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RECUPERANDO ECOSISTEMAS URBANOS

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Tailor-made nature-based solutions assessment systems for INTERLACE cities

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Contents

Executive Summary

This INTERLACE project deliverable presents the tailor-made assessments systems for restorative nature-based solutions (NBS) resulting from the implementation of the INTERLACE Pilot Assessment Framework in the six INTERLACE cities: Metropolia Krakovska, el Corredor Biológico Interurbano María Aguilar (CBIMA), Granollers, Portoviejo, Envigado and Chemnitz. The development of tailored assessment systems has gone through an AGILE development process.

The INTERLACE Pilot Assessment Framework is a step-wise, modular and hierarchical assessment framework with flexibility to be tailored to specific needs for evaluating restorative NBS, in a specific context, in line with the city-specific planning cycle, and across different spatial scales (from site to regional scale). It now consists of seven core modules (each of them consisting of several sub-modules). The different modules can be stepwise combined into a tailor-made assessment framework.

Background

In recent years, the rapid transformation of cities has presented numerous challenges across multiple dimensions. The increase in population density, resource demands, and greenhouse gas emissions has given rise to various environmental and social issues. In response to this situation, plenty of works have remarked on the significance of Nature-Based Solutions (NBS) in comprehensively addressing urban challenges and advancing sustainability. NBS, as outlined in the literature, refers to strategies that predominantly leverage the inherent capabilities of nature and its processes to address challenges encompassing social, economic, and environmental domains within urban regions. These solutions integrate natural elements and processes into urban environments, such as green infrastructure, urban forests, and green spaces, to yield various benefits, including climate change mitigation, biodiversity conservation, and enhanced human well-being (Kabisch et al., 2017).

This scientific-technical report explains the implementation of the INTERLACE pilot assessment framework for restorative nature-based solutions (NBS) in the six INTERLACE cities, in completion of Task 3.3 of Work Package 3 (*WP3: Tools for the assessment of restorative NBS*). This deliverable is a confidential document and it aims to be a demonstrator. It presents the second stage of a three-staged process shown in Figure 1. The primary objective of this report is to co-produce and test the INTERLACE pilot assessment framework by developing city-tailored assessment systems for restorative NBS. This process is still ongoing as only two cities have finished implementing their assessment systems, i.e. Metropolia Krakovska and CBIMA. Therefore, the results presented here should be considered as preliminary as four assessment systems are still being developed.

In addition, this report will create a foundation for the development of a generalised assessment framework for restorative NBS, which will be developed over the course of the project and to which the experiences from the INTERLACE case studies in implementing this pilot framework will contribute.

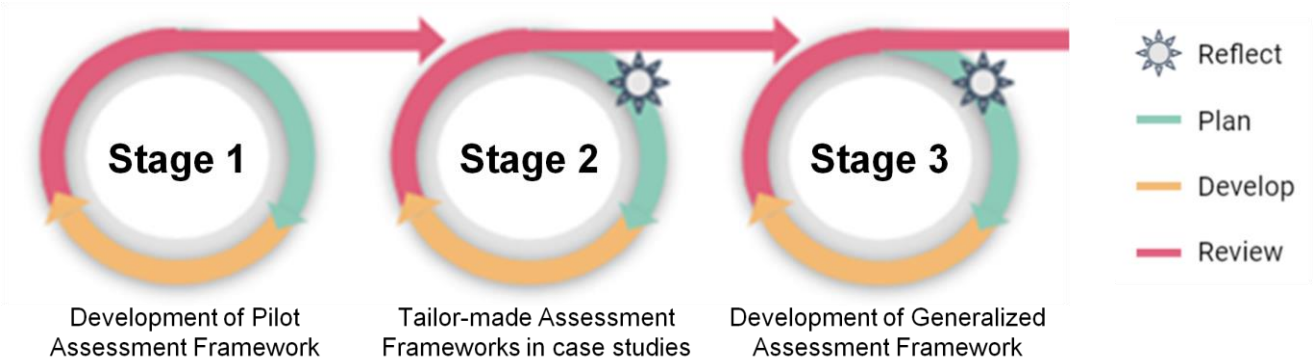


Figure 1. Development stages of the INTERLACE NBS Assessment Framework following an AGILE approach.
Each stage embeds several smaller feedback loops not demonstrated here.

1. Implementation of the INTERLACE Assessment Framework

The INTERLANCE assessment framework is based on a participatory assessment of nature-based urban solutions (NBS), encompassing stages from formulation to result analysis. By tailoring the process to municipality dynamics and involving various stakeholders, the assessment framework is effective in addressing the specific objectives regarding NBS. To tackle the intricate challenges of urban changes driven by environmental concerns and diverse stakeholder interests, the project adopts the Multi-Criteria Decision Analysis (MCDA) theory (see Del. 3.2).

The INTERLACE Pilot Assessment Framework has been re-adapted as a result of the demands expressed through the co-creation process with different stakeholders to ensure its easy uptake as well as making it user-friendly and understandable. It now consists of six single modules (Figure 2), which constitute tier one of the assessment framework. Some modules have a second and third tiers (see Figure 3). The modular approach of the assessment framework supports cities in creating tailor-made assessment systems in different situations based on their needs, while relying on the same general foundations. The assessment framework has three different entry points depending on the specific needs of the city regarding NBS: i) to spatially prioritize the places to implement NBS based on a vulnerability analysis; ii) to design NBS and iii) to monitor already existing NBS. Each of these three entry points correspond to one of the selectable core modules seen in Figure 2. Therefore, each city has implemented the three basic modules and one of the selectable modules resulting into a tailor-made assessment framework. Metropolia Krakovska and CBIMA have spatially prioritise the places to implement NBS; Granollers and Portoviejo have established assessment systems to design NBS; and Envigado and Chemnitz need to monitor already existing NBS. They have also the opportunity to implement the complementary module on financial mechanisms. In the following section we describe each of the modules in detail.

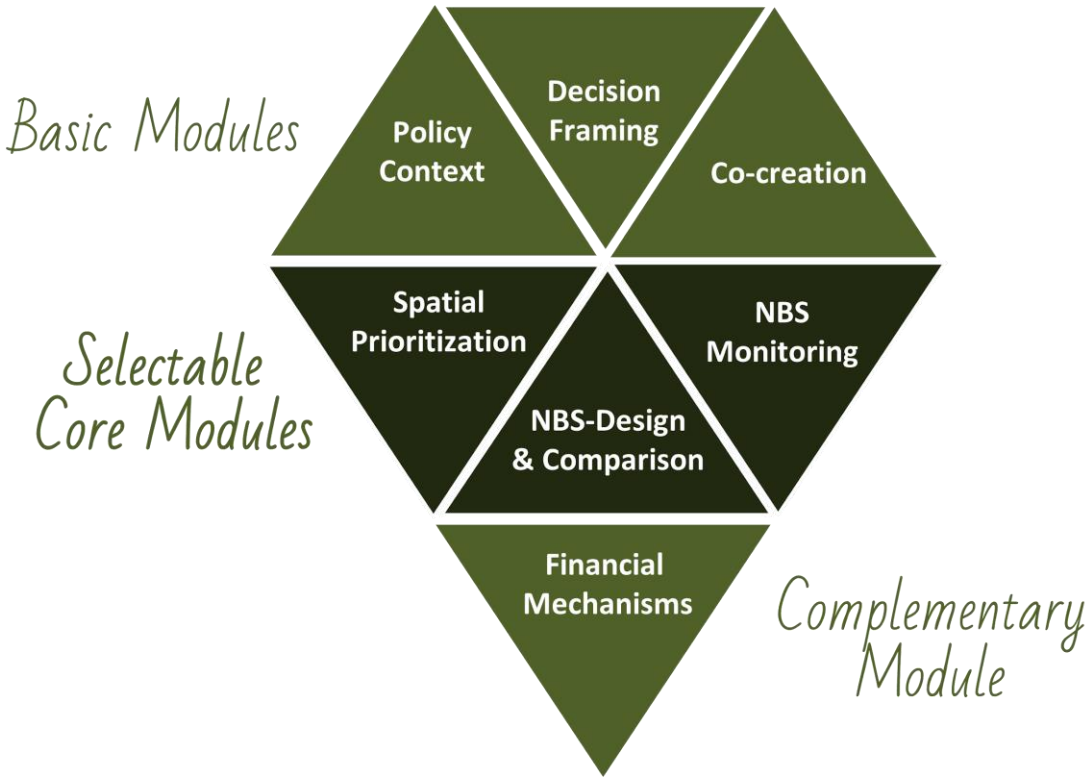


Figure 2. The updated version of the INTERLACE Pilot Assessment Framework – Tier 1

- Module I elaborates on the evaluation of the **Policy-Governance Context**. This module supports the coherent integration of restorative NBS within existing and new strategies and policies and appropriate governance approaches across multiple scales. Module I embraces a *policy coherence analysis* and a *governance analysis* that have been further developed within task 2.1. We will integrate this module and results from its implementation in the generalised assessment framework.
- Module II addresses the **Decision Framing**. This module has to be addressed in order to conduct all following steps. However, the decision framing might already be pre-determined in a given NBS implementation context. Where this is not the case, we suggest dividing the decision framing into the sub-steps of *pre-definition of challenges* (MII.I), *selection of scale* including considering cross-scale implications (MII.II), and *scope and potential constraints* (MII.III).
- Module III describes the design of a **Deliberative Co-creation** process. This module supports an inclusive stakeholder engagement process. Although specific planning contexts might constrain the level of stakeholder engagement, co-created NBS assessment frameworks are more meaningful and add legitimacy to the evaluation. We thus recommend applying this module in all cases, even if the depth of the engagement might differ from case to case.
- Module IV discusses **Spatial Screening.** This module is generally addressing a wider scale (e.g. city or metropolitan area) and supports the definition of geographical priorities in the implementation of restorative NBS. As such, it may be used to develop NBS and green-blue infrastructure strategies; it may also help to identify socio-spatial inequalities, such as areas of stronger social-environmental risks or areas with lower access to ecosystem services. This module is structured into five steps,

including *selection of criteria* (MIV.I), *selection of indicators* (MIV.II), *indicator mapping* (MIV.III), *weighting of criteria* (MIV.IV), and *spatial prioritization and reflection*, including considerations of feasibility for NBS implementation (MIV.V).

- Module V elaborates on the **NBS Design and comparison**. This module builds on existing resources to provide examples of NBS. Design is characterised by the use of technical modelling, visualisation and simulation tools that facilitate the understanding of problems, feed the co-creation process and enable the potential impacts of the solutions studied to be assessed a priori, as well as their feasibility. It further provides a rigorous framework for the evaluation of different restorative NBS design alternatives/scenarios. This module is structured into a sequence of seven consecutive steps, including: a *diagnosis* (MV.I), *definition of design criteria* (MV.II), *weighting of criteria* (MV.III), *definition of indicators* (MV.IV), *definition of strategies* (MV.V), *design and modelling* (MV.VI) final design and preparation for the implementation (MV.VII).
- Module VI provides a framework for **Monitoring of NBS** ex-post the intervention. This module is structured into six steps, including the *selection of criteria* (MVI.I), *weighting of criteria* (MVI.II), *selection of indicators* (MVI.III), *definition and implementation of the monitoring plan* (MVI.IV), *impact assessment* (MVI.V), and *evaluation/reflection* of the results (MVI.VI).
- A complementary module on **Financial Mechanisms** encompasses economic and fiscal instruments that can enable or disable NBS; at the same time, they are core for the implementation of restorative NBS. This module will be further defined over the course of the project in relation to the development of task 3.5 and incorporated into the general assessment framework.

