MULTISOURCE

Nat4Wat: technology selection tool, prototype complete

Deliverable 4.4

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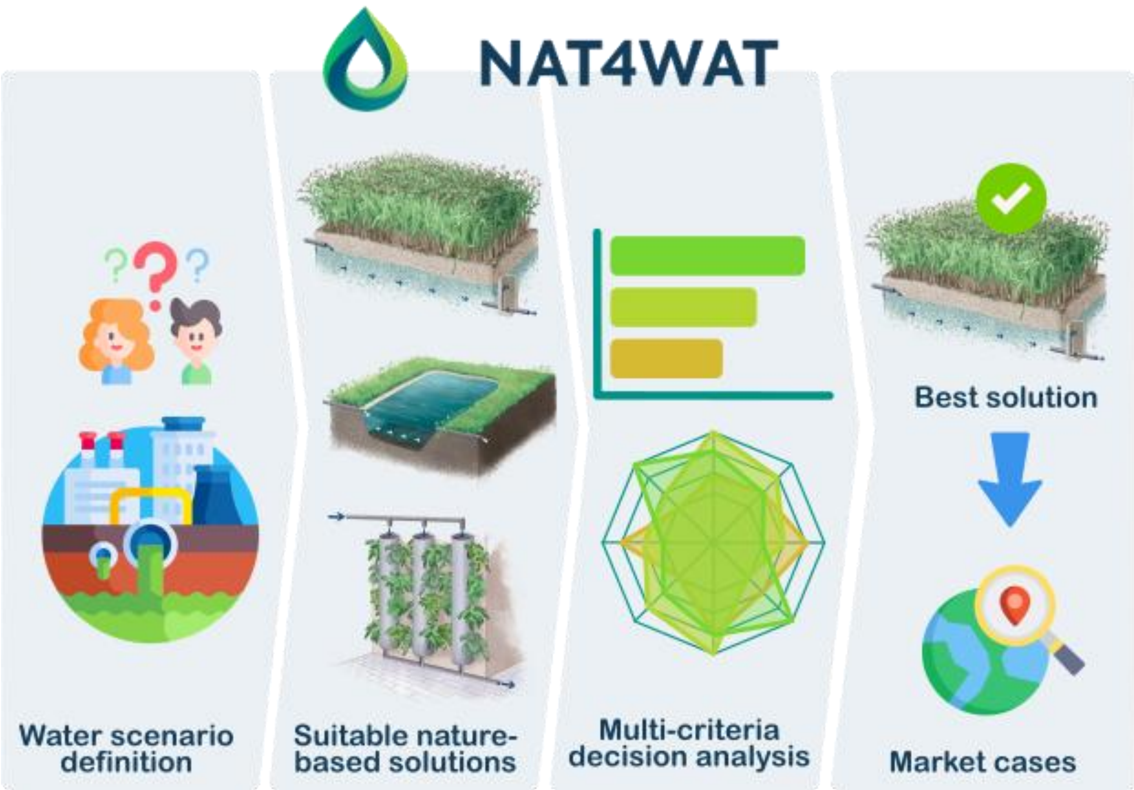
TABLE OF CONTENTS

EXECUTIVE SUMMARY

Nature-based solutions (NBS) have gained prominence as sustainable approaches to urban water management, addressing critical challenges like wastewater treatment and stormwater management while offering additional environmental and social benefits. One of the key advantages of NBS is their role in decentralizing urban water management, allowing cities to distribute water treatment and storage systems across different locations, reducing pressure on traditional centralized infrastructure. However, the diverse range of available NBS options, each suited to different contexts, presents a significant challenge for decision-makers. The Nat4Wat decision-support system (DSS) was developed to aid in navigating this complexity by assisting stakeholders in selecting, comparing, and evaluating NBS options for wastewater treatment and stormwater management. Through the integration of multicriteria decision analysis (MCDA), Nat4Wat evaluates various factors—such as cost-effectiveness, environmental performance, operational requirements, and social benefits—to guide users toward the most appropriate and sustainable NBS for their specific context. This document details the development of Nat4Wat and presents the dissemination strategy designed to increase the impact of the tool within and beyond the MULTISOURCE project. The goals of the dissemination strategy are to increase the number of users as well as the number of companies providing market cases. It includes activities such as social media campaigns, ambassadors and demonstrations in conferences and bilateral meetings with companies and potential users.



1. INTRODUCTION

The overarching goal of the MULTISOURCE project is to facilitate the systematic, citywide planning of nature-based solutions for urban water treatment, storage, and reuse. To realize this objective, the project comprises two primary components: the implementation of pilots featuring enhanced natural treatment systems and the development of tools to assist stakeholders and decision-makers in adopting nature-based solutions. The selection, (pre)design and assessment of NBS technologies for water management require decision is a complex problem where decision support tools can help offering quick, consistent, and qualified solutions.

Among the tools created within MULTISOURCE, the Technology Selection Tool serves as a decision-support system, aiding users in choosing the most suitable NBS, including the enhanced natural treatment systems (ENTS) tested in the MULTISOURCE pilots, for a specific water treatment, storage, or reuse scenario. In this context, a water scenario encompasses inflow conditions, outflow requirements, space availability, and other considerations such as the provision of specific ecosystem services or the skills required to operate the technology.

The NBS Technology Selection Tool not only guides users in choosing and pre-designing the most adequate technology for the water scenario but also considers various other variables of interest, including cost, surface requirements, environmental impact, co-benefits (multifunctionality), and operational needs. This multiple criteria assessment allows a comparison and overall ranking of all viable technologies for a given scenario.

Keeping these objectives in mind, the aim of this deliverable is to introduce Nat4Wat, a user-friendly web-based DSS to select, compare and explore NBS for WWT and SWM at the urban scale, which first prototype is already freely accessible online (https://nat4wat.icra.cat). We describe the development process of the DSS, including the interaction with experts and stakeholders, its implementation, and its operation. Then, we present the strategy designed to disseminate the tool among all interested parties.

