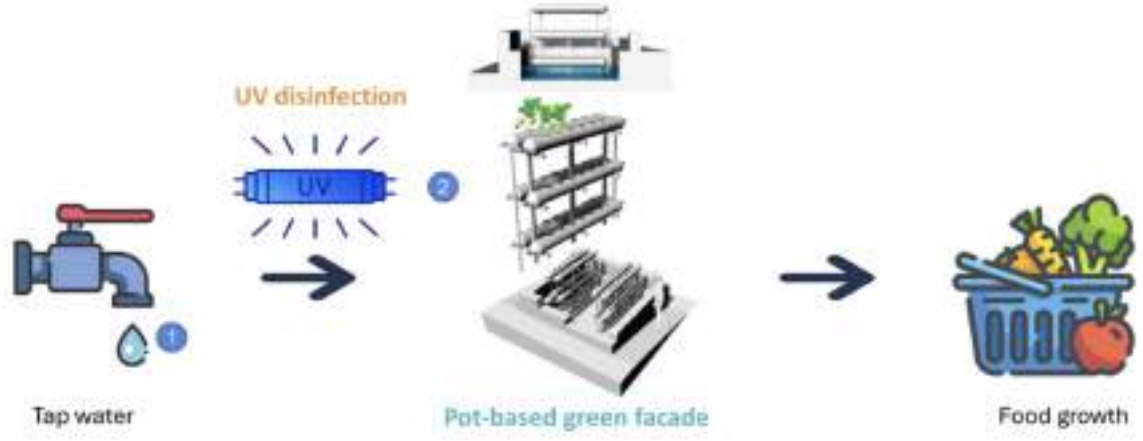
DEMO9.3: Nikosia - Gardens of the Future

9.3.1 Water Indicators

9.3.1.1 Water Monitoring Plan

Sampling points

Nurturing Urban Nature: Enhancing Food Security with Pot-Based Green Facades.



Sampling point	Location	Purpose
SP-01	Inlet of the UV disinfection treatment	Monitor tap water consumption (volume)
SP-02	Inlet of the pot-based green facade	Monitor reclaimed water production (volume)

Parameters to be analyzed

Parameter	Applicable Sampling point	Related indicator/s	Type
Volume of tap water consumed	SP-01	TWCPC; WFP-WFN	water flow measurements [volume/time]
Volume of reclaimed water produced	SP-02	WFP-WFN	water flow measurements [volume/time]

Sampling method

Water flow measurements:

Direct measurement of volume provided during a time period or water flow with flow meters and/or water level sensors.

a) Automatic method

Automatic flow meters can be installed at the recommended sampling points (SP). For the automatization process, it is recommended to register the measurements with a datalogger/digital control system in the DEMO. It is recommended to measure the flow at the recommended sampling points (SP).

Data should be stored in a datalogger/digital control system and then be able to be exported in a spreadsheet to calculate the associated indicators. When this is not possible, manual readings of the flow meters can be done instead.

b) Manual method

This could be applied as the last option if there is no possibility to apply the automatic method.

- Periodic manual measurements
- If no devices are available to measure, correct and reliable estimates must be made to assess the indicator.
- Measure the volume at the point of reuse or approximate the value based on the amount of water demand met by the green facade for reuse.

Sampling calendar

Water flow measurements:

Data should be collected frequently for a relevant time period (e.g., daily, weekly, monthly) to allow for accumulation over the entire reporting period (yearly). This high frequency is also relevant to study seasonal variations.

Equipment

Water flow measurements:

Water flow meters are essential tools for monitoring and assessing the efficiency of these systems, as they provide real-time data on water movement and usage through the treatment processes and the different pipes, helping to determine the volume of water at those particular locations.

Some indicative providers of these water flow meters are:

- Endress+Hauser
- Systec Controls
- Aobo instrument

9.3.1.2 Water Footprint (WFP)

- **Code**: Nikosia-3_Water01
- **Environmental Sector:** Water / Water resource efficiency
- **Units:** m^3/m^3

Meaning and importance of the indicator

The Water Footprint (WFP) is a global indicator of freshwater resource appropriation, defined by the Water Footprint Network (WFN). It encompasses three types of water usage:
- Green water footprint: Associated with rainwater absorbed by vegetation.
- Blue water footprint: Relates to the consumption of surface and groundwater.
- Grey water footprint: Refers to the volume of freshwater required to assimilate pollutants, reflecting water contamination.