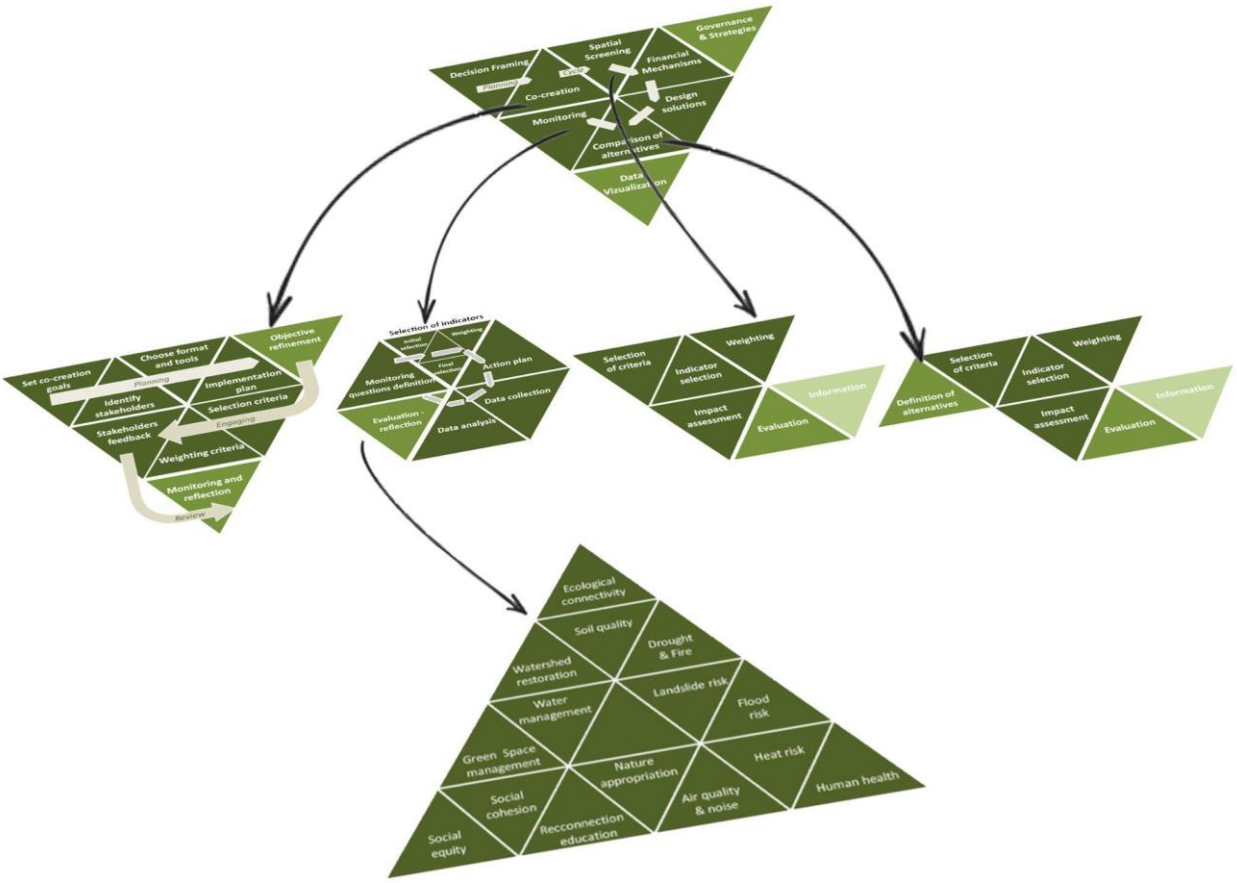


Figure 3. Tiers one, two and three of the INTERLACE Pilot Assessment Framework

In the following section we describe in detail each of the modules of the assessment framework.

1.1. Module I. Policy-governance context

Understanding and analysing the governance and policy context of a NBS intervention requires to look at several aspects of governance such as the ongoing policy processes, the policy strategies and instruments (the policy mix) in place and their respective coherence, comprehensiveness, consistency, etc. It is also important to consider which dimension(s) governance will be looked at, whether it is within a certain policy field or sector (e.g. Tourism or Energy), at a certain governance level (e.g. at city or regional level), in a certain geographical area (e.g. a neighbourhood or along a river) or at a certain time (e.g. looking in the past or the future). Under Deliverables 2.1 'Policy coherence analysis report' and 2.2 'Governance performance assessment', detailed methodologies have been defined and implemented to assess the governance and policy context of the six INTERLACE cities. We do not include these methodologies and results here but refer to the above-mentioned deliverables. We will integrate this module and results from its implementation in the generalised assessment framework.

1.2. Module II. Decision Framing

Decision Framing is a critical aspect in the assessment of urban SES. While stakeholder participation has been promoted to add legitimacy to decision making (Hauck et al., 2014), especially since the recognition of plural values (Kenter, 2016); the importance of decision-framing for inclusive urban planning has been often overlooked. In this context it is critical to question “the presence of equitable spaces of engagement (Martin et al., 2016) that determine who is involved with shaping the social, built, and ecological conditions of the city and how that involvement takes place”. This embeds the challenge of identifying a diversity of priorities, knowledge and practical needs from a variety of interest groups, enabling the negotiation of contradicting and incommensurable values, and compromising professional experiences and political strategies with local stakeholders wishes and priorities. It involves the following three steps:

1.2.1. Pre-definition of challenges

Restorative NBS — as other projects — start with the initial definition of challenges to address and consequent specific objectives. It is important to make the initial challenges and specific objectives explicit, because they are a critical component in framing the decision-making. If the framing is narrowly focused on a specific challenge the assessment process will mirror this narrow focus and might lack in providing a holistic understanding of restorative NBS and their multifunctionality. If the initial objectives are broadly formulated the assessment is going to be wider, more holistic and also more inclusive, as a larger set of potential stakeholder preferences are taken into account. A broader set of objectives is also in line with multifunctional NBS whereby NBS multifunctionality might enhance adaptive capacities and ultimately the resilience of urban environments. The INTERLACE project departs from an initial list of 15 objectives, in the project context defined as challenges. See Deliverable 3.2 (Langemeyer et al. 2022) for a list of the challenges and Deliverable 1.3 (Knoblauch et al., 2021) for details about how the challenges are persistent in cities.

1.2.2. Scale

An important sub-step of the framing is the definition of the principal scale to work at; this can be an entire Metropolitan Region or single site of an NBS intervention. Apart from the principal working scale, smaller and larger scales (n-1, n+1, n+2 etc.) shall be considered for being affected or for potential interrelations with the working scale. The consideration of smaller and larger scale relations will increase the potential for NBS to be successful particularly if different planning objectives are aligned across different scales.

1.2.3. Scope and potential constraints

Defining the scope of the assessment system implies identifying the extent of the area or subject matter that the assessment system deals with or to which it is relevant and the opportunities for action regarding

the ecological restoration of urban spaces. Another related sub-step concerns the identification of potential (initial) constraints in implementing the assessment framework in the specific case studies, e.g. from subordinated planning frameworks or data availability, to help formulate strategies to overcome these constraints when possible.

1.3. Module III. Deliberative co-creation

Co-creation is a form of collaborative governance that promotes cooperation and stimulates learning between different stakeholders to design, implement, evaluate and monitor NBS. A stakeholder is any group or individual that potentially has a direct or indirect interest in, is affected by, or has an influence on the project (Reed, 2008). In the context of NBS, this can include stakeholders who can provide important resources (knowledge, expertise, etc.), stakeholders who are affected by or have an influence on the city's challenges or the planned NBS interventions to address them, or stakeholders who are more distant from NBS but active or interested in restorative NBS (Leone et al., 2021). Through the involvement of stakeholders, issues, concerns, expectations, interests and opportunities regarding NBS can be explored from various viewpoints. By incorporating a greater quantity and diversity of knowledge and perspectives, tailored, locally-adapted and more equitable NBS can be created whilst increasing stakeholders' appropriation of the NBS and its sustainability. Stakeholders such as public institutions, formal and also informal community organisations and private organisations are involved from the very beginning in the process with a special consideration of non-usual subjects, e.g. marginalized communities.

We present the roadmap below (see Figure 4) as a stepwise approach to guide the creation and implementation of a tailor-made deliberative co-creation process for the assessment framework. The roadmap consists of nine steps, some of which are implemented within this module and others are cross-cutting to all selectable core modules. Depending on the user needs, some steps can be skipped; however, we generally recommend considering all steps when applying the INTERLACE Assessment Framework.

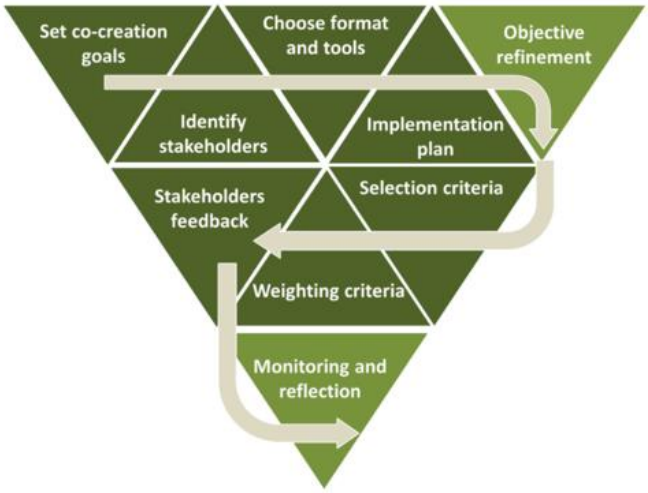


Figure 4. Roadmap to develop a deliberative co-creation of the assessment framework (Langemeyer et al., 2022).

1.3.1 Setting co-creation goals

In this regard, the first step, "Setting Co-creation Goals," is focused on defining the reasons to involve specific stakeholders and their roles in the assessment framework modules. Stakeholders have diverse functions across different modules, guided by their roles and specific calls to action. Establishing clear collaboration objectives is essential, considering the values that stakeholders bring through their actions. To help define the goals of the stakeholder engagement, we recommend to first decide which stakeholder roles (see Table 1 in section 1.3.2) and 'calls to action' are most relevant, and secondly define what the added value of the call to action is. The following formulation can be used to help setting co-creation goals: "For the assessment framework, the -stakeholder and stakeholder role- will - call to action - in order to - added value(s) of engagement". Ex: To adapt the pilot assessment framework to cities' needs, cities will be involved as shapers to make sure the end-results meet their expectations as an end-user.

1.3.2. Stakeholder identification

The second step, "Stakeholder Identification," is done through a mapping exercise to understand stakeholders' roles, interests, and knowledge within the evaluation framework. Stakeholders are grouped based on their role or function within the assessment framework (see Table 1) and based on their professions or interests (see Table 2). Regarding the first classification, five key stakeholder roles are considered. A single stakeholder can take up one or more of these roles, changing over the course of the assessment framework. Stakeholders are further grouped based on their profession, knowledge, expertise, needs or interests.