2. METHODS

The Nat4Wat DSS was designed as an knowledge-based system, which consists of a knowledge base and an inference engine, meaning it uses rules and a procedure for processing information (Krueger et al., 2012). In our case, the knowledge base combines expert opinions with measured data from literature and experiments. The type of decision supported by the system is semi-structured, denoting that the problem is well-defined, but the solutions are open to interpretation. As a result, multiple potential solutions exist for the clearly defined problem (Walling & Vaneeckhaute, 2020).

Developing a clear storyline is crucial when designing a DSS, as it helps define the tool's boundaries (Dong et al., 2013). For Nat4Wat, the storyline begins with a user interested in NBS for water management, whether they are part of an administrative body or an individual with varying levels of expertise. The user inputs information about their water scenario and objectives. They then receive a list of suitable solutions, which they can compare using MCDA. After selecting a solution, the user is provided with relevant information, including knowledge and market cases offered by companies. Finally, they have the option to contact these companies to initiate an implementation project.

The following sections will explore these concepts and steps in greater detail.

2.1 Development process

The development process was organized into a series of steps that combined progress tasks with workshops involving experts and stakeholders to gather feedback on the latest advancements of the tool (**Erreur ! Source du renvoi introuvable.**).

Figure 1. Summary of the development process.

Since Nat4Wat was conceptualized as an evolution of the SNAPP tool (Acuña et al., 2023), the first step in the development process was to perform reverse engineering on the SNAPP tool. We had access to the codebase, which allowed us to examine the algorithms, models, and interface interactions to develop the first draft of the workflow. In parallel, we consulted with tool developers and scientists involved in the SNAPP project to identify the tool's strengths and weaknesses. Using this information, we drafted the Nat4Wat workflow. One key issue identified during meetings with experts was a lack of trust in the tool's data-driven surface estimations.

The primary changes from SNAPP to the first version of the Nat4Wat workflow included a shift in architecture: while SNAPP ran all algorithms on the frontend, Nat4Wat moved them to the backend, allowing it to function both as a web-based tool and a REST API. An MCDA module was also added as a final step, enabling users to compare all suitable options.

These workflows were discussed during the first annual meeting of the MULTISOURCE project. During the workshop, attendees worked in groups of six, reviewing printed versions of the workflow diagrams and noting their feedback. Tool developers were present to listen, answer questions, and clarify doubts. The workshop produced five key outcomes (summarized in Table 1). First, solutions for stormwater management (SWM) were added to the Nat4Wat tool (SNAPP had focused only on WWT) to align with stakeholder interests. Second, surface estimations based on regression models were replaced with a cascade of models to improve credibility. Third, market cases and the companies providing them were incorporated as the final step in the user journey, a recommendation from technology providers who did not want to see the DSS as a competitor. They stressed that users should not proceed directly with construction based solely on the tool's results, their statement was literally that “they cannot start digging after using the tool”. This final step benefited all parties: users gained access to advice on full scale implementation, technology providers received promotional opportunities, and the tool itself gained recognition and improved data accuracy through company-provided information.

Table 1. Summary of feedback received from the workflow discussion.

Topic	Comments	Decision
SWM	The tool only consideredwastewater treatment (WWT) and SWM solutions should be included.	SWM solutions will be added as a separate module, as inputs, data, and models differ from WWT.
Constraints for the receiving environment	Outputs can be influenced by the conditions of the receiving environment.	If user provides target concentrations for the receiving environment along with upstream flow and concentration, the outflow concentration can be calculated using a mass balance.
Water types	Runoff water can be polluted. Campsite and offices wastewater should be added.	Solutions for runoff water must have removal capacity. Campsite: 0.8 people equivalent (PE) ≈ 48 gr/person of DBO Offices: 0.5PE ≈ 30 gr/person of BOD
Models and algorithms	Results being instantaneously synchronized with any change in input parameters (as SNAPP did) is confusing.	Users define one scenario with all available information, which is then used for solution selection and comparison.
Models and algorithms	Data-driven models cannot be always trusted.	Implement the cascade of models (explained below).
Workflow steps	After using the tool, users cannot immediately proceed with construction.	The final output will include real-world implementations by MULTISOURCE companies and others, with contact information.

Based on the feedback from the workshop, we developed a new workflow version, which was validated by the project consortium in an online meeting. Once validated, we began designing wireframes. Some stakeholders found the workflow diagrams too abstract, so the wireframes helped ground the process and provided a second round of feedback before the graphical design phase. The wireframe workshop was held during the second annual MULTISOURCE meeting, following a similar structure. In this case, attendees reviewed printed wireframes. As expected, non-expert stakeholders were more active in this workshop, providing input on the homepage content, user journey (e.g., which inputs should be optional), and what information was useful. Additionally, technical feedback was received, such as adding COD to the list of pollutants and excluding phosphate or pathogens as key parameters for surface estimations, as these were not common practices. All feedback was discussed with the UX designer, who then prepared the mock-ups.

Once the mock-ups were finalized, we began programming the tool. We started with the backend, structured as an independent REST API backed by a *MariaDB* engine database (MariaDB Foundation, 2024). Development used *node.js*, with *Express.js* (OpenJS foundation, 2024) as the server engine, *nodejs-polars* (Vink, 2020) for data manipulation, and *ml-regression-multivariate-linear* (mljs, 2017) and *jstat* (jStat, 2013) for statistical modeling. All dependencies are available in the code repository (https://github.com/icra/nat4wat-api). Once the backend functionalities were in place, we programmed the tool's graphical interface using the *Nuxt* framework (Nuxt Team, 2016).

The first prototype of Nat4Wat was validated during the third annual MULTISOURCE meeting. Attendees were asked to use the tool and answer questions via online forms. NBS experts tested the tool's accuracy by defining known scenarios and checking if the tool returned the expected solutions. Non-experts focused on user-friendliness and their overall experience with the tool. A third form allowed all stakeholders to report bugs or suggest improvements. While the bug report form was highly successful (receiving 55 entries and ongoing feedback), the other two forms received fewer responses. NBS experts preferred discussing accuracy issues directly with developers, and the user experience form garnered only five responses. A key takeaway was that stakeholders preferred discussing issues in person rather than through an online form.

All suggestions and issues, whether submitted in person or via forms, were translated into development tasks and progressively addressed by the developers. As the tool undergoes continuous use by stakeholders, new feedback is received, leading to further improvements.