In various sectors, water footprint is mainly observed during production (blue water), contamination from chemicals (grey water), and raw material production (green, blue, and grey water). The water footprint of a product, process, or organization represents both direct and indirect water use. Direct water use refers to the water consumed and/or contaminated during production, including water incorporated in the final product. Indirect water use, on the other hand, includes water consumed for producing raw materials throughout the supply chain.

For the consumption of $1m^3$ of drinking water or the treatment of $1m^3$ of wastewater, the WF accounts for both directly used water, such as that involved in production or treatment, and indirectly used water, which pertains to the water used in creating the systems, products, and processes supporting the production or treatment. Moreover, NBS can contribute by providing water for reuse, such as for aquifer recharge, surface discharge, ecosystem restoration, or onsite reuse, further shaping the water footprint.

Expected evolution of the indicator

The expected evolution of the WF indicator, as defined by the WFN, is geared towards refining and optimizing the assessment of freshwater use and its associated impacts. As methodologies and data collection techniques advance, more precise and comprehensive value ranges are anticipated to be established, aiding in better benchmarking and management practices. There will be a growing emphasis on reducing both direct and indirect water usage through improved efficiency and sustainability measures.

Possible relationship with other water indicators

Water Footprint (ISO), Water quality compliance: biological, physical and chemical parameters.

Data obtention

Sampling plan:

To assess the water footprint of a utility, the following data must be collected:

Drinking Water Production:

3. Direct water usage: The total water used by the utility to produce 1 m^3 of drinking water. This includes water used in the treatment plant, for network operation, and water lost through leakages.
4. Indirect water usage: Water used in producing resources and products necessary for drinking water production, such as:
    - Electricity and energy for treatment and distribution (pumping)

- Chemicals for treatment
- Equipment for treatment and distribution (e.g., pipes, pumps, valves)

Data is typically collected annually or more frequently through metering systems.

Wastewater Treatment and Reclamation:

3. Direct water usage: Total water used for collecting and treating 1 m^3 of wastewater and reclaimed water, including water used in the treatment plants and for network operation, and water lost through leakages.
4. Indirect water usage: Water used in producing resources for wastewater treatment, such as:
   - Electricity and energy for treatment and distribution (pumping)
   - Chemicals for treatment
   - Equipment for treatment and distribution
   -

Additional Data:

- Conductivity, COD, TSS, TN, TP
- Temp; consumables (e.g. caustic soda, disinfectant, etc.);
- Energy consumption;
- Volume wastewater treated.

Calculation formula

$$WFPdw = \frac{WFdw}{DWP} \; or \; WFPww = \frac{WFww}{TWW}$$

Where:

- WFdw (Water footprint in the drinking water system) and WFWW (Water footprint in the wastewater system): should be collected for every process and product that is being used in the system (this includes water used in the whole of the treatment plant, water used for operation of the network, and water which is lost through leakages in the drinking water network) through a period of time (e.g., year) (m^3/year),
- DWP: Annual drinking water production; used for drinking water systems (m^3/year),
- TWW: Volume of wastewater treated; used for wastewater systems (m^3/year).

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

- Alegre, H., Baptista, J.M., Cabrera, E., Cubillo, F., Duarte, Hirner, W., Parena, R. (2016). Performance Indicators for Water Supply Services: Third Edition. IWA Publishing, Volume 15. DOI: https://doi.org/10.2166/9781780406336.
- Romeiko, X. X. (2019). Comprehensive water footprint assessment of conventional and four alternative resource recovery-based wastewater service options. Resources, Conservation and Recycling, 151, 104458. DOI: https://doi.org/10.1016/j.resconrec.2019.104458

- Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M. & Mekonnen, M.M. (2011) The water footprint assessment manual: Setting the global standard, Earthscan, London, UK. https://waterfootprint.org/en/resources/publications/water-footprint-assessment-manual/
- B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

9.3.1.3 Tap Water Consumption (TWC)

- **Code**: Nikosia-3_Water02
- **Environmental Sector:** Water / Water consumption
- **Units:** L/day or L/year

Meaning and importance of the indicator

The tap water consumption is an indicator on how effectively water is used by the inhabitants served by a public water supply. It provides insight into the efficiency of water use within a community, and indirectly measures the extent to which water-saving products and installations are adopted by the NBS. The assessment requires accurate data on annual tap water consumption provided through the public water supply system.