Table 1. Stakeholder roles in the assessment framework

Stakeholder role	Definition
Developers	Stakeholders who are part of the development team, developing project products and activities (usually project partners).
Shapers	Stakeholders who provide input and feedback on project outputs.
End-users	Stakeholders who use the outputs of the INTERLACE project (products) for real-world applications outside the project.
Enablers	Stakeholders who are capable of helping the project to reach and engage a diversity of other audiences, or to achieve other desirable impacts (e.g. promoting and disseminating project outputs). Have significant social capital and standing in a community.
Interested public	Stakeholders who can generate 'bottom-up' support for NBS and help translate the work of INTERLACE to other stakeholders (improved understanding, increased relevance).

Table 2. Stakeholder groups

Stakeholder group	Definition	Scale
Political representatives	Those who are elected in public office and make political decisions within governmental settings, e.g. mayors, ministers, elected officials.	● National ● Regional ● Local
Governmental authorities	Those who develop laws, strategies or plans and administrators who are controlling and maintaining these laws, e.g policy makers, urban planners, public servants from municipal departments.	● National ● Regional ● Local

Civil society	Those who hold the space for collective action around shared interests, purposes and values, generally distinct from government and commercial for-profit actors.	● Community-based organisation/ neighbourhood association ● NGO ● Children and youth organisation ● Environmental and social movements ● Trade unions ● Professional associations ● Cultural institutes ● Foundation and charitable organisations ● Others
Citizen	**-**	-
Academia, research and education	Those doing research and wanting to advance knowledge and/or share knowledge to students and interested parties.	● Research institutes and universities ● High or primary schools ● Environmental education projects
Private sector	Those who make part of a country's economic system and run individual and company businesses with the intention to make profit.	● Private company / consultancy ● Design and/or architecture office ● Co-operative ● Landowners and land managers ● Farmers
Media	Those who produce and spread news and stories.	
Networks	Where a mix of audiences connect/meet, e.g. national and regional associations of municipalities/local governments.	
Finance sector and funders	Those who have access to financial resources and want to invest in promoting NBS / achieving sustainability goals.	

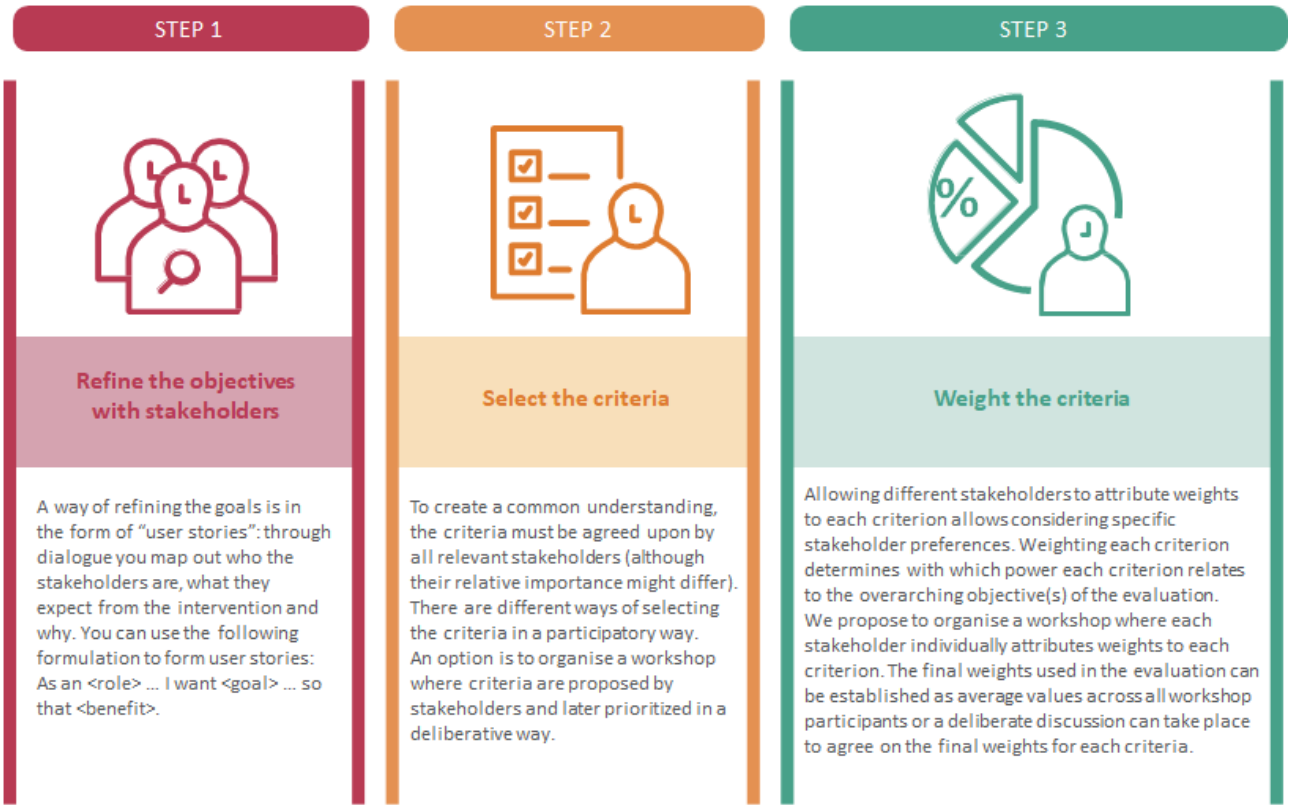
1.3.3 Formats and tools

The third step involves choosing specific co-creation formats and tools, which becomes crucial for each process stage towards the goals, always considering the objectives, stages, and participating actors. There is a wide range of tools, such as workshops, focus groups, interviews, questionnaires, emails, and one-on-one meetings.

1.3.4. Developing an implementation plan

The implementation plan is a logical order of your planned engagement activities, their objectives, who to engage with and through which format and tools. Planning should consider realistic sequences and

timing, allowing updates based on new insights. The following engagement activities need to be considered in the implementation plan:



We describe in detail each of these engagement activities in the following sections:

1.3.5. Objective refinement

At this point, the objectives of the implementation of the assessment framework are shared and discussed with stakeholders to ensure their relevance as well as a common objective defined. General objectives should be acknowledged without ignoring minority objectives.

1.3.6. Selection of criteria

As the next step, the "Selection of Criteria" aims to achieve an agreement between stakeholders on a set of criteria for the spatial screening, the design of NBS or the monitoring of NBS. There are various ways to select criteria in a participatory manner. A suggested approach involves the development of an in-person workshop with stakeholders.

1.3.7. Weighting of criteria

"Weighting of Criteria" is necessary to continue the process, considering stakeholders' preferences. Assigning weights to each criterion determines its influence on overall objectives. A workshop is

suggested for collectively prioritising criteria based on the importance attributed. The specific technique proposed in the workshop is the Pebble Distribution Method. This tool is valuable in MCDA (Multi Criteria Decision Analysis) processes to allocate relative weights (high, medium, or low) or importance to different criteria or factors. This way, participants are engaged physically and didactically to identify their preferences and priorities about each criterion. Participants were given a set of beans representing a total of 100 points and they had to distribute them reflecting the overall importance of each criterion under consideration (Langemeyer and Baró, 2021).

1.3.8. Feedback from stakeholders

The next level involves "Feedback from Stakeholders." Collecting feedback from stakeholders after each participation is crucial, verifying if objectives were met and evaluating the process and outcomes. Keeping participants informed about project progress, including results and future steps, is recommended. Following module results, discussing them in a workshop with diverse groups for open debates with facilitators taking notes is advised.

1.3.9. Monitoring and reflection

The final step, "Co-creation Monitoring and Reflection," aims to evaluate participation's effectiveness, impacts, and outcomes. Completed objectives, appropriate tools and processes, stakeholder impact, and unexpected outcomes are assessed (Langemeyer et al., 2022).

1.4. Module IV. Spatial screening

The need for systematic NBS planning is becoming increasingly vital in the face of escalating environmental challenges and rapid urbanisation. A cornerstone of this approach is the focused identification and mapping of urban vulnerabilities. This process, crucial for the strategic implementation of NBS, involves a detailed understanding of both natural and anthropogenic risks that cities face. By doing so, it becomes possible to integrate natural processes and elements into urban environments in a way that is not only efficient but also equitable and sensitive to the unique challenges of each locale. The INTERLACE assessment framework provides a structured approach to NBS planning that hinges on this detailed vulnerability mapping, enabling cities to address environmental concerns with precision and foresight. This methodology underscores the significance of a tailored approach, recognizing that each city has its unique set of vulnerabilities that require customised strategies for effective NBS implementation. The spatial screening approach can be broken down into five sequential steps, detailed in the following (see Figure 5).

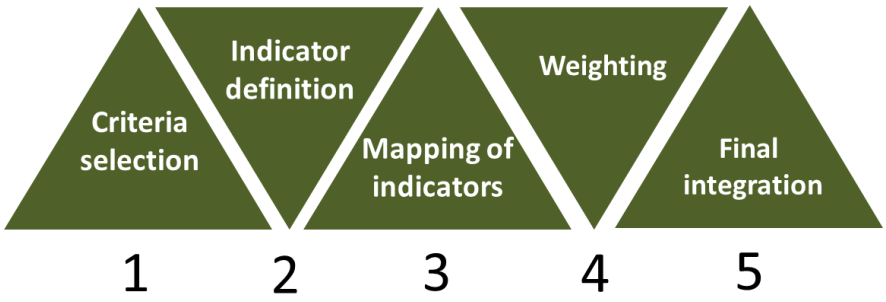


Figure 5. Stepwise approach to spatial vulnerability mapping for NBS prioritisation.

1.4.1 Criteria selection

The process begins by bringing together diverse stakeholders to identify the specific vulnerabilities a city faces. This step involves collaborative efforts with various regional planning bodies and groups to understand the unique challenges of an area. The aim is to create a shared understanding of the vulnerabilities and set clear objectives for the co-creation process, managing stakeholders' expectations regarding their influence on the planning process.

1.4.2 Establishing Spatial Indicators

After identifying vulnerabilities, the next step is to establish spatial indicators that map these vulnerabilities. This involves identifying both the hazards (like flooding or extreme temperatures) and descriptors of ecological and social sensitivity (e.g., areas with high concentrations of vulnerable populations like the elderly). A theoretical “wish list” of indicators is initially developed from existing literature. Due to data limitations, proxy indicators might be used when raw data collection is too resource-intensive. Expertise and knowledge of locally available spatial data are critical in this step.

1.4.3 Mapping Vulnerabilities

Using the indicators identified in the previous step, experts in Geographical Information Systems (GIS) map each vulnerability. This involves a detailed process where hazards, and social and ecological sensitivities are represented spatially. Vulnerabilities are understood to arise at the intersections of hazards and sensitivities. This step also involves thoughtful normalisation of each indicator, considering aspects like non-linearity and thresholds.

1.4.4 Weighting Vulnerabilities

This step revisits the stakeholder group to debate and determine the relative significance of each vulnerability criterion. Known as “Weighting” in multi-criteria decision analysis, this phase can employ various methods to ascertain stakeholder weights. One effective method is the "Pebble-Distribution-Method," where stakeholders use pebbles or similar items to denote the importance of each vulnerability, reaching a consensus through discussion and adjustment.

1.4.5 Prioritization Map

The final step is to combine the individual vulnerability layers into a comprehensive map using a GIS environment. This is typically achieved through weighted summation, based on the weights assigned during the Pebble-Distribution-Method. To ensure the robustness of results, uniform weights can also be applied for comparison. For large areas, this weighting process may be repeated for smaller regions to reflect localised priority variations.