2.2 Implementation

The Nat4Wat user journey is structured into three steps.

1) First, the user is prompted to input information about their water requirements and objectives.
2) Then, all suitable options are displayed with details about their capabilities, estimated surface area, and construction costs. The user can select all the solutions or a subset to compare using a MCDA.
3) Based on the MCDA results, the user chooses the most appropriate solution and is provided with further information about the selected option, including, again, its capabilities, estimated surface area and construction costs, but also relevant reports, scientific papers, and any available market cases related to the selected alternative. At the core of this process is Nat4Wat's knowledge base.

2.2.1 Knowledge base

Nat4Wat's knowledge base is organized as a relational database with four tables. The first table contains a catalogue of NBS included in the tool, with expert-based knowledge regarding 53 variables related to treatment performance, stormwater management (SWM) capacity, ecosystem services provided, operational requirements, construction costs, and the types of water each solution can handle. This table is used by the algorithms responsible for selecting suitable options and calculating the MCDA. Ecosystem services and operational constraints are provided as a qualitative scale from 0 (none) to 3 (high).

The second table contains metadata of scientific publications related to the NBS in the catalogue, primarily serving to help users retrieve the relevant scientific papers about the selected solution. The third table holds data on NBS for wastewater treatment (WWT) collected from both scientific and grey literature, including information on surface area, hydraulic loading rate, and pollutant concentrations at the inflow and outflow. This data is used to fit regression models for surface estimation and to validate expert opinions provided in the catalogue. While both tables were originally compiled through a literature review, users can contribute with new records.

The fourth table contains market cases uploaded by companies. This includes a description, a picture, and details on the surface area, location, construction and operational costs, and the year of construction. This table is used to provide users with real-world examples of NBS and information about the companies responsible for implementing them.

Any records provided by users or companies are published only after undergoing a peer-review process by experts in NBS for WWT and SWM. Further information on the development and validation of the knowledge base can be found in Deliverable 4.2.

2.2.2 Scenario definition

In this step, the user is asked to enter all the available data for their case. However, the only mandatory field is the water type. Based on the water type, the scenario definition can take one of three paths: wastewater treatment, stormwater management, or combined sewer overflow (CSO) discharge treatment. Each of these paths follows a different method for estimating surface area. If the user only specifies the water type, all solutions capable of handling that type of water are marked as suitable, but no information about the surface area or construction costs is provided.

In addition to these three paths (which will be explained in detail in the following sections), there are generic inputs that apply to all solutions and are used to filter out unsuitable solutions. The selection of solutions is based on Table 1, which summarizes consensus on expert opinions for each technology. The user's inputs are compared with the attributes of each technology, and technologies that do not meet one of the criteria are excluded. The available inputs include: only household building solutions, energy requirements, include vertical solutions, co-benefits (or ecosystem services) provided, and operational constraints. For example, if the user selects "include vertical solutions," vertical solutions like green walls are included in the selection, though this does not exclude horizontal technologies. If "household building solutions" is selected, larger-scale solutions such as detention basins or ponds are excluded. However, if this option is not selected, no technologies are rejected. When the user provides input for an ecosystem service, only technologies with an equal or higher score for that service are selected. For example, if a user selects level 2 for temperature regulation, only technologies with scores of 2 or 3 in temperature regulation are selected. Similarly, when an operational constraint is specified (such as required manpower, required skills, or biohazard risks), technologies with higher scores than the user's input are rejected. For example, if the user selects level 2 for required skills, only technologies with scores of 0, 1, or 2 are selected. If the user indicates that energy is required, all technologies that rely on electrical energy are selected. Conversely, if energy is not required, all such technologies are excluded. By default, all technologies, regardless of their energy requirements, are selected.

For NBS in WWT, solutions can also be filtered based on the pollutants they remove. In this case, BOD, COD, TN, and NH_4 have associated removal percentages, while NO_3, PO_4^{3-}, and pathogens (*E. coli* and Helminth eggs) are binary variables. For BOD, COD, TN, and NH_4, if these pollutants are selected, any technology with a removal percentage lower than the user's required performance (default is 80%) is excluded. However, if the user specifies both input and output (or target) concentrations, the required removal percentage is calculated, and technologies are filtered accordingly. For example, if an aerated treatment wetland has a TN removal rate of 60%, it would be excluded if the user only selects TN in the list of pollutants of interest. However, if the user also specifies an input concentration of 20 mg/L and a target concentration of 10 mg/L, the aerated treatment wetland would be selected since the required removal percentage is 50%, which it can satisfy. For NO_3, PO_4^{3-}, and pathogens, any technology that is inactive for the selected pollutants is rejected.

For SWM solutions, the user can also reject technologies that do not provide infiltration into the ground.

2.2.3 Surface estimation for wastewater treatment technologies

The method used to estimate the surface area for a WWT solution depends on two factors: the information provided by the user about water requirements and the information available in the knowledge base for that solution (purple and pink colours, respectively, in Figure 2). The cascade of models was implemented to improve the credibility of surface estimates, as suggested by stakeholders.