Expected evolution of the indicator

The expected trend for this indicator should ideally show a decrease over time as water-saving technologies, public awareness, and regulations improve. The optimal value range depends on local conditions, such as climate, water availability, and population density, but generally, a lower TWC with equally smooth operation of the NBS (in this case, correct crop growth with the lowest possible water consumption) indicates more efficient water use.

Possible relationship with other water indicators

Water footprint.

Data obtention

Sampling plan:

- Tap water consumption compared with the previous years to track changes over time (L/day or L/year)
  Cumulative values during a year will be needed. If this is not possible, average yearly values can be obtained. The average can be done from monthly average data obtained from sampling at the DEMO.

For more details on data obtention methods, sampling calendar, equipment, external subcontracting and others, please refer to the Individual Water DEMO Monitoring Plan below.

References

Indicator adapted from Drinking Water Consumption (DWC). B-WaterSmart project (2022). Water-Smartness Assessment Framework. European Union's Horizon 2020 Research and Innovation programme. https://b-watersmart.eu/results-downloads/water-smartness-assessment-framework/

9.3.2 Biodiversity Indicators

9.3.2.1 Number of Individuals Producing Edible Fruits

- **Code**: Nikosia-3_Bio01
- **Environmental Sector**: Plant / Plant Biodiversity
- **Units:** Individuals per species

Meaning and importance of the indicator

Urban agriculture is growing in many urban areas to supply fresh food locally and to provide multiple benefits for the sustainable development of urban landscapes, local economic development, increased social cohesion and support for ecosystem services such as pollination and climate change mitigation. Local policy instruments are needed to regulate concerning land use planning, health and environmental policies. One of the main indicators to assess the productive capacity of the urban agriculture is the number of individuals producing edible fruits per species.

Expected evolution of the indicator

The number of individuals producing edible fruits (per species) is expected to increase over time, particularly if planted plants are immature or young and have not yet reached their full fruiting potential.

Data obtention

Required data:

Total number of individuals producing edible fruits, differentiated per species.

Sampling plan:

Field sampling. All mature individuals producing edible fruits of each species will be counted every year.

Sampling calendar

Each park or garden will be sampled every year at the same time of the year. The optimal period is after the dry season, and winter should be avoided for deciduous species to prevent confusion between species or dead and dormant individuals.

References

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9.3.2.2 Fruit Production Per Species

- **Code**: Nikosia-3_Bio02
- **Environmental Sector**: Plant / Plant Biodiversity
- **Units:** Kg Or Kg/M^2

Meaning and importance of the indicator

Urban agriculture is growing in many urban areas to supply fresh food locally and to provide multiple benefits for the sustainable development of urban landscapes, local economic development, increased social cohesion and support for ecosystem services such as pollination and climate change mitigation. Local policy instruments are needed to regulate concerning land use planning, health and environmental policies. One of the main indicators to assess the productive capacity of the urban agriculture is the total fruit production per species.

Expected evolution of the indicator

Fruit production per species is expected to increase over time, particularly if planted plants are immature or young and have not yet reached their full fruiting potential.

Possible relationship with other biodiversity analyses

Number of individuals producing edible fruits (Nikosia-3_Bio01).

Data obtention

Required data:

- Total kilograms of fruits produced per species in each park or garden.
- Total kilograms of fruits produced per species related to the area of park or garden.

Sampling plan:

The production of fruits of each species will be recorded every year, distinguishing between the total kilograms of fruit per species produced in each park or garden, and the total kilograms of fruits per species produced in relation to the area of each park or garden.

Sampling calendar

Each fruit harvested for each species will be weighted, the total production (kg) will be calculated every year.

Equipment

A balance.

References

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9.3.2.3 Flying Insect Sampling

- **Code:** Nikosia-3_Bio03
- **Environmental Sector:** Biodiversity / Fauna
- **Units:** Number of flying insects, Number of species

Meaning and Importance of the Indicator

Urban parks serve as key green spaces that support biodiversity within cities. Insect populations in these parks provide valuable ecosystem services, such as pollination and pest control, while also serving as food for urban wildlife. Yellow sticky traps are a common methodology used to monitor flying insects in urban environments, offering insight into the health of insect populations. These traps attract and capture flying insects drawn to the colour yellow, particularly pest species like aphids, leafhoppers, and flies, as well as pollinators and other beneficial species. Monitoring the diversity and abundance of flying insects in urban parks helps to evaluate the ecological quality of these green spaces and can reveal the impacts of urbanization, pollution, and habitat fragmentation on insect communities.