This methodology provides a robust foundation for prioritizing NBS in a spatially focused manner. It allows for a detailed assessment of numerous spatial vulnerabilities while aligning closely with local priorities and contexts. This process not only aids in developing more equitable and efficient NBS strategies but also ensures that resources are directed where they are most needed. This strategic planning approach underlines the importance of a vulnerability-centric perspective in the development of NBS, enhancing the resilience and sustainability of urban environments.

1.5. Module V. NBS Design and comparison

The design module applies to the scale of the urban intervention project. The choice of site must be based on the results of the spatial analysis, which also sets out part of the programmatic specification for the project. To these must be added elements of the local context that correspond to the specific features of the site and the programmatic demands or constraints resulting from the political or technical will to launch the project.

This module is designed for urban designers, who must seek to transform project ideas and wishes into pragmatic urban elements that are integrated into their environment. The special feature of the module is that it seeks to facilitate the integration of NBS into the urban proposals that are designed through this process. To do this, the design module is based on urban design practices and on the processes usually authorised for the design of ecosystem restoration projects. We have sought to reconcile the two approaches so that, when thinking about public space, we can combine an understanding of both the natural ecosystem of the area in question and the urban space, with its dynamics and needs.

The design module is made up of 6 essential steps to be applied in a defined order, with repetition loops (co-creation) between certain steps (Figure 6). The module is also based on three supporting stages that must be defined in advance, with specific requirements for the design module.

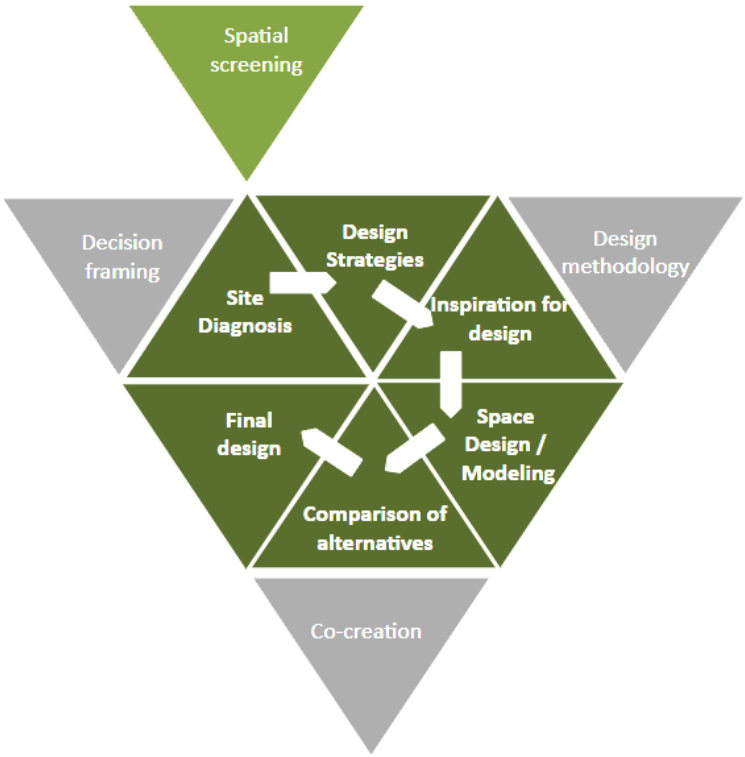


Figure 6. Conceptualisation of the NBS design and comparison module with its 6 essential stages (dark green) and 3 supporting stages (grey)

These three supporting stages are designed to justify, fuel and open the design process, by establishing a constructive relationship of exchange with the stakeholders. The exchange is based on a relationship between urban design experts (town planners, architects, landscape architects, biologists, engineers) and those who know the area to be worked on, *inter alia*, local councillors, municipal technicians, and representatives of residents. It includes the following stages:

Decision framing: This module is defined generically in the NBS assessment system (cf. section 1.2). In the more specific context of the design module, this module guides the decision making that feeds into most of the 6 essential stages. To define it, it is necessary to specify the political decision-making framework (what are the objectives, how is the decision-making mandate formalised, what is the process for validating a decision and how does the project fit in with the local political agenda). This information enables the design team to know whether a decision has really been validated or whether it can still be called into question. For this module, it is also necessary to define the administrative or organisational process implemented in the project. Decision-making must be based on tangible information that corresponds to the political and technical objectives of the players involved, as well as on the specific needs of the site (urban needs and environmental needs).

Design methodology: The choice of design methodology is the equivalent of the decision framing module, but this time for the team carrying out the design process. There are different ways of designing an intervention, and it is advisable to use a formal design-centred methodology that will facilitate the execution of the process and ensure the quality of its outcome. Rather than using traditional waterfall planning, we recommend the use of more advanced methodologies such as Design Thinking or Agile.

Both are oriented towards users and impact, while leaving room for flexibility and experimentation. At INTERLACE, we use Agile in particular, which involves short, iterative development loops culminating in an exchange with the user. This is precisely the approach we have used to conceptualise the design module as a whole.

Co-creation: the process for co-creation is detailed in section 1.3. For the design module, it is essential to be able to transmit qualitative and explicit information to the parties involved, which for the design with NBS means to balance the information provided between urban and environmental criteria. It is even advisable to start with the environmental criteria, which are generally less well known and less taken into account by local stakeholders. The co-creation process is of particular importance for steps 2. *Strategies* and 4. *Design / models*, and as a cycle between these two steps as shown in Figure 7.

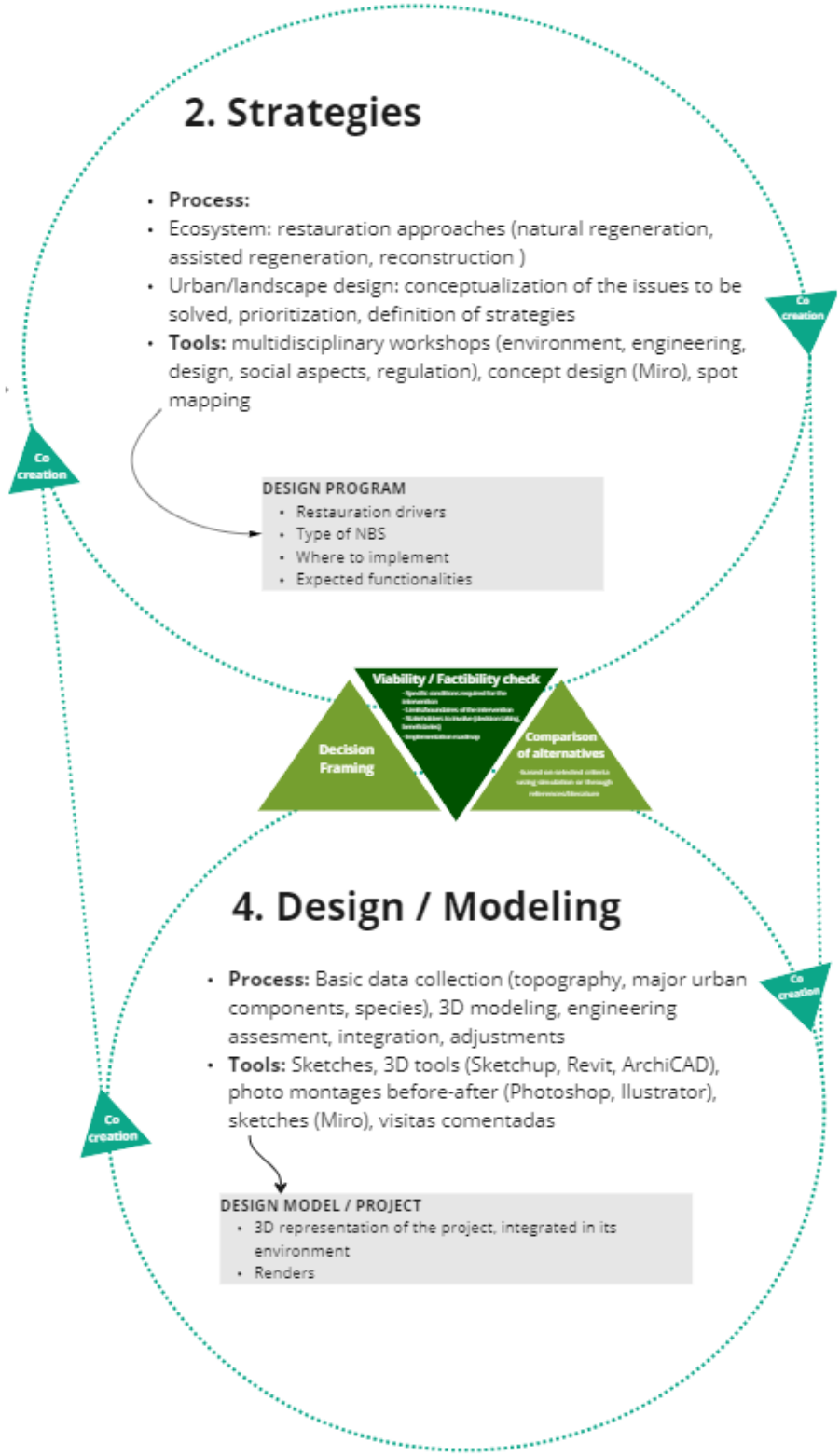


Figure 7. Co-creation is involved in several loops within the design module, especially between step 2-strategies and step 4-design.

The 6 essential stages will enable us to successfully complete a design project that incorporates NBS. We recommend that you follow the process step by step and document each stage. The essential steps are shown in the list below and key elements of each step defined in terms of process, supporting tools, criteria to be included, outcomes and links between steps.

1.5.1. Site diagnosis

The first stage of the module is the most important. It establishes the foundations of the project based on the programmatic information already defined, the conditions of the site and the conditions of the ecosystem that exists there or that we are seeking to create. It is important to be able to call on different areas of expertise for this stage, as multiple viewpoints will help to capture the complexity of the site, which is essential for the design.

Process: data collection, site visits, meetings, workshops

Tools: GIS, co-creation tools (Unlimited Cities), co-creation maps (Debatomap)

Criteria to be included:

- Nature**:**
    - Context: existing natural ecosystems, topography, corridors, relevant natural fluxes (*inter alia* water, wind, sun, fauna), risks, climate change scenarios.
    - Ecosystem to be restored: description (composition, structure, function), level of degradation, restoration potential.
- Places**:** public plots, local land use regulation, urban dynamics, private and public green spaces, public infrastructures (*inter alia* water, transport, buildings), accessibility to green areas, specific urban challenges (*inter alia* safety, memory, heritage).
- People**:** social composition and homogeneity**,** perception of nature, relationship with urban green, uses of public areas (type of user, schedules, activities, expectations/added value of the green area), inclusion.

Outcomes: design requirements

- CLIMATE conditions
- LOCAL ECOSYSTEM key parameters
- LANDSCAPE perception/design
- FUNCTIONALITY of the place
- RISK related to the area

Links: Step 1 is delivering the inputs of step 2. It also directly informs the process of decision framing and can support the definition or adjustment of criteria, indicators and weighting.

1.5.2. Design strategies

Based on the project's technical and programmatic specifications, the design team can initiate the proposal work by defining intervention strategies. These strategies must address both the environmental and ecosystem restoration challenges and the urban challenges (e.g. accessibility, relationship with mobility, relationship with urban facilities, urban landscape, inclusive character of the public space).