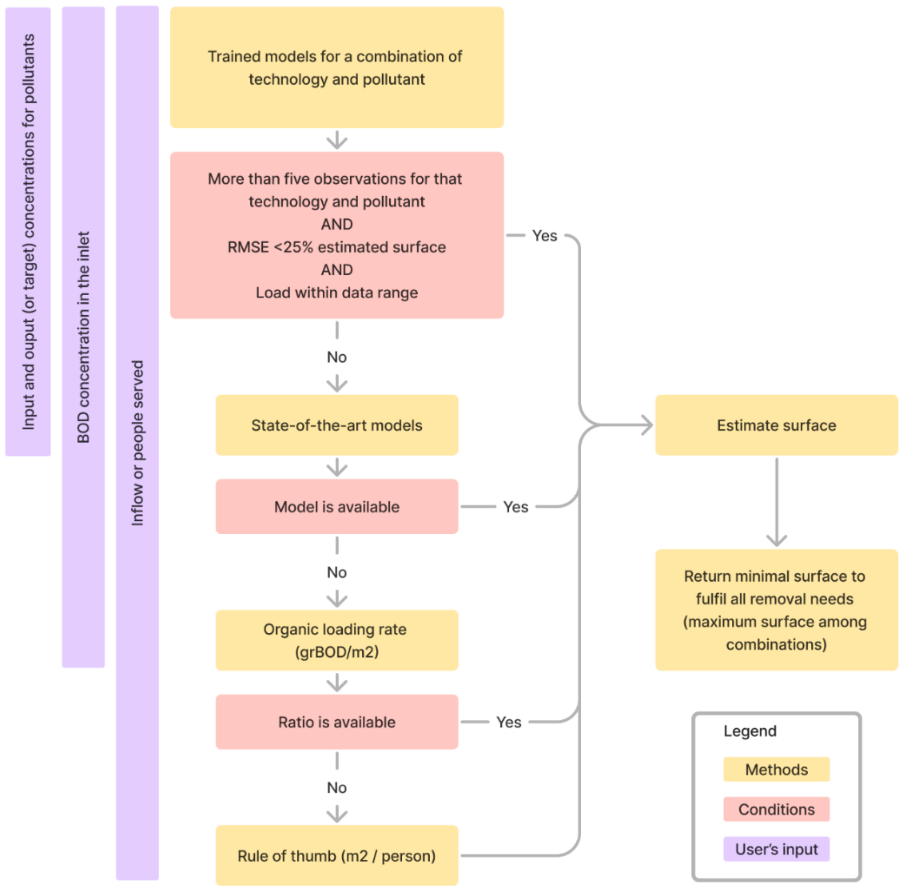


Figure 2. Diagram of the cascade of models used to estimate the surface for WWT solutions.

The first step in the cascade consists of regression models. For each combination of solution and pollutant, three regression models (linear, exponential, and power) were fitted if more than five observations were available. The surface area was isolated from these regression models to facilitate predictions:

Linear model: $$L_o = L_i - \beta S + \varepsilon \rightarrow S = \beta(L_i - L_o) + \varepsilon \qquad \text{(eq. 1)}$$

Exponential model: $$L_o = L_i e^{-\beta S} + \varepsilon \rightarrow S = \beta ln(\frac{L_i}{L_o}) + \varepsilon \qquad \text{(eq. 2)}$$

Power model: $$L_o = L_i - \alpha S^{\beta} + \varepsilon \rightarrow \log_{10} S = \alpha + \beta \log_{10}(L_i - L_o) + \varepsilon \qquad \text{(eq. 3)}$$

Where L_o and L_i represent pollutant loads in the outflow and inflow, respectively, S is the surface area, α and β are regression parameters, and ε is an error term.

If the user provides input and output concentrations for more than one pollutant, the surface returned is the minimal area needed to meet all removal requirements (i.e., the maximum surface among the pollutants used in the estimation).

Note that the linear and exponential models (eq. 1 and eq. 2) have no intercept (i.e., zero removal = zero surface), while the power model includes an intercept. In the power model, β can adopt negative values, which are not mechanistically feasible. Therefore, any power models with negative β values were discarded. After fitting the models, we calculated the Relative Median Absolute Error (RMAE) for each, using the median instead of the mean to make the errors more robust to outliers. Relative errors were used instead of absolute errors for better interpretation by end users. For example, a 2 m^2 absolute error represents a 50% error for a 4 m^2 NBS but only a 5% error for a 40 m^2 NBS. The model with the lowest

RMAE was chosen. If the RMAE was lower than 25%, the model was deemed suitable for predicting the surface of new technologies. However, the model is only applied when the user's input falls within the range of the model's training data, with a tolerance of 25%. For instance, if the BOD loads for a horizontal flow green wall ranged between 10 and 30 grams of BOD per day, and the user's input was below 7.5 or above 37.5, the model would not be used, and the next step in the cascade would be applied. Uncertainty is a relevant issue in DSS (de Kort & Booij, 2007), especially in relation to results credibility (Walling & Vaneeckhaute, 2020). Therefore, we opted to be conservative and surface estimates are presented as ranges representing the 95% confidence interval of the prediction.

If no suitable regression models are available, mechanistic models are used. Currently, the only available mechanistic model is the Tank-in-Series model (Kadlec & Wallace, 2008), which applies to solutions with horizontal subsurface flow (constructed wetlands and green walls). Detailed information on the equations and parameters of this model can be found in the Nat4Wat guidelines (https://nat4wat-api.icradev.cat/reference_manual.html#tank-in-series-model).

If neither regression nor mechanistic models are applicable, or if the user only enters inflow concentrations for BOD without specifying target concentrations, the organic loading rate is used. This rate defines the amount of organic matter (in grams of BOD per day) that a technology can handle. Based on consensual expert opinions, values were defined for each solution across four climate zones classified by the Köppen system (tropical, dry, temperate, and continental). Users can also provide the average temperature of the coldest month in their area to help classify the climate. In terms of organic loading rate, no differences are made between tropical and dry climates.

If the user provides only inflow data or specifies the number of people served, or if none of the previous methods are available, surface estimation relies on the rule of thumb. This rule, based on expert opinions, defines the area required per person equivalent (PE), equaling 1 PE to 60 g of BOD per day. The PE is calculated according to the number of people served and the type of wastewater. **Erreur ! Source du renvoi introuvable.** presents the equivalencies between people served and PE for various wastewater types. For example, 10 people served by a technology treating greywater is equivalent to 3.3 PE. If the user inputs inflow rather than the number of people served, the PE is calculated using the liters per person per day for each type of water, as shown in **Erreur ! Source du renvoi introuvable.** As with the organic loading rate, the rule of thumb is applied for the same four climate zones.

Table 2. Characterization of water types.

Water type	People equivalent	g BOD/day	Litres/person/day
Any wastewater	1	60	120
Raw domestic wastewater	1	60	120
Greywater	0.33	20	100
Secondary treated wastewater	0.05	3	120
Pretreated domestic wastewater	0.80	48	120
River diluted wastewater	0.05	3	120
Camping wastewater	0.80	48	120

Users can request target concentrations for the outflow or receiving environment. In the case of receiving environment targets, a mass balance is used to calculate downstream concentrations based on the load in the outflow and upstream data. The user must provide upstream flow rates and concentrations for each pollutant they are interested in.