Expected Evolution of the Indicator

In a healthy urban park, a balanced population of both pest and beneficial insects should be present. Over time, any shifts in insect populations—such as an increase in pests or a decline in pollinators—could indicate environmental stresses, such as excessive pesticide use, air pollution, or habitat degradation. When introducing landscape or vegetation changes to the park it is especially useful to monitor changes in insect populations and can help urban park managers make informed decisions about maintenance practices, plant diversity, and habitat restoration efforts.

Data obtention

Required data:

- Number of flying insects caught on yellow sticky traps, categorized by morphospecies or morphological groups (e.g., aphids, flies, pollinators, beetles).

Sampling plan:

- Bright yellow adhesive-coated traps (dimensions: 10-15 cm x 20-30 cm) will be used to capture flying insects.
- Traps will be placed at various locations within the park, focusing on areas with high insect activity, such as near flowering plants, water features, or shrubs.
- Traps will be mounted vertically on poles or tree branches at approximately 2-3 meters above the ground to capture a wide range of flying insect species, and also to avoid the general public access to the traps.
- A minimum of 10 traps will be deployed across the park, ensuring that different habitats within the park (e.g., flowerbeds, lawns, and wooded areas) are covered.
- The traps will be left in place for 24-72 hours during each sampling event to allow for sufficient insect capture. After this period, the traps will be collected, and the captured insects will be identified and recorded. If the traps fill too quickly, this time can be adjusted.
- Traps should be placed in open areas with direct sunlight, as yellow is most effective at attracting insects in well-lit locations.

- Traps should be replaced after each sampling event to ensure accurate results. Traps that become too saturated with insects or debris may lose their effectiveness.
- Insects captured on the traps should be identified in the lab or by an expert.

Sampling Calendar

Sampling will be conducted monthly from May to September, covering the active flight periods of most flying insect species in the park. Monitoring will take place annually over the duration of the demo action.

Equipment

- Adhesive-coated yellow traps (10-15 cm x 20-30 cm).
- Poles, stakes, or tree branches to mount the traps at 2-3 meters above the ground.
- Plastic containers or zip bags to transport traps and collected insects for analysis.

External subcontracting

Yes, external subcontracting may be required for detailed taxonomic identification of the insects captured on the yellow sticky traps. While basic identification can be performed in the field (e.g., categorizing into functional groups such as pollinators or pests), species-level identification should be handled by professional entomologists or specialized laboratories.

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9.3.3 Energy Indicators

9.3.3.1 Electricity Use In Agriculture

- **Code**: Nikosia-3_Energy01
- **Environmental Sector**: Energy
- **Units**: kWh/m^2 land

Meaning and importance of the indicator

"Electricity use in agriculture" measures the amount of electrical energy consumed in agricultural activities, including irrigation, lighting, heating, cooling, and operating machinery and equipment. This indicator is crucial for assessing the energy efficiency and environmental impact of agricultural practices. High electricity consumption can indicate inefficiencies, leading to increased operational costs and higher carbon emissions. Conversely, optimizing electricity use enhances sustainability by reducing greenhouse gas emissions and lowering production costs, which is vital for the economic viability of farming. Monitoring this indicator helps identify opportunities for implementing energy-saving technologies and practices, such as precision agriculture, renewable energy integration, and efficient irrigation systems. Ultimately, reducing electricity use in agriculture supports broader sustainability goals, including resource conservation, climate change mitigation, and the promotion of eco-friendly farming practices.

Expected evolution of the indicator

The expected evolution of the indicator "Electricity use in agriculture" is towards greater efficiency and sustainability, driven by technological advancements, economic considerations, and environmental regulations.