Strategies are defined primarily in terms of functions (e.g. retaining run-off water at this location) and not in terms of techniques (e.g. implementing rain gardens). The proposed functions must respond to the needs and opportunities offered by the site, and their definitions must be sufficiently precise. They must also meet the design criteria defined for the project and weighted in a participatory way (see module III on co-creation). The functions need to be located and the project's capacity to meet the needs to be scaled.

Working with the strategies in this way allows a certain amount of design freedom, so that the process is not locked into technical details, and essential functions that the project must incorporate are not forgotten. It also enables vague requirements to be reformulated into technical parameters for the design. This work can take the form of a functional plan, using the site map as a basis.

At this stage, it is important to discuss the choice of strategies with the stakeholders, to start introducing them to the spatial dimension of the project and the choices to be made to prioritise the design options. It is also important to realize a feasibility check with the local authorities, to confirm whether there are technical impediments for the strategies to be implemented as defined.

Process:

- Ecosystem: restoration approaches to be applied (natural regeneration, assisted regeneration, reconstruction).
- Urban/landscape design: conceptualization of the issues to be solved, prioritization, definition of strategies.

Tools: multidisciplinary workshops (environment, engineering, design, social aspects, regulation), concept design (Miro), spot mapping

Outcomes: design program

- Restauration drivers
- Type of NBS that could be used
- Where to implement
- Expected functionalities

Links: Receives inputs from step 1; provides inputs to steps 3 and 4; is integrated in a co-creation agile loop with step 4.

1.5.3. Inspiration for design

Designers often look for inspiration in existing examples or past projects, whether it is for defining great design principles for a project or for very specific details of a particular technique. This step is not compulsory but corresponds to a widely spread approach.

As well as providing inspiration, this stage also helps to communicate ideas to stakeholders, by showing examples of what could be achieved. Introducing the aesthetic aspect of the proposal facilitates dialogue and frees up ideas, it also contributes to structure the landscaping proposal.

Process: Ideation, references/examples (including reference ecosystems), initial dimensions, initial feasibility assessment (technique, cost, context).

Tools: Libraries of projects (Pinterest, Archdaily), design and landscape magazines (Dezeen), local examples (conferences, social medias), international examples (social medias), site visits.

Outcomes: design concept/proposal

- Places of interventions for each NBS
- Types of techniques and basic dimensions

Links: Receives inputs from step 2; provides inputs to steps 4

1.5.4. Space design and/or modelling

Stage 4 is the heart of the design module. It consists of transforming the strategies defined previously into a detailed and coherent public space design. This is a classic design stage, where the use of 3D tools makes it easier to take account of topography and dialogue with stakeholders. Traditional tools do not incorporate much information specific to NBS (a barrier that INTERLACE is trying to overcome, see D3.4), so it is advisable to refer to existing technical documentation and standards to be able to incorporate it as effectively as possible. It is also important to be able to draw on the advice of environmental experts when sizing solutions and choosing which species to include.

Process: Basic data collection (topography, major urban components, species), 3D modelling, engineering assessment, integration, adjustments.

Tools: Sketches, 3D tools (Sketchup, Revit, ArchiCAD), photo montages before-after (Photoshop, Ilustrator), sketches (Miro), guided tours.

Outcomes: design model/project

- 3D representation of the project, integrated in its environment.
- Renders.

Links: Receives inputs from steps 2 and 3; provides inputs to steps 5 and 6

1.5.5. Comparison of alternatives

While some of the ecosystem services that NBS can provide can be analysed using the implementation plan alone, others require the support of specialised tools to measure their impacts more accurately and thus be able to define whether the proposed solutions are appropriate and sufficient.

There are various tools available for this purpose, of varying degrees of complexity, the choice of which will depend on the objectives of the project and its size. These solutions provide scientific support that is a real added value for integrating NBS into a project.

Process:

1. Definition of design scenarios
2. Definition of evaluation criteria
3. Modelling (3D, size calculation, modelling in a specific simulation tool)
4. Multicriteria evaluation

Tools: Simulation tool, calculation based on literature values, calculation based on local references, rendering (landscape integration)

Criteria to be included:

- Viability / feasibility check**:** land tenancy, infrastructures, ongoing or planned projects, public policy, budget, etc.
- Urban integration: functionality, accessibility, landscape, etc.
- Ecosystem restoration: reducing impacts, repairing ecosystem functions, supporting natural recovery.
- Social acceptance: inclusion, co-design, social value, etc.

Outcomes: understanding of the impacts for different design scenarios.

Links: Direct link with the step 4

1.5.6. Final design

This final stage consists of formalising the plans for the urban intervention, which prefigure the implementation. It is a simple technical stage in this module in the sense that it is not advisable to modify the design at this stage; everything should have been discussed and validated previously with the project stakeholders.

Process: System dimensioning, species selection, CAD design, technical details, implementation process, costs and technical specifications.

Tools: CAD tools (Autocad, BIM) + GIS

Outcomes: Implementation plans

- Lay-out
- Cross-sections
- Technical details

Links: Receives inputs from step 4

1.6. Module VI. Monitoring of NBS

The Monitoring module is designed to measure the effectiveness of NBS to address specific challenges, in terms of its socio-environmental impacts or co-benefits and how these change over the course of its intervention. In this sense, the effectiveness of NBS is measured in terms of their ability to generate co-benefits (environmental, social and economic, including the contribution of social value and cost savings compared to traditional solutions) (Garcia et al., 2018).

NBS monitoring module is adapted from the monitoring cycle designed by the Humboldt Institute, the so-called "participatory monitoring cycle between scientists and the general public", which includes the processes of planning, implementation and evaluation of (biodiversity) monitoring strategies (Sanchez-Clavijo et al., 2018; Werner et al., 2016). The approach is based on adaptive management, which again is in line with the principles of participation and co-creation proposed by the INTERLACE Assessment Framework.

In the Pilot version of the Assessment Framework (Langemeyer et al. 2022) the monitoring Module was structured into six steps, including: selection of criteria (MVI.I) selection of thematic indicators (MVI.II), weighting (MVI.III), definition and implementation of the action plan (MVI.IV) impact assessment (MVI.V), and evaluation/reflection of the results in order to incorporate changes (MVI.VI), if necessary, in the next monitoring cycle (Figure 8).

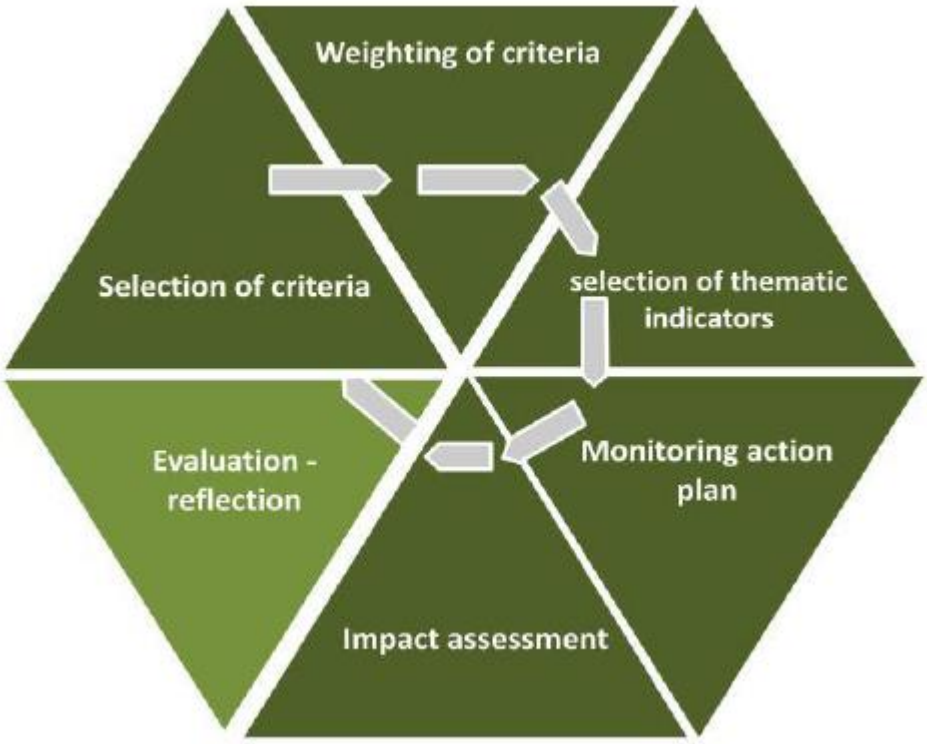


Figure 8. Steps to monitor NBS. Adapted from Sanchez-Clavijo et al. (2018).

After the implementation in different partner cities, the order of such steps have changed: step 1. Selection of criteria; step 2. Weighting of criteria; step 3. Selection of thematic indicators; step 4. Definition and implementation of the action plan; step 5. Impact assessment; and step 6. Evaluation/reflection of the results. The first four steps are meant to define and plan an evaluation and monitoring strategy for a given NBS, step 5 corresponds to the implementation (collecting and analysing defined indicators; and step 6 consists of reflecting on the obtained results and incorporating changes to the next monitoring cycle.

1.7. Module VII. Financial mechanisms

The identification of financial mechanisms to foster private investment in restorative NBS through municipal public policy is key to enable NBS implementation. We do not include financial mechanisms here but refer to Deliverable 3.6, which provides a detailed overview of policy instruments and business cases for fostering restorative NBS in the INTERLACE cities. We will integrate this module and results from its implementation in the generalised assessment framework.

2. Methodology for the co-production of city-specific assessment systems

2.1. AGILE development of the assessment systems

The development of this deliverable followed an AGILE work process. The goal of this AGILE approach was to ensure that the development of city-specific assessment systems meet stakeholders' needs; in this case, public and private planners and practitioners who plan, implement and manage restorative NBS in the six INTERLACE cities. The AGILE process started in October 2021 and it is ongoing. It included several feedback mechanisms to shape and reshape the city-specific assessment systems. The lead authors conducted weekly progress meetings to coordinate the implementation of the assessment systems, two of them in charge of one city and two of them in charge of one. To ensure feasibility, we started with two metropolitan areas (Metropolia Krakovska and CBIMA) and reflect on the process. As a result of this self-reflections, a protocol was deemed necessary to ensure a systematic process of implementation of the framework. From the beginning of the assessment systems implementation (beginning November 2021), bilateral meetings with city knowledge brokers and representatives of the cities conforming the *City Focal Points* were conducted to ensure a systematic process of development and monitor it. In addition, a series of meetings with project internals aimed at gathering feedback took place. An overview of the main events held from an agile approach to develop this report is given in Box 1.

Box 1. Summary of the AGILE process for the development of city-specific assessment systems

- On October 2021, an internal workshop to initially discuss the development of cities assessment systems was carried out, involving representatives of the project partners ICTA-UAB (ES), Humboldt Institute (CO), Yes Innovation (EC), and Tecnalia (ES).
- On November 3, 2021, a second workshop was carried out with the INTERLACE City Focal Point members to gain a more detailed understanding of cities' needs in relation to planning, implementation and management of restorative NBS.
- Beginning in November 2021, bilateral meetings to discuss the implementation of The INTERLACE pilot assessment framework were held with INTERLACE City Focal Points from CBIMA (CR), Chemnitz (DE), Granollers (ES), and Metropolia Krakowska (PL).
- Beginning in January 2022, regular bilateral meetings with INTERLACE City Focal Points from CBIMA (CR), and Metropolia Krakowska (PL) were conducted to identify the objective of implementing the assessment systems and establish a workflow.
- During the 2nd INTERLACE annual meeting in Costa Rica, a workshop was held on May 10, 2022, with representatives from the Steering Committee of INTERLACE, research institutions, networks of cities and consultancies members of the project to present the process of developing the cities assessment systems,

collect feedback and formulate questions to explore during the learning process of implementation of the assessment framework.