Any model, aside from regression models, includes uncertainty measures. To increase the credibility of the results, estimated values are presented as a range of ±25%, a value agreed upon by the experts.

2.2.4 Surface estimation for stormwater solutions

To estimate the surface area for SWM solutions, the DSS employs a simplified volume balance equation. This simplification assumes that the solutions have a uniform storage layer and that rainfall is constant throughout the event. The model was simplified to make user input easier and to increase transparency (Walling & Vaneeckhaute, 2020). We departed from the volume that a solution can store accounting for the infiltration and a potential drainage as follows:

$$V = A(\phi K_t t_1 + K_s t_2) + Q_d t_2$$

if $K_t t <= H$, then $t_1 = t$ and $t_2 = 0$

otherwise, $t1 = H/K_t$ and $t_2 = t - t_1$ (eq. 4)

Where V is volume at the time t that the technology can retain or infiltrate (m3); A is surface of the technology (m^2); K_t is hydraulic conductivity of the solutions' layers (m/s), when the technology stores water in a superficial layer, this is assumed as 10 m/s; K_s is hydraulic conductivity of the receiving soil (m/s); t is: duration of the rain event (s); ϕ is the porosity of the solution (m^3/m^3); H is the height (or depth) of the solution (m); Q_d is the flow of the drainage pipe (m^3/s); t_1 is the time spent for water to arrive to the bottom of the solution (i.e. time to be filled); and t_2 is the time since the technology was filled by water. (eq. 4 assumes that infiltration into the ground and drainage begin once the solution's layers are filled. If the solution is sealed or lacks drainage, K_s and Q_d are set to zero.

Using (eq. 4, the surface area of the solution can be estimated as follows:

$$A = \frac{V - Q_d t_2}{\phi K_t t_1 + K_s t_2} \quad \text{(eq. 5)}$$

Where V can be approximated as a function of rainfall and catchment area:

$$V = \frac{r_{cum(t)} A_c}{1000} \quad \text{(eq. 6)}$$

Where $r_{cum(t)}$ is the accumulated rainfall at time t (mm) and A_c is the catchment area draining to the solution (m^2).

From (eq. 5, Q_d is calculated as the pipe section (A) multiplied by water velocity (v), which can be estimated by the Manning equation (Manning, 1891):

$$Q_d = A \frac{1}{n} \left(\frac{A}{P}\right)^{2/3} S^{1/2} \quad \text{(eq. 7)}$$

Where A is the section of the pipe (m^2), n is the roughness coefficient of the pipe material (default: 0.0011), P is the perimeter of the pipe (m), and S is the slope of the pipe (default: 3%). The user can provide pipe diameter; if not provided, it is assumed there is no drainage pipe.

For the hydraulic conductivity of the receiving soil (K_s), i.e. the soil were the solution is built on, the user can input a value directly (in mm/hour) or specify the soil type, which is converted into a conductivity value according to **Erreur ! Source du renvoi introuvable.** (Rawls et al., 1982).

The output of this method includes the surface area required to retain or infiltrate the specified volume and the daily volume that the solution can manage. If the user provides the available area, the tool calculates the surface area required to manage the reported volume, regardless of the available area. It also reports the maximum volume that can be retained or infiltrated by the solution within the available area. If the required surface is smaller than the available area, the maximum volume is equal to the reported volume. A flag indicates when the available area exceeds the surface needed to handle the reported flow.

Table 3. Characterization of soils (Rawls et al., 1982)

Type of soil	Hydraulic conductivity (mm/hour)
Sand	209
Loamy sand	61
Sandy loam	26
Loam	13
Silt loam	6.8
Sandy clay loam	4.3
Clay loam	2.3
Silty clay loam	1.5
Sandy clay	1.3
Silty clay	1
Clay	0.5

To account for uncertainty, ranges were collected instead of single values for ϕ and Kt (eq. 5). The upper and lower bounds of the surface area are calculated using the high and low values of these parameters.

2.2.5 Surface estimation for CSO discharge water

The method used to estimate the surface area for solutions dealing with CSO discharges relies on the yearly hydraulic loading ratio (HLR), which experts identified as more reliable than the first flush capture method (Masi et al., 2023). The surface area is calculated as follows:

$$S = \frac{V_s}{HLR} \qquad \text{(eq. 8)}$$

Where V_s is the volume discharged per year (m^3/year) and *HLR* is the hydraulic loading rate of the solution ($m^2m^{-2}year^{-1}$).

Estimating the volume discharged per year can be challenging. However, it is expected that users interested in CSO discharge solutions, such as sewage managers, will have sufficient expertise in estimating or obtaining this parameter. As with SWM solutions, HLR values were collected as a range to account for uncertainty.

2.2.6 Multicriteria decision analysis

At this step, the user is presented with a list of all suitable solutions based on their water scenario (i.e. the inputs they provided). If sufficient context is available, each solution includes information about the required surface area and estimated construction costs. To calculate construction costs, we collected data from expert opinions and the literature, expressed as a range of €/m^2. The upper bound of this range is multiplied by the upper bound of the surface area, and the lower bound of the cost is multiplied by the lower bound of the surface area. This provides the user with a range of expected construction costs.

In the graphical interface, solutions are displayed as cards, each containing the solution name, an illustration, and a button that opens a window with more detailed information. This includes the estimated surface area, construction costs, ecosystem services provided, and operational constraints. For

WWT solutions, it also specifies which pollutants the technology can remove. For SWM solutions, the information includes whether the solution provides infiltration into the ground, storage capacity (i.e. porosity), and hydraulic conductivity. In both cases, there are links to view relevant scientific publications and market cases (Figure 3).