Data obtention

Field measurement or assessment based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

9.3.3.2 Food production (yield in terms of weight for energy footprint)

- **Code**: Nikosia-3_Energy02
- **Environmental Sector**: Energy
- **Units**: kg

Meaning and importance of the indicator

"Food production" measures the amount of food produced per unit area of land or per unit of input (such as water, energy, or labour). This indicator is crucial for evaluating the efficiency and productivity of agricultural practices. High food production yields indicate effective use of resources and successful implementation of agricultural techniques, contributing to food security and economic stability. Monitoring this indicator helps identify best practices and areas for improvement, guiding policy decisions and resource allocation to enhance agricultural productivity. It also supports sustainable farming practices by promoting the efficient use of inputs and minimizing environmental impacts. Ultimately, optimizing food production yield is essential for meeting the growing food demands of the global population while ensuring the sustainability of agricultural systems.

Expected evolution of the indicator

The expected evolution of the indicator "Food production" in terms of yield is towards a gradual increase, driven by advancements in agricultural technology, improved farming practices, and sustainable resource management.

Data obtention

Field measurement.

Frequency

Once per month with field measurements.

9.3.3.3 Renewable Energy Sources (RES) units integrated and capacity

- **Code**: Nikosia-3_Energy03
- **Environmental Sector:** Energy
- **Units**: kWh RES

Meaning and importance of the indicator

"RES units integrated and capacity" measures the number of renewable energy source (RES) units, such as solar panels, wind turbines, hydroelectric generators, and biomass facilities, that have been integrated into the energy system and their total generating capacity. This indicator is crucial for assessing the progress and effectiveness of transitioning to sustainable energy systems. It highlights the extent to which renewable energy technologies are being adopted and utilized to meet energy demands. Monitoring this indicator is important because it reflects the contribution of renewable energy to reducing greenhouse gas emissions, enhancing energy security, and decreasing reliance on fossil fuels. Additionally, it helps policymakers and stakeholders evaluate the success of policies and investments aimed at promoting renewable energy, guiding future decisions to further accelerate the deployment of clean energy technologies. Ultimately, increasing the integration and capacity of RES units supports global sustainability goals and the fight against climate change.

Expected evolution of the indicator

The expected evolution of the indicator "RES units integrated and capacity" (Renewable Energy Sources units integrated and their capacity) is towards a significant increase, reflecting global efforts to transition to sustainable energy systems.

Data obtention

Desk calculation of RE generated and/or used by the case study.

Frequency

None due to desk study.

9.3.3.4 Gross Renewable consumption relative to total gross final consumption

- **Code**: Nikosia-3_Energy04
- **Environmental Sector:** Energy
- **Units**: kWh RE/kWh total

Meaning and importance of the indicator

"Gross Renewable Consumption Relative to Total Gross Final Consumption" measures the proportion of energy consumed from renewable sources compared to the total energy consumption across all sectors, including residential, industrial, and transportation. This indicator is crucial for assessing the progress of a region or country in transitioning to a sustainable energy system. A higher proportion indicates a greater reliance on renewable energy, which is essential for reducing greenhouse gas emissions, mitigating climate change, and decreasing dependence on fossil fuels. Monitoring this indicator helps policymakers and stakeholders evaluate the effectiveness of energy policies, identify areas for improvement, and set targets for increasing the share of renewable energy. Ultimately, increasing the percentage of gross renewable consumption supports environmental sustainability, enhances energy security, and contributes to achieving global climate goals.

Expected evolution of the indicator

The expected evolution of the indicator "Gross Renewable Consumption Relative to Total Gross Final Consumption" is towards a significant increase, reflecting global efforts to transition to cleaner energy sources and reduce carbon emissions.

Data obtention

Field measurement or assessment based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

9.3.3.5 Increase In Renewable Energy Use In The Area

- **Code**: Nikosia-3_Energy05
- **Environmental Sector:** Energy
- **Units**: kWh RE/kWh total

Meaning and importance of the indicator

"Increase in renewable energy use in the area" measures the growth in the consumption and integration of renewable energy sources, such as solar, wind, hydro, and biomass, within a specific region over a defined period. This indicator is crucial for evaluating the progress and effectiveness of policies and initiatives aimed at transitioning to sustainable energy systems. An increase in renewable energy use signifies a reduction in reliance on fossil fuels, leading to lower greenhouse gas emissions and improved air quality. It also reflects advancements in energy technology, economic investments in green infrastructure, and societal shifts towards sustainability. Monitoring this indicator helps stakeholders identify successful strategies, allocate resources efficiently, and set future targets for renewable energy adoption. Ultimately, increasing renewable energy use supports global efforts to combat climate change, enhance energy security, and promote sustainable development, contributing to a cleaner and more resilient energy future.