- A workshop was held on 22/09/2022 during the Cities Talk Nature event happening in Krakow to showcase and test the INTERLACE assessment framework with representatives from European cities.
- Beginning in September 2022, regular bilateral meetings with INTERLACE City Focal Points from Granollers (SP), Envigado (CO) and Chemnitz were conducted to identify the objective of implementing the assessment systems and establish a workflow.
- During November 2022, a protocol was designed and distributed among the cities to systematize the development of assessment systems across INTERLACE cities.
- Beginning in February 2023, regular bilateral meetings with INTERLACE City Focal Points from Portoviejo (EC) were conducted to identify the objective of implementing the assessment systems and establish a workflow.
- During the 3rd INTERLACE annual meeting in Chemnitz, a session was organised with the City Focal Points where each city presented the stage of implementation of their assessment system and the faced difficulties and added value.
- Workshops to co-create and weight criteria for the assessment systems were held in the six INTERLACE cities: on 06-05-2022 in CBIMA, on 07/07/2022 in the municipality of Curridabat, on 11/07/2022 in the municipality of San José, on 12/07/2022 in the municipality of Montes de Oca, on 13/07/2022 in the municipality of La Unión, on 14/07/2022 in the municipality of Alajuelita (CR); on 19-09-2022 (and expected repetition on 10-11-2023) in Metropolia Krakowska (PL), 08-03-2023 in Envigado (CO), on 21-03-2023 in Granollers (ES), on 18-09-2023 in Chemnitz (DE) and on 18-09-2023 in Portoviejo (EC).

2.2. Protocol as a tool to systematise the development of assessment systems

To ensure a systematic implementation of the assessment systems in the six INTERLACE cities, a protocol was developed for cities and knowledge brokers to fill in all the relevant decisions and actions taken through the process. They have been supported by members of WP3 in reporting the relevant information in all the stages. The protocol is also considered as a useful tool to later allow the extraction of lessons learned from the implementation of the tailored-assessment systems in the six INTERLACE cities to improve the general assessment framework. In addition, it will enable to explore to what extent and how the INTERLACE assessment framework contributes to transformative governance in social-ecological systems and to shed light on the types of social resistance and political lock-in processes that need to be overcome when promoting transformative governance and its principles.

3. Metropolia Krakovska

3.1. Description of Metropolia Krakovska and the area of intervention

The metropolitan area is composed of Poland's second largest city Krakow, as well as the 14 neighbouring municipalities Biskupice, Czerniów, Igołomia-Wawrzeńczyce, Kocmyrzów-Luborzyca, Liszki, Michałowice, Mogilany, Niepołomice, Skawina, Świątniki Górne, Wieliczka, Wielka Wieś, Zabierzów and Zielonki. In 2014 the municipalities formed the Metropolia Krakówska Association, with the goal to tighten cooperation, work towards a joined planning and realize development projects together (Metropolia Krakówska n.d.).

The region stretches over 1275 km² and is located in the Southern voivodeship Małopolska (Lesser Poland). Regarding the geomorphology and also coinciding with the climatic conditions, the study area is split into three regions. The Southern part of the metropolitan area belongs to the mountain range of the Outer Western Carpathians, with the Northern Subcarpathians adjacent and the Central Poland highlands following even further North. The whole area lies within the Upper Vistula river basin, with the main stream of the Vistula crossing the MK from West to East (Metropolia Krakówska 2020). The MK is under pressure of pollution mainly originating from the combustion of fossil fuels and is projected in experience increasing environmental pressures with the intensification of climate change (Metropolia Krakówska 2020).

As of 2019 the MK was inhabited by 1.07 million people, of which approximately 72% live within the city of Krakow, where the population density is nine times higher (2384 people/km²) than in the region's average (267 people/km²). In the past years, with the exception of Igołomia-Wawrzeńczyce, the population increased in all municipalities and this trend is projected to continue in the future mainly due to a positive migration balance (Metropolia Krakówska 2021b). After the Russian invasion into Ukraine in February 2021, 150.000 people escaping the war arrived in Krakow, of which about 50.000 are still estimated to live there (City of Krakow 2022). Within Poland, the MK is a rather affluent area, with an average per capita income of 1189 €, however significant income differences exist between the different municipalities. The region is characterized by a clear ageing trend and social inequalities are deepening (Metropolia Krakówska 2021b).

In order to tackle current and future challenges, the MK set up the Strategy Metropolia Krakowska 2030, in which the municipalities formulate the vision of reaching an environmentally friendly and climate neutral region with a high quality of life (Metropolia Krakówska 2021a).

3.2. Status of implementation of the assessment system

The development of the assessment system has been completed from the standpoint of INTERLACE Work Package 3. Meanwhile, the Metropolitan Area of Krakow is actively adopting and adapting this model, tailoring it to suit their specific needs within the framework of their climate change adaptation strategy. This adaptation signifies a practical application and refinement of the approach, demonstrating its flexibility and relevance in addressing local urban challenges.

3.3. Module II. Decision Framing

The spatial vulnerability assessment framework developed in this study breaks down the analysis of social-ecological vulnerabilities in a stepwise and hierarchical approach. In a multi-criteria decision analysis (MCDA) it combines complex workings of social and ecological systems to identify spatial priority areas for NBS interventions. The framework is supposed to be easily adaptable and understandable. In this way, MCDA can increase transparency in decision making processes (Langemeyer et al. 2016). Building up on the work of Langemeyer et al. (2020) and a growing body of index-based spatial vulnerability assessments (Raška et al. 2020; Kok et al. 2016; Thiault et al. 2018) it consists of three main steps: 1) setting the frame, 2) selecting relevant challenges, 3) selecting and mapping indicators and 3) determining the weighting of the individual components.

First, the overarching planning objectives are defined to determine the scale and scope in which the analysis takes place. As presented above, the MK seeks to become an environmentally friendly and climate neutral region with a high quality of life, thus the main objectives are thus reaching social and ecosystem well-being in the whole metropolitan region. The different challenges that prevent or endanger the achievement and maintenance of these objectives are identified in the second step in an iterative co-created approach as presented in the following chapter (3.4). The framework considers only challenges, that can be tackled or at least ameliorated by the implementation of NBS. To display existing vulnerabilities towards those challenges, quantifiable indicators where selected that represent local dynamics.

As defined above, vulnerability is here understood as a function of exposure, sensitivity and adaptive capacity, which all are distributed unequally in space. For instance, within the metropolitan area of Krakow the exposure to air pollution differs. In some areas PM_{10} concentrations are higher, e.g. because more households in the surroundings rely on combustion stoves for heating (Samek et al. 2021). Poor air quality can affect the quality of life for all people, but some groups in society, such as elderly people experience more adverse health effects (Namdeo et al. 2011). They are equally exposed but more sensitive to the threat of air pollution. Finally the adaptive capacity refers to the ability of society and ecosystems to adjust to occurring changes or cope with the effects of a hazard (Frazier et al. 2014; Turner II et al. 2003; Thiault et al. 2018). Compared to the other components, the adaptive capacity is less straightforward to identify and especially to map. Adapting to air pollution for instance heavily depends on behavioural changes, such as avoiding physical activity at high pollution levels or using face masks

(Thanvisitthpon et al. 2021). Considering the given scope of a master thesis, this study thus only examines the exposure and sensitivity in the vulnerability mapping.

Once mapped out, the indicators representing the sensitivity and exposure respectively were combined for each challenge, to then calculate the individual vulnerabilities. Again in the co-created approach, the weightings of the challenges were identified (RO2) to then merge all challenges in a combined vulnerability map as described in section 3.5. The hierarchical structure of the approach is supposed to increase clarity and coherence.

Definition of the assessment system

Describe the challenges to be addressed

1. To identify priority areas for NBS interventions to reduce social-ecological vulnerabilities, with the ultimate aim to reduce spatial injustices.

2. To use the climate change vulnerability maps in the development of KMAs strategy for adaptation and mitigation to climate change (strategic document).

3. The climate change vulnerability maps as a tool to support officials' decisions regarding counteracting the negative effects of climate change.

Definition of scale

Define the scale of the intervention, including considering cross-scale implications, Scale n =

Scale n = Metropolia Krakowska
(15 municipalities; ca. 127 500 ha; ca. 1.1 million inhabitants)

Definition of scope and constraints

1. The data availability, especially in vector data format. Spatial data in Poland (provided for free) often has only a vector format, which cannot be edited or processed.

2. In order to obtain vector data, it is often necessary to submit letters to specific institutions, which include a request for access and the possibility of data processing - this significantly extends the processing time.

3. No access to data on the number of inhabitants in individual villages, average wages, etc.

3.4. Module III. Co-creation

Taking on board local decision makers and administration staff from the relevant departments in a co-creative process right from the start increases the chances for this study to actually feed into real world impact (Stier and Smit 2021). Already the research design was set up in consultation with the Metropolia Krakowska office as well as with the Sendzimir Foundation functioning as a knowledge broker, in order to ensure that the study is feasible, embedded well into the local context and adds valuable knowledge.

To identify which challenges, that NBS could tackle, perceive locals as most impacting social-ecological well-being, an iterative participatory process was conducted. As a starting point served a list of relevant challenges in the MK obtained in a previous stakeholder workshop moderated by the Sendzimir Foundation in March 2021. The group of stakeholders comprised representatives of the participating municipalities, the MK office and the Lesser Poland Marshall's office, the state forest service and Ojców National Park, and the State Water Holding "Polish Waters" as well as researchers.

Based on the Strategy MK 2030 (Metropolia Krakówska 2021a, 2020) and a literature review this list was enriched for this study and a first set of quantifiable indicators depicting the social and/or ecological vulnerability towards the challenges was proposed. This proposal was presented to the stakeholders in a second online workshop held in spring 2022. The 14 present participants were asked about the relevance of the selected challenges and indicators, and had the possibility to add topics not yet covered. To lower participation barriers, the active part of the workshop was held in Polish, again moderated by the Sendzimir Foundation, who also provided an English translation of the results afterwards. Once the challenges were chosen, the place specific relevance and feasibility of the indicators was assessed in personal exchanges with a subset of the stakeholders who where particularly interested and had in-depth knowledge of the topics covered. In this way it was ensured that the indicators accurately represent exposures and sensitivities towards the selected challenges in the study area and that spatially explicit datasets were available and accessible.

After creating the vulnerability maps for each challenge, the "pebble distribution method" was used to determine the relative importance of the different challenges for the weighting in the integration (Figure 9). This participatory tool has been used to determine people's perception and preferences in ecosystem service research and decision-making processes about natural resources (Langemeyer et al. 2020; Wilkinson and van Duc 2017). By having to distribute a limited amount of points, this method displays the trade-offs occurring in planning decisions. In a workshop held during the "Cites Talk Nature" Conference on the 21st of September 2022 participants were tasked to distribute 100 pebbles according to the relevance of the challenges for hampering social and ecosystem well-being (see Figure 10). Since only

8 people participated in the workshop and the group included people not familiar with the study region, the exercise was repeated in an online survey, and these results were used instead. Here the 13 respondents stated their perspective individually, instead of reaching a consensus within a group.