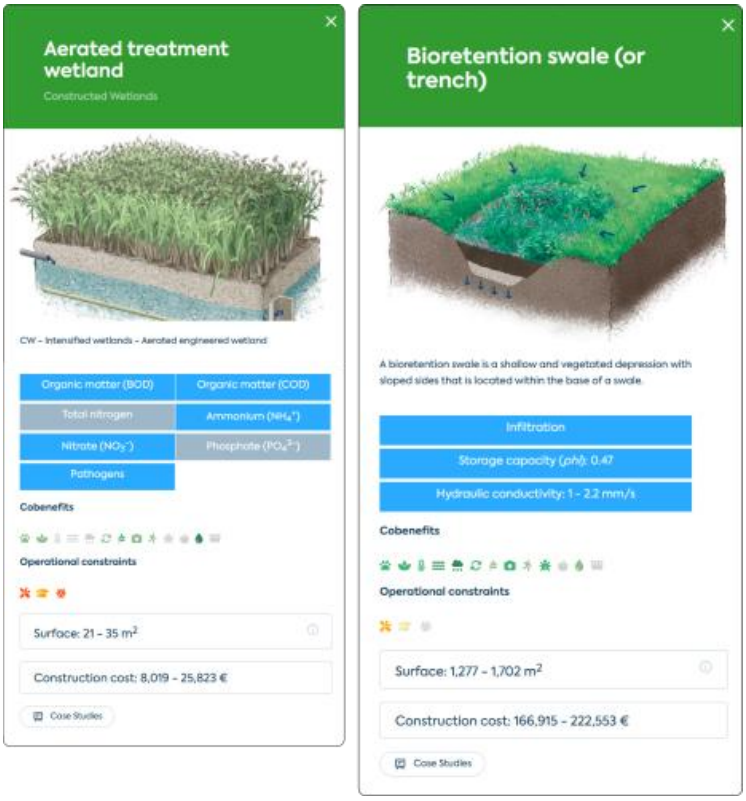


Figure 3. Examples of solution cards in the graphical interface.

To increase transparency and avoid the perception of a "black box" (Reiter et al., 2018), the system allows users to view a table listing all solutions and the reasons why any were excluded. This feature was requested by experts in the validation workshop, who had difficulty understanding some of the DSS results.

Regarding the MCDA, the first version of Nat4Wat used five criteria: environmental impact, multifunctionality, construction costs, operational requirements, and space requirements. However, stakeholders commented that these criteria were too generic, especially multifunctionality. As a result, the criteria were expanded to eight: biodiversity, circularity, social benefits, removal performance, environmental impact, construction costs, operational requirements, and space requirements. We defined the method for calculating each criterion based on the variables included in the knowledge base, which was primarily inherited from the SNAPP tool (Acuña et al., 2023).

Environmental impact (EI). Calculated as a combination of energy use, eutrophication risks (from ammonium, nitrates, and phosphates), and climate change mitigation (due to carbon sequestration):

$$EI = \frac{(1 - e) + 2r_{NH_4} + r_{NO_3} + r_{PO_4^3} + \frac{cs + r_{CSO}}{3}}{7} \quad \text{(eq. 9)}$$

Where *EI* is environmental impact ($\epsilon[0,1]$ with 1 representing the lowest impact); *e* is energy use ($\epsilon\{0,1\}$); *r* represents the removal capacities of the solution for ammonium, nitrates, and phosphates ($\epsilon\{0,1\}$); and *cs* and r_{CSO} are the carbon sequestration capacity and CSO mitigation potential ($\epsilon[0,3]$).

Biodiversity (B). Considers the solution's ability to enhance biodiversity by supporting flora, fauna and pollinators:

$$B = \frac{B_{flora} + B_{fauna} + H_{pollinators}}{9} \quad \text{(eq. 10)}$$

Where *B* is biodiversity enhancement ($\epsilon[0,1]$), B_{flora} and B_{fauna} represent the solution's capacity to support plant and animal diversity, and $H_{pollinators}$ represents the solution's support for pollinators. All in a qualitative scale ($\epsilon[0,3]$).

Space requirements. The surface area required for the solution, normalized by dividing the surface of each technology by that of the solution requiring the least space. This ensures that the most space-efficient solution receives a score of 1, while others receive a score between 0 and 1. If the scenario provides enough information to estimate the surface area, the estimated mean surface is used. Otherwise, for WWT solutions, the rule of thumb ratio is applied; for SWM solutions, the porosity is multiplied by the depth; and for CSO discharge solutions, the hydraulic loading rate (HLR) is used.

Social benefits (SB). The benefits people obtain from the solution. Calculated from the aesthetic value, recreational function (reduced if biohazard risks exist), temperature regulation, and flood mitigation:

$$SB = \frac{av + \frac{rf(3 - br)}{3} + tr + fm}{12} \quad \text{(eq. 11)}$$

Where *SB* is the social benefits score ($\epsilon[0,1]$); *av* is the aesthetic value ($\epsilon[0,3]$), *rf* is recreational function ($\epsilon[0,3]$), *tr* is the temperature regulation ($\epsilon[0,3]$), *fm* is flood mitigation ($\epsilon[0,3]$) and *br* is biohazard risk ($\epsilon[0,3]$).

Circularity (C). Reflects the solution's potential for water reuse and material circularity, calculated as:

$$C = \frac{(1 - lf)(pr + r_{BOD})}{2} + \frac{bsp + bmp + fp}{9} \quad \text{(eq. 12)}$$

Where *C* is the circularity score ($\epsilon[0,1]$); *lf* is flowrate loss ($\epsilon[0,1]$); *pr* is pathogens reduction ($\epsilon\{0,1\}$); r_{BOD} is BOD removal performance ($\epsilon[0,1]$); *bsp*, *bmp* and *fp* are the scores for biosolids, biomass, and food production, respectively ($\epsilon[0,3]$).

Operation and maintenance (OM). Calculated based on required manpower, skills, biohazard risks, and energy requirements:

$$OM = 1 - \frac{mp + sk + br + e}{10} \quad \text{(eq. 13)}$$

Where *OM* is the operation and maintenance score ($\epsilon\{0,1\}$ with 1 representing the lowest operation and manteinance); *mp* is required manpower ($\epsilon[0,3]$); *sk* is required skills level ($\epsilon[0,3]$); *br* is biohazard risk ($\epsilon[0,3]$); and *e* indicates if energy is required to operate the solution ($\epsilon\{0,1\}$).