Expected evolution of the indicator

The expected evolution of the indicator "Increase in renewable energy use in the area" is towards a substantial and continuous rise, driven by various factors including technological advancements, economic benefits, and regulatory support.

Data obtention

Field measurement or assessment based on purchased fuel. If both approaches are not possible, energy consumption assessment will be based on electrical capacities of equipment and total using time.

Frequency

Once per month with field measurements or once per year when electrical capacities are used.

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CLIMATE ADAPTATION AND RESILIENCE
DEMONSTRATED IN THE MEDITERRANEAN REGION

Deliverable 2.2

ANNEX J: Social Indicators

ANNEX J: Social Indicators to be developed

The research of inclusive governance of Nature-based Solutions in CARDIMED will draw on a series of indicators that encompass different components of institutional capacity, stakeholders, knowledge, and governance. Three key social indicators that we are proposing to be assessed in all DEMOs are:

1. change in rules and regulations;
2. activation of public-private collaboration;
3. community involvement in implementation.

These indicators will be based on information reported by the DEMO teams as part of the monitoring plan activities and require the teams to keep track of different aspects of the implementation.

The indicator of change in rules and regulations considers how challenging was the process of obtaining permits according to the implementation teams. For this reason, this indicator will be measured using Likert scale scores assigned by the DEMO leaders before and after implementation to assess how the teams perceive changes in regulatory processes.

The activation of public-private collaboration will be monitored through records of the relevant partnerships established as the projects are implemented. This assessment will be made based on the reports of the DEMO leaders, who are expected to keep notes on the number and purpose of these partnerships.

The assessment of community involvement in implementation is based on the record of who and how many participants were present in important milestones in each of the projects. The DEMO teams will assign a Likert scale score for community involvement based on their knowledge of the communities.

Who and How: All these three indicators require qualitative data and data analysis methods that need social sciences expertise. As thus, these indicators will be assessed over the course of the project through the activities in WP3 and WP7 (Task 7.1) and will be assessed through interviews with DEMO teams (including DEMO leaders) and policy stakeholders that will be realised and assessed by the Utrecht University research team. These indicators will be analysed in tandem with the work developed in WP3 to provide a deeper understanding and generate insights into how knowledge is translated and adapted to specific contexts as the projects are implemented. Additional qualitative aspects that will provide nuance and detail on how community involvement, regulatory processes and collaborations can lead to the mainstreaming of nature-based solutions will be the focus of subsequent work under Task 7.1 that will deepen insights into mainstreaming strategies and the institutional shifts realised due to NBS implementation in the DEMO sites.

Frequency: During spring 2024 we have already monitored these indicators as part of the research in Task 2.6 and collected data across all the DEMOs. These are our “baseline” data for the indicators as the NBS were under implementation in the DEMOs. Spring 2025 we will have another round of monitoring

interviews as part of Tasks 3.1, 3.3 and 7.1 where these indicators will also be assessed qualitatively. A plan for 2026 and 2027 is to be formulated early next year for their monitoring.

Activation of Public-Private Collaboration

- **Sector**: Societal / Participatory Planning and Governance

Meaning and importance of the indicator

Establishing lasting collaborations between governmental actors and private partners can significantly improve the chances that nature-based solutions will achieve their full potential. Access to private expertise, networks and resources can accelerate the learning process and help nature-based solutions effectively respond to local conditions and constraints (Rauf et al. 2024). In doing so, public-private partnerships are an important step towards improving awareness and gathering support for the mainstreaming of nature-based solutions from stakeholders in the public and private sectors (Frantzeskaki and Kabisch 2016).

Establishing these relationships is also critical for the long-term success of the projects, as involving private partnerships in all stages of the project can serve as a foundation for innovative governance practices and participatory management (Hasselman 2017). Public-private collaborations can lead to the emergence of new models of participation in which different segments of society can contribute to different aspects of governance, including supporting maintenance, serving as a consultative body or actively participate in monitoring efforts (Conrad and Hilchey 2011).

Expected evolution of the indicator

Based on practical experiences with the implementation of nature-based solutions in different contexts, partnerships between public and private stakeholders are expected to remain stable or to increase as projects unfold. These partnerships can be a response to new challenges or proactively emerge as implementors realise the benefits of additional expertise or resources to support operations. The expansion of these partnerships can facilitate the operation of projects by building upon the know-how of experts or the logistical capabilities of specialised partners (European Investment Bank 2023).