Figure 9. Pebble Distribution method, applied in Krakow with the local bean variety Piękny Jaś z Doliny Dunajca instead of pebbles.

The following stakeholders have been considered relevant to involve in the co-creation of the assessment framework for MK (Table 3):

Table 3. List of stakeholders, their role in the assessment framework and the group they belong

Representative's Name	Organization	Role of stakeholders	Stakeholder Group
Municipal officials of the Metropolia Krakowska	Municipalities: Biskupice, Czernichów, Igołomia-Wawrzeńczyce, Kraków, Liszki, Michałowice, Mogilany, Niepołomice, Skawina, Świątniki Górne, Wieliczka, Wielka Wieś, Zabierzów, Zielonki	Shapers, End-users, Enablers, Interested public	Local governmental authorities
Specialists and experts	Kraków City Hall, Kraków urban greenery	Shapers, End-users, Enablers	Local and regional governmental authority

	management, Marshal Office of Lesser Poland, Krakow poviat, State Water Holding "Polish Waters", State Forests, Ojców National Park		
Researchers	Krakow University of Economics	Shapers, End-users, Enablers, Interested public	Academia, research and education
Researchers	The Sendzimir Foundation	Developers, Shapers, End-users, Enablers, Interested public	Academia, research and education

The following co-creation goals were defined:

- ➔ To adapt the vulnerability maps to municipalities' needs, representatives of municipalities' offices were involved as shapers to make sure the end-results meet their expectations as an end-user.
- ➔ Specialists and experts provided valuable information on challenges, criteria and indicators for the vulnerability maps
- ➔ Researchers supported process of criteria selection and provided some of the data

In February 2022, we conducted an online workshop using the Miro board. The stakeholders listed in the Table 3 provided the information on the challenges, criteria and indicators needed (Figure 10).

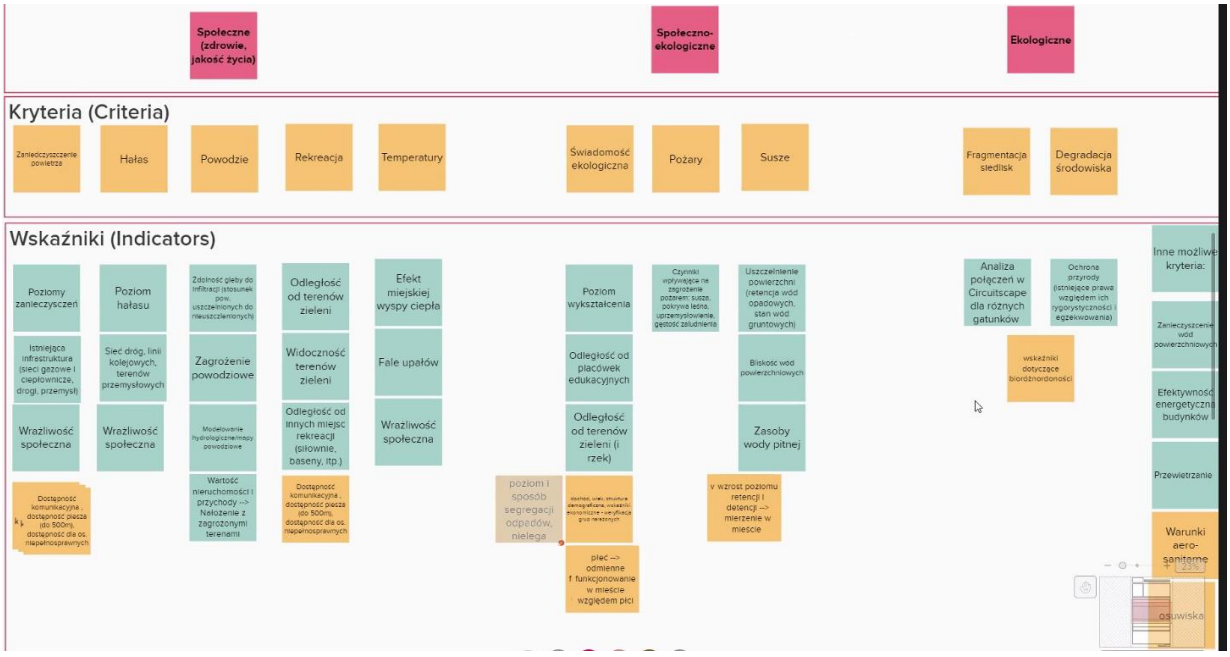


Figure 10. Refinement of objectives during online workshop (screenshot of Miro board).

The following participatory activities have been conducted to co-create the assessment system (Table 4).

Table 4. List of stakeholders, their role in the assessment framework and the group they belong

Participation Activity	Objective	When to do it	Who to Involve	Format
Selection of criteria	Choosing the main criteria	February 2022	CAN	online workshop
Selection of indicators	Selecting and matching appropriate indicators to the criteria	February 2022	CAN	online workshop
Weighting	weighting	September 2022	CNA and conference participants	workshops as part of the Cities Talk Nature conference Survey for the above stakeholders
Weighting and discussion on possible application of the climate change vulnerability maps	final weighting with local stakeholders	October 2023	CAN	workshops

3.5. Module IV. Spatial screening

The following describes the challenges that were identified as most relevant by the stakeholders to negatively impact social and ecological well-being in the region, as well as the components describing sensitivities and exposures towards them. A detailed description of the GIS processing for the individual indicators can be found in Busse (2022).

Selection of criteria and indicators

3.5.1 Lack of recreational opportunities

Green and blue spaces such as parks or lakes provide recreational opportunities and aesthetic values, which in turn contribute to physical and psychological well-being (Chiesura 2004; Wang et al. 2019). Compared to the rest of the country, citizens of the South of Poland are less satisfied with the quality of green areas in their neighbourhood, however still the majority is pleased with the current offer (Ministerstwo Klimatu i Środowiska 2020). The city of Krakow put efforts into increasing greenery in the urban landscape (Urzędu Miasta Krakowa 2019a). Still, some areas of the MK lack access to natural resources and a lack of coherent protection and management leads to unattractive green spaces (Metropolia Krakówska 2020). NBS can tackle this challenge by installing new green spaces or restoring and improving the accessibility of existing ones. Haase (2017) for example highlights the recreational possibilities of wetlands and riparian forests. In dense urban areas, vertical greening and street trees can provide visual access.

3.5.1.1 Exposure to the lack of recreational opportunities

To describe the exposure to the lack of recreational opportunities this study considers the physical and visual access to green and blue spaces, as well as non-green recreational facilities. People living closer to green spaces are more likely to visit them (Bozkurt 2021), and profit from the ecosystem services they provide. Indeed residential proximity to greenery is for instance linked to lower rates of behavioural problems in children (Markevych et al. 2014) and less treatments for anxiety and mood disorders (Nutsford et al. 2013).

In this study the physical access to green spaces is differentiated in the *walking distance to green spaces up to 0.5 ha,* to which citizens in Krakow are supposed to have access within 300 meters (Urzędu Miasta Krakowa 2019b), and the *walking distance to green spaces above 0.5 ha,* which provide more amenities. The cut-off distances determining where people still benefit from green spaces varies greatly (e.g. Markevych et al. (2014) considered 500 m compared to 3 km in Nutsford et al. (2013)). For the walking distance to larger green spaces I instead adopted the approach of the 15-minute city, which is a concept in planning aiming to provide residents with amenities within 1200 m walking distance (Noworól et al. 2022). Both indicators were realized by calculating the network distance of walkable streets to green space entry points through a service area in QGIS. Green spaces for recreational use are in this study defined as being parks, forests or also allotment gardens. According to the regulations of the Polish Association of Allotment Gardeners, hedges and fences within a garden colony cannot exceed 1 m in height (Polski Związek Działkowców 2018, § 52), allowing passers-by to enjoy the diverse landscape. Since official statistics on the distribution of green spaces in Poland are not comprehensive (Feltynowski et al. 2018), the official land-use data (BDOT) was combined with layers from Open Street Map and the land-use model developed for the Strategy MK 2030.

Nutsford et al. (2016) found that visual access to water bodies is linked to lower psychological distress. While in their study the same did not hold true for greenery, other research suggests that also the visibility of green spaces provides benefits for mental and physical health and well-being (Lottrup et al. 2015; Yoo

et al. 2022; Kaplan 2001; Nutsford et al. 2013). Since *visibility of greenery* also is impacted by gardens and other vegetated areas of private land, I determined green spaces for the visual access using a NDVI threshold. To reduce the computing capacity for the viewshed analysis, which was conducted in ArcGIS using a Digital Surface Model, I allocated sample points in the green areas as suggested by Cimburova and Blumentrath (2022) and Qiang et al. (2019). The same was repeated to calculate the *visibility of blue spaces.*

As a last exposure indicator the *distance to non-green recreation* facilities, including as playgrounds, sports centers and dog parks, was added to account for alternative recreational opportunities. Proximity to different facilities makes them easily accessible and thus has shown to increase physical activity in the community (Giles-Corti and Donovan 2002). As for the larger green space the concept of the 15-minute city was adapted and thus a Euclidean distance decay a maximum distance of 1200 m was calculated.

3.5.1.2 Sensitivity to the lack of recreational opportunities

Children are especially sensitive to the lack of access to greenery and other recreational opportunities, they are thus considered in the indicator *percentage of population under the age of 14.* Green spaces facilitate adventurous and creative play of children (Chawla 2015), which fosters the formation of identity and a sense of belonging, as well as providing opportunities for learning and development. (Carroll et al. 2019). The exposure to greenery in young ages further influences people over their whole lifespan. Engemann et al. (2019) found that residential proximity to parks throughout childhood lowers the risk of psychiatric disorders at older ages. Children who frequent natural areas are also more likely to make use of green spaces as an adult (Thompson et al. 2008).

A second group especially sensitive to the lack of access to green spaces and other recreational opportunities are economically disadvantaged people. Compared to higher income groups, lower socioeconomic strata rely more on positive health outcomes from green spaces since they lack access to other health-facilitating resources (Rigolon et al. 2021). To display population groups with low economic status an indicator displaying the *percentage of population receiving social assistance* was used. Also unemployment is linked to poverty in the study area (Urzędu Miasta Krakowa 2019b), thus the *percentage of unemployed population in the working age* is added as a second indicator to display this group. To assess how many people are affected by little access to recreational opportunities, the *population density* was included.

3.5.2 Air pollution

In Poland citizens nationwide consider air pollution as the most pressing environmental problem (National Fund for Environmental Protection and Water Management 2020). Even in the countrywide comparison, emissions in the MK are high (Wojewódzki Inspektorat Ochrony Środowiska w Krakowie 2018). The main sources of air pollution are the combustion of solid fuels for heating combined with industrial and traffic related pollution (Samek et al. 2021; Mikulski et al. 2021). In the MK high emissions are paired with unfavorable ventilation conditions due to the location in the trough of the Vistula valley, which leads to a slow dispersion of pollutants due to reduction (Metropolia Krakówska 2020; Olczak et al. 2021).