Construction costs. Normalized similarly to the space requirement criterion. If insufficient information is available to estimate costs, default values are used for various scenarios (e.g., 100 people served in a temperate climate for WWT solutions).

Removal performance (RP). Applied only to WWT solutions, calculated based on the removal capacities of various pollutants:

$$RP = \frac{r_{BOD} + r_{COD} + r_{TN} + r_{NH_4} + r_{NO_3} + r_{PO_4^3} + r_P}{7} \quad \text{(eq. 14)}$$

Where RP is the removal performance score ($\epsilon[0,1]$); r_{BOD} is the removal performance in BOD ($\epsilon[0,1]$); r_{COD} is the removal performance in COD ($\epsilon[0,1]$); r_{TN} is the removal performance in total nitrogen ($\epsilon[0,1]$); r_{NH4} is the removal performance in ammonia ($\epsilon[0,1]$); r_{NO3} express the capacity to remove nitrates ($\epsilon\{0,1\}$); r_{PO43} express the capacity to remove phosphates ($\epsilon\{0,1\}$); and r_P express the capacity to reduce pathogens (*E.coli* and Helminth eggs) ($\epsilon\{0,1\}$).

2.2.7 Weighting method for MCDA

Research indicates that complex methods for assigning weights in MCDA, such as the analytical hierarchy process (AHP), can cause users to lose trust in the system (Bojórquez-Tapia et al., 2005). To balance transparency, simplicity, and robustness, Nat4Wat uses the sum weighted method (Ren et al., 2017). Users can assign a weight to each criterion using a 5-point Likert scale, from "Not important at all" to "Very important." The weights are then normalized to proportions:

$$p_{wc} = \frac{w_c}{\sum w} \quad \text{(eq. 15)}$$

Where p_{wc} is the proportion ($\epsilon[0,1]$) of the weight for criterion c; w_c is the weight ($\epsilon[0,5]$) and Σw is the sum of the weights of all criteria.

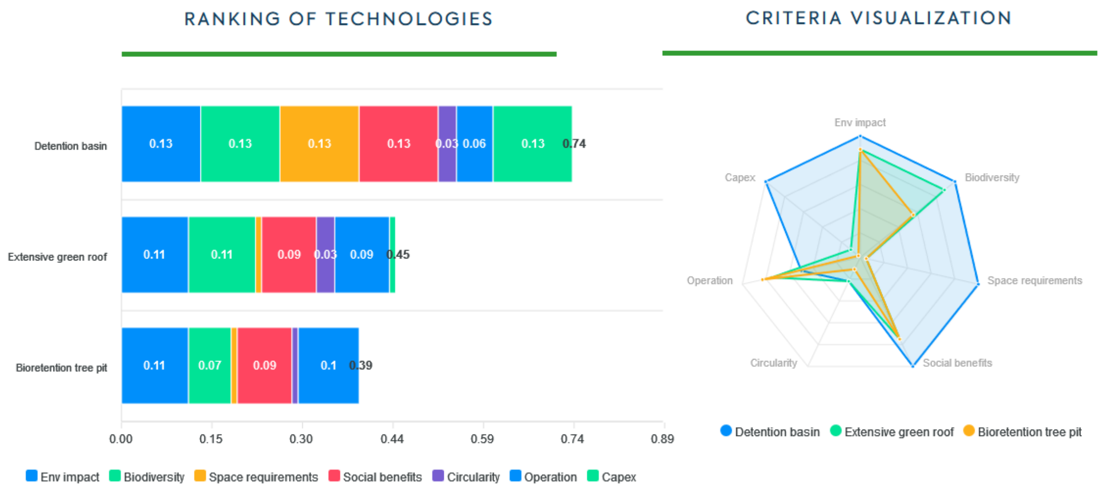


Figure 4. Screenshots of the graphical results of the MCDA provided by Nat4Wat.

Using the sum weighted method, each solution is given a score ($\epsilon[0,1]$), with the highest score representing the optimal solution. The user can view the results as a ranked list or as individual scores for each solution (Figure 4), and it is ultimately up to the user whether to select the highest-ranked solution.

2.2.8 Knowledge of the selected solution

Once the user selects a solution from the MCDA results, the tool presents all the relevant knowledge about that solution, organized into three sections: General Information, Scientific Publications, and Market Cases.

In the **General Information** section, the user sees the same information presented on the solution card from the previous step, along with additional reports and static documents that provide useful insights. These may include deliverables from the MULTISOURCE project, grey literature, or design guidelines.

In the **Scientific Publications** section, users can access a list of scientific papers focused on the selected solution. For WWT solutions, this section also includes data on treatment performance extracted from scientific publications.

The **Market Cases** section displays real-world examples of the selected solution, uploaded by companies. Each case provides a description of the project, the year and location of construction, as well as information on the surface area, construction and operational costs, and the number of people served (in the case of WWT). It also includes a link to the company's website. Each market case is linked to the company that submitted it, allowing users to contact companies with expertise in the recommended solution to initiate an implementation project.

This feature, suggested by companies within the MULTISOURCE consortium, enhances Nat4Wat's potential to be recognized in the market as a valuable product (Walling & Vaneeckhaute, 2020).

2.3 Operation

Nat4Wat offers two interfaces for interacting with the tool: a web-based graphical interface and a REST API. The graphical interface, located at https://nat4wat.icra.cat, is freely accessible. Users can browse all read-only pages without registration. However, pages requiring database modifications, such as creating a scenario to find solutions, or uploading market cases or scientific publications, require the user to register. The registration process only requires an email, password, and name. Companies also need to provide contact details, a description, and a logo, which are displayed with the market cases they upload.

The homepage includes two introductory videos—one about the tool and another on the concept of nature-based solutions for WWT and SWM. The main menu option, "Find your solution," initiates the process of creating a scenario to find the most appropriate solution for the user's needs. Other menu options serve as shortcuts to various steps in the user journey, including the list of all solutions, scientific publications, and market cases. Additional links to the tool's guidelines and FAQs complement the menu. Currently, a "test session" link allows users to report bugs and provide feedback on the tool. In future versions, this will be replaced by a helpdesk with a contact form to reach the tool's support team.