Under specific conditions, an increase in the number of collaborations is expected to fill in possible gaps in the knowledge of local implementors, preventing the adoption of costly operations and prolonged “trial and error” implementation strategies. The meaningful involvement of collaborators in the implementation of nature-based solutions is essential to create conditions for future partnerships (Collier et al. 2023), foster trust between implementors and society, generate opportunities for experimentation, and foster open dialogues about the short and long-term effects of the projects.

Data Obtention

Required data:

To be analysed at each milestone: Teams should keep a record of how many public private collaborations or established partnerships contributed to the implementation or scale up of the nature-based solution. The records should also contain details of why these partnerships were established and their outcomes.

Possible relationship with other indicators

Related to "Community Involvement In Implementation" as both are components of participatory planning and governance.

Data obtention method

The establishment of public-private partnerships in the implementation of projects is listed as a "outcome-based" indicator in the European Commission's handbook on the evaluation of nature-based solutions, which acknowledges collaborations under the section of participatory planning and governance (European Commission 2021). As such, project leaders are expected to report how many public private collaborations or established partnerships contributed to the implementation or scale up of the nature-based solution. It is also important to keep track of the reasons for these partnerships (e.g. to access expertise, increase logistical capabilities or enhance social acceptance).

Change In Rules and Regulations

- **Sector**: Societal/ Factors of Success
- **Units:** Likert scale

Meaning and importance of the indicator

Regulations that accommodate the specificities of nature-based solutions are critical to facilitate the implementation and mainstreaming of climate adaptation projects. Navigating existing rules can often be politically challenging and time consuming (Zuniga-Teran et al. 2020), making the application for permits a barrier for projects advancing innovative nature-based solutions. For this reason, the steps required for permit applications are an important indicator of how favourable the regulatory environment is towards nature-based solutions (European Investment Bank 2023). Mapping the transformation of regulatory processes is particularly relevant in contexts where governance frameworks might be biased towards conventional infrastructure-provision models (Frantzeskaki and Kabisch 2016).
Monitoring changes in governmental processes (such as permits) can provide important insights into the institutional and legal transformations required for mainstreaming nature-based solutions (Frantzeskaki et al. 2019). These insights can inform future policies and advance nature-based projects by proposing alternative governance models that oppose conventional views of infrastructure and, instead, promote more participatory, decentralized and adaptive climate adaptation strategies. Considering that some implementors might have less resources and limited capabilities to apply for permits, fostering regulatory frameworks that are favourable to nature-based solutions is also critical to allow for a more equitable access to climate adaptation in different contexts (Kotsila et al. 2021).

Expected evolution of the indicator

The projects are expected to promote changes in the permits necessary for the implementation of nature-based solutions. This change in the regulatory frameworks, in turn, is expected to make space for other ambitious projects employing nature-based solutions in the future. Projects pioneering the use of nature-based solutions represent an opportunity to raise awareness about the legal, spatial, financial and environmental characteristics of novel climate adaptation strategies (Chausson et al. 2020).

Obtention

Required data:

- TO BE ANALYZED ONLY THE FIRST TIME: Implementors should use the 5-point Likert scale to indicate how costly and demanding (in terms of time and resources) is the process of applying for permits before the project.
- TO BE ANALYZED AFTER IMPLEMENTATION: Implementors should use the 5-point Likert scale to assess how costly and demanding (in terms of time and resources) is the updated process of applying for permits following the conclusion of the project.

Recommended 5-point Likert scale to examine the regulatory processes before/after the project:
Ranging 1 (very simple and practical) to 5 (very costly and demanding), rank how time consuming and resource demanding is the process of applying for permits for the implementation of nature-based solutions in your context:
Very simple and practical *1( ) 2( ) 3( ) 4( ) 5( )* ***Very costly and demanding***

Data obtention method

Implementors should provide a score (using the Likert scale) that reflects the challenges encountered during the process of applying for permits. Later, they should convene to reflect on which (if any) changes in the regulatory process were derived from the lessons learned and agree on another score to reflect the permit application process after the project. The comparison of the Likert scale scores given before and after the implementation of the project will provide an indication of the extent to which the project has contributed to, or inspired, changes in rules and regulations (particularly in the process of applying for permits).