In the recent years policies have been adapted to modernise heating systems, banning boilers, stoves or fireplaces from the city of Krakow and increase standards for the whole Lesser Poland voivodship (XVII/243/16 2016; XXXII/425/17 2017). The implementation however remains slow and currently still half of the inhabitants of MK are exposed to health threatening levels of particulate matter (Metropolia Krakówska 2020). This poses a major threat to the health of the residents since air pollution can lead to cardiovascular and respiratory diseases and reduce the birth weight of children (Rosser et al. 2020; Ratajczak et al. 2021; Namdeo et al. 2011; Merklinger-Gruchala and Kapiszewska 2015). NBS can provide air purification, filtering pollutants and influencing the deposition and dispersion (Gómez-Baggethun and Barton 2013; Janhäll 2015). Consequently, for example green walls and roofs, as well as

trees and hedges have proven to improve air quality along streets in urban contexts if designed appropriately to the local conditions (Abhijith et al. 2017).

3.5.2.1 Exposure to air pollution

To estimate the exposure to air pollution the *average concentration of PM_{10}, $PM_{2.5}$ and NO_2* were mapped, as the permissible levels for these pollutants are exceeded in the study region (Wojewódzki Inspektorat Ochrony Środowiska w Krakowie 2018; World Health Organisation 2021). For all three indicators, interpolated air quality data prepared by the European Environmental Agency for the year 2019 was used (European Environment Agency (EEA) 2022).

3.5.2.2 Sensitivity to air pollution

Children have a higher sensitivity to the adverse health outcomes of air pollution, as their respiratory system is immature and still developing. Besides, they have a higher mouth breathing and ventilation per body weight. Compared to adults, they also spend more time outside, which increases their exposure to ambient pollutants (Miller et al. 2002; Selevan et al. 2000). A Polish case study clearly indicates a positive relationship between upper respiratory tract symptoms such as coughing and exposure to PM10 and PM2.5 in the age group of 3-12 years (Ratajczak et al. 2021). In turn, increasing air quality has shown to improve lung growth amongst youths (Gauderman et al. 2015).

Since part of their vulnerability stems from the higher respiration rate when being physically active, identifying where this activity takes place is crucial. For children living in urban and sub-urban areas, the largest portion of their physically active time is spent when walking or cycling on their way to school (Rainham et al. 2012). The Air Quality and Land Use Handbook prepared by the California Air Resources Board (2005) suggests considering residential as well as non-residential sensitive land uses where susceptible population groups spend time when examining justice based vulnerability to air pollution (Sadd et al. 2011). Thus this study takes into account the residential location of children by including the indicator *percentage of population below the age of 14,* as well as the *distance to elementary schools* and the *distance to playgrounds* where children are especially active.

The indicator *percentage of population above the age of 65* displays a second group especially sensitive to air pollution – elderly people (Tibuakuu et al. 2018)**.** For example pneumonia related mortality in connection with exposure to air pollutants increases for adults above 65 years (Fischer et al. 2003). Studies have also reported a negative impact of air pollution on depression symptoms in higher age groups (Lim et al. 2012; Altuğ et al. 2020). As a non-residential sensitive land uses the *distance to health and care facilities* realized with a 100 m distance decay was included, assuming a higher concentration of elderly at and in close proximity to those locations.

Lower income groups face more stress, which leads to overall poorer health (U.S. Environmental Protection Agency 2019), a precondition which makes them more sensitive to additional environmental stressors, such as air pollution. This phenomenon is relatively widely studied in the USA. However the findings of Knurowski et al. (2005) indicate that this might hold true also for the study area, as at least among elderly people higher income groups are healthier in Krakow. Again the *percentage of population receiving social assistance* and the *percentage of unemployed population in the working age* were used as proxies for the presence of lower income groups. Finally, the *population density* was included to account for the number of people affected by air pollution.

3.5.3 Noise pollution

In Europe 113 million people are affected by traffic noise levels above 55 dB and 22 million are exposed to railway noise (European Environment Agency 2020). The Environment and Space report of the

Strategy MK 2030 highlights the importance of noise stress especially along railway lines and national and provincial highways (Metropolia Krakówska 2020).

Exposure to noise pollution poses a threat to health, which can lead to preventable mortality among others due to cardiovascular conditions (Halonen et al. 2015; Tobías et al. 2015; Thacher et al. 2020). While noise often receives less attention compared to air pollution Tobías et al. (2015) found that a reduction of the diurnal noise level by 1 dB compares to a reduction of 10 $\mu g/m^3$ in $PM_{2.5}$ levels when examined to prevent mortality among elderly people. Noise also decreases the attention of children and thus can impact their learning experiences (Weyde et al. 2017). Reducing noise pollution is thus highly relevant for ensuring the health and wellbeing of citizens. NbS can alleviate these effects, for example vertical green walls can reduce noise (Paull et al. 2020; van Tang et al. 2021). Schäffer et al. (2020) further found that residential green reduces citizens' annoyance of noise from roads or railway lines. NbS could also create quiet areas, which can provide relief (European Environment Agency 2020).

3.5.3.1 Exposure to noise pollution

The exposure to noise pollution is displayed in this study by the *traffic noise level* above 50 dB. Following the EU Noise Directive, member states are required to report traffic noise levels from roads trafficked by more than 1 million vehicles per year, and railways frequented by more than 30.000 trains (European Parliament and Council). The Krakow Noise Map prepared by the City of Krakow (2017) also accounts for less busy but still noisy areas. However, it doesn't cover the surrounding municipalities. Based on this map, the daytime emission noise levels for all tram and railway lines as well as and roads differentiated by their street class were measured, and buffers were created around the features accordingly. Finally all noise sources were combined.

3.5.3.2 Sensitivity to noise pollution

In the legislation of European countries, it is common to define maximum allowed or targeted noise levels differentiated by land use. This rationale takes into account higher sensitivity of elderly, citizens with medical pre-conditions and children and of residential areas (European Network of the Heads of Environment Protection Agencies 2019). The *land use sensitivity* indicator in this study is based on Polish legislation, which sets out maximum permitted noise levels for hospital areas, care facilities, development areas related to the permanent or temporary stay of children and adolescent, residential areas, and recreational and leisure areas, with stricter values for areas outside of urban areas (Ministerstwo Środowiska 2007). Higher sensitivity values are assigned to areas with lower permitted noise levels. Besides, also the *population density* is considered in the sensitivity, to account for the number of people negatively affected by noise pollution.

3.5.4 Heat

Due to climate change already, a warming trend is clearly visible in Krakow and the number of hot days with a temperature of above 30°C is projected to increase further (Tomczyk et al. 2022). The formation of urban heat islands and a lack of ventilation aggravate the challenge in the study areas (Metropolia Krakówska 2020). A wide body of literature has proven the adverse effects of heat stress on human health, leading to an increase in respiratory, cardiovascular and all-cause mortality (Kovats and Hajat 2008; Curriero et al. 2002; Conti et al. 2005). NBS to mitigate heat stress include strategies to increase shading by planting trees, leveraging evapotranspiration from plants as well as evaporative cooling from water bodies or increase building insulation through green roof and wall structures (Balany et al. 2020).

3.5.4.1 Exposure to heat

To display the exposure to heat stress, the *heat island intensity* was mapped, based on satellite imagery during a heat wave as also proposed by Olczak et al. (2021). The land surface temperature is linked but

not identical to the near surface air temperature. Accordingly, it can serve as a proxy for identifying heat islands, even though in complex urban landscapes with a great diversity of land covers with different thermal properties this relationship varies (Amani-Beni et al. 2022). The selected day, 7th of August 2013 at 9:35 a.m. local time was the second day of a nationwide heatwave. Using imagery from the Landsat 8 sensor, areas with a land surface temperature above 30°C were identified following Sobrino et al. (2004) and Avdan and Jovanovska (2016).

3.5.4.2 Sensitivity to heat

The first indicator describing the sensitivity to heat is the *percentage of population above 65 years.* Elderly people are more likely to face adverse health outcomes from heat stress (Kovats and Hajat 2008; Curriero et al. 2002; Depietri et al. 2013). As for the sensitivity to air pollution *the distance to health and care facilities* was also included. Living in care facilities or hospitals statistically increases the mortality risk (Kovats and Hajat 2008). A second group sensitive to heat are people from lower income groups (Kovats and Hajat 2008; Michelozzi et al. 2005). As mentioned above this group is more likely to have a poor health status, which makes them more susceptible to heat stress. As proxies again the *percentage of population receiving social assistance* and the *percentage of unemployed population in the working age* were used. Finally the *population density* was included in the sensitivity to heat.

3.5.5 River flooding and runoff

River flooding from the Vistula river and its tributaries is a recurring phenomenon in the study area (Nachlik and Kundzewicz 2016). Surface runoff from heavy precipitation events also possibly leading to sewage overflows is increasingly seen as a challenge in MK (Metropolia Krakówska 2020). Surface runoff and river flooding are interlinked phenomena. In Krakow, the storm overflows, draining excess rainwater and sewage into the river close once the Vistula surpasses a certain water level, which is still meters below a 100-year flood. This leads to rainwater accumulating in the city as it can not effectively drain (Nachlik and Kundzewicz 2016). With climate change the risk of river flooding and the occurrence of heavy precipitation events resulting in flash floods are projected to increase globally (Yin et al. 2018) and also in the study area (Osuch et al. 2017).

Tackling stormwater runoff is one of the most common applications for NBS. Increased infiltration and filtering provided by raingardens, impervious surface covers and other types of green infrastructure can reduce surface runoff and the introduction of pollutants into aquatic ecosystems (Oral et al. 2020). The concept “Sponge City" calls for implementing such measures on a city wide scale to increase infiltration (Chan et al. 2018). NBS targeting fluvial flooding often focus on river restoration, increasing the natural storage capacity, and reconnecting rivers to floodplains (Chiu et al. 2022). For river flooding NBS can reduce adverse impacts especially for smaller flood events, which are less destructive but happen more frequently (Lallemant et al. 2021).

3.5.5.1 Exposure to river flooding and runoff

The exposure to river flooding is based on the official flood risk maps prepared by the State Water Holding Wody Polskie in accordance with the EU Floods Directive (Państwowe Gospodarstwo Wodne Wody Polskie n.d.a). The *risk of river flooding* indicators differentiates the risk for flooding events with a 0.2%, 1% and 10% probability.

To estimate the exposure to surface runoff in the case of high precipitation events, a simple *runoff coefficient* was calculated using land-use cover permeability classes and slope correction coefficient values proposed by Cecchi et al. (2007), also applied by Langemeyer et al. (2020). Originally the approach uses CORINE land-use data, to yield a more detailed result, I used the official Polish land-use data BDOT (Head Office of Geodesy and Cartography n.d.).

3.5.5.2 Sensitivity to river flooding and runoff

Flooding can cause damages to critical infrastructures (CI) which can have disrupting outcomes for society, involving cascading effects over different spatial and time scales (Pant et al. 2018; Sörensen et al. 2016). To account for this, I located *critical infrastructures*, including major roads and railway lines as well as objects of special social importance, such as hospitals, schools or fire protection units, as defined by the Polish flood risk maps (Państwowe Gospodarstwo Wodne Wody Polskie n.d.b). To account for the people affected by flooding events, the *population density* was included as well.

3.5.6 Landslides

Landslides and hillside erosion occur predominantly in the south of the MK, mainly due to the geological structure of the Carpathian Flysch Belt as well as heavy and prolonged precipitation (Małopolska Region 2021; Metropolia Krakówska 2020). In this latter way, landslides occur as secondary or cascading threats (Wells et al. 2022). Also constructions around foothills and the expansion of the road network triggers mass movement in the region (Małopolska Region 2021). NBS target shallow landslides and erosion for example by stabilizing slopes through vegetation cover (Apollonio