Users with coding skills can also interact with the tool's functionalities via a REST API, which adheres to REST architecture principles. A REST API uses HTTP requests to access data and algorithms. Users can freely use the API to find suitable NBS and run MCDA on those solutions, but authentication tokens are required to upload data, such as new scientific publications. The API does not organize user workflows into scenarios, leaving it up to the user to structure their requests and pipelines.

The API offers two GET endpoints: one to retrieve the list of solutions and the other for scientific publications. For finding and comparing solutions, two POST endpoints are available. The first endpoint (*/find-nbs*) expects inputs defining the scenario (i.e., water requirements and user goals) and returns a list of suitable solutions with estimated surface area and construction costs. The result from this endpoint can be passed to the second endpoint (*/mcda*), along with optional weights for the MCDA criteria. This returns the same list of solutions but with added raw and weighted scores. Between these steps, users can opt to remove some solutions from the list of suitable options. Documentation for interacting with the Nat4Wat API is available at https://nat4wat-api.icradev.cat/.

3. Dissemination strategy

The dissemination strategy has been designed in collaboration with Water Europe, leaders of Work Package 7 about communication, clustering and dissemination. The final goals of the strategy are:

- Increase the number of users of the tool.
- Increase the number of companies providing market cases.
- Increase the number of experts providing scientific publications.

The actors identified as potential multipliers of the dissemination campaign are:

- International Water Association
- NetworkNature
- ICLEI
- Water Europe

The planned activities are detailed in Table 4.

Table 4. Planned activities of the dissemination strategy

Activity	Responsible	Timeline
Elaborating a carousel explaining the added value of the tool and its main features.	WE	M43
Extensive campaign in social media networks, mainly LinkedIn.	WE	M43 – M48
Adding a new page on the MULTISOURCE website	WE	M43
Elaborating a "Call to action" flyer with a QR code to the tool	WE	M43
Direct mailing and bilateral meetings with companies	WE, ICRA	M43 – M48
Nat4Wat ambassadors in conferences adding a final slide in the communications presenting the tool and a QR code.	WE, ICRA	M43 – M48
Webinar introducing the tool and its use	WE, ICRA	M45
Disseminating the webinar recording in social media networks	WE	M46 – M48
In-situ demonstration at physical events	WE, ICRA	M43 – M48

In order to ensure that the advisory outcomes of the tool are grounded in real and credible information, a structured pathway for the inclusion of new data and market cases has been established. Companies will be able to contribute by registering in the platform and uploading their cases through a standardized form included in the tool for users registered as companies, which requires key details such as location, climate zone, design parameters, and costs. All new entries, whether scientific datasets, literature references, or market cases, will undergo a peer-review process by experts in NBS for WWT and SWM before publication, ensuring that only high-quality and reliable content becomes visible in the tool.

To motivate companies and broaden the coverage of technologies, Nat4Wat offers visibility benefits: each accepted case is published with the company's logo, description, and website link, and companies can be directly contacted by users interested in implementation. In addition, targeted bilateral meetings, webinars, and calls to action will be complemented by collaboration with NbS technology provider networks and associations (e.g. Water Europe NBS Cluster, IWA Specialist Group, Global Wetland Technology, NetworkNature, ICLE) to invite their members to showcase their solutions.

To strengthen the local and regional dimension of the tool, market cases include location, enabling users to identify technologies relevant to their specific contexts. Future developments will enhance filtering and visualization options to make regional applicability even clearer. Moreover, categories will be progressively extended to include references to applicable standards and norms (e.g. ISO, EU directives, national or regional guidelines), ensuring alignment with regulatory frameworks and reinforcing the credibility of the advisory outcome.

Two ambassadors from ICRA were present in the 18th International Conference of Wetlands Systems, organized by IWA in Martinque, France (25 – 29 November). The ambassadors also added a last slide in their communications presented (Figure 5). There was also an in-situ demonstration using a video tutorial (https://youtu.be/gzMwcVMiSys) played in loop in a screen.

Figure 5. Slide added at the end of the communication made by Nat4Wat ambassadors.

Finally, Nat4Wat tool was also presented in the last WETPOL 2025 conference: *Swipe right on your wetland: decision-support made simple with Nat4Wat*. Pueyo-Ros, J., Mendoza, E., Buttiglieri, G. and Comas, J.

4. Conclusions

The Nat4Wat decision-support system (DSS) provides a comprehensive and user-friendly tool for selecting and comparing NBS for urban water management. By integrating multicriteria decision analysis (MCDA), the tool assists decision-makers in navigating the complex trade-offs among various NBS options, ensuring that solutions are both environmentally sustainable and context-appropriate. Nat4Wat aims at guiding users in making informed decisions that balance technical, economic, and social factors. Furthermore, the tool fosters transparency and stakeholder participation, key elements for the successful implementation of decentralized water management systems. As urban water challenges intensify, tools like Nat4Wat are crucial in promoting more resilient, distributed, and sustainable water infrastructures.

The continuous inclusion of peer-reviewed, place-based, and standards-aligned market cases, together with the involvement of technology provider networks, will ensure that Nat4Wat evolves as a credible and widely used decision-support system for NBS.

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The overall goal of MULTISOURCE is to, together with local, national, and international stakeholders, demonstrate a variety of about Enhanced Natural Treatment Solutions (ENTS) treating a wide range of urban waters and to develop innovative tools, methods, and business models that support citywide planning and long-term operations and maintenance of nature-based solutions for water treatment, storage, and reuse in urban areas worldwide. The project includes seven pilots treating a wide range of urban waters. Two individual municipalities (Girona, Spain; Oslo, Norway), two metropolitan municipalities (Lyon, France; Milan, Italy), and international partners in Brazil, Vietnam, and the USA will contribute to each of the main project activities: ENTS pilots, risk assessment, business models, technology selection, and the MULTISOURCE Planning Platform. The use of urban archetypes in the Planning Platform will enable users to quickly classify regions (in both developed or developing countries) suitable for the application of nature-based solutions for water treatment (NBSWT) and compare scenarios both with and without NBSWT.

MULTISOURCE
enhanced natural treatment solutions

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