Community Involvement in Implementation

- **Sector**: Societal/ Participatory Planning and Governance
- **Units:** Number (0-5)

Meaning and importance of the indicator

Successful nature-based solutions are highly dependent on community support and involvement in the implementation. Particularly in contexts where communities are not yet familiar with the benefits of nature-based solutions, a disconnection between projects and society could lead to the discontinuation of these solutions in the long term (Sarabi et al. 2020). The active involvement of society, conversely, is proven to improve environmental awareness and promote a sense of stewardship among the community, which is expected to result in enhancing the social, political and financial support for the projects. By engaging communities, project implementors are able to create dialogues in which potential disruptions during the implementation process can be discussed, questions from the community can be clarified and disagreements can be negotiated (Collier et al. 2023). The involvement of communities in the implementation of projects is also relevant from a social and environmental justice perspective. The active participation of local stakeholders in the production of nature-based solutions plays an important role in reducing the chances that the projects could cause unintended consequences or unequally distribute the costs and burden of the implementation (Cousins 2021). Community participation in the implementation phase, therefore, is expected to create opportunities for all voices to be heard and their concerns continually considered over the life cycle of the projects.

Expected evolution of the indicator

Projects are expected to report a gradual increase in the involvement of society, as implementors gain insights into how climate adaptation strategies can be integrated with the everyday life of the community. Increasing community participation is highly desirable, since implementing nature-based solutions that are sensitive to the specificities of each community can enhance acceptance while accounting for local capabilities and context-specific priorities. While lessons from other projects can suggest ways in which nature-based solutions can be replicated in different contexts, the implementation of projects can be undermined by a lack of community engagement, potentially reducing the potential benefits and affecting the long-term viability of the projects (Wolff et al. 2022). As such, the gradual increase in community participation in the production of nature-based solutions is expected to provide opportunities for implementors and society to iteratively reflect on the project goals, development and long-term impacts in each specific context (Frantzeskaki et al. 2019).

Data Obtention

Required data:

- TO BE ANALYZED ONLY THE FIRST TIME: number of local community organisations represented and total number of attendees (excluding experts) in the first scoping meeting(s) of the project. This list should also include a brief description of why or in which way these organisations were involved (template in table 1 below). The DEMO leadership team should evaluate this participation considering the local context and give it a score (Likert scale) from 0 to 5. Zero represents virtually no involvement and 5 represents perfect involvement.
- TO BE ANALYZED AT EACH MILESTONE: number of local community organisations represented and total number of attendees (excluding experts) at each key project milestone and at the time the

implementation phase is concluded. This list should also include a brief description of why or in which way these organisations were involved (template in table 1 below). The DEMO leadership team should evaluate the participation at each milestone considering the local context and give it a score (Likert scale) from 0 to 5. Zero represents virtually no involvement and 5 represents perfect involvement

Table 1: Template for data collection on community involvement in implementation.

Key Events and Milestones	List of involved organisations	Number of represented organisations	Total number of participants/ attendees	Community Involvement Score (Likert Scale 0-5 to be filled by DEMO leader)	More Info (e.g. how organisations are involved, reasons if score is ZERO)
Scoping meeting	Residents committee	1	8	1	Initial engagement with local representatives
Scoping meeting 2	Residents committee, local business owners' association	2	18	2	Introduction to project and initial awareness workshop
Co-design workshop	Residents committee, local school representatives	2	12	2	Consultation, mutual learning, addressing concerns
Event at end of implementation phase	Residents committee, local business owners' association, local school representatives, regional office of farmers' union	4	40	4	Official delivery of project and consolidation of long-term collaborations for maintenance

Possible relationship with other indicators

Related to "Activation of Public-Private Collaboration" as both are components of participatory planning and governance.

Data obtention method

The European Commission's handbook on the evaluation of nature-based solutions lists community involvement as a "process focused" indicator within the section of participatory planning and

governance (European Commission 2021). Data on this indicator, therefore, should be recorded during important stakeholder meetings and project milestones. The teams should keep track of how many local community organisations are represented and of the total number of attendees (excluding experts) involved in the key moments of project implementation. The teams should also record how these organisations contributed to the implementation or why these organisations were not involved (if the score given is ZERO).

Sampling calendar

Data on attendees and number of organisations represented (excluding experts) should be recorded in all relevant stakeholder engagement meetings and project milestones (particularly at the conclusion of the implementation phase).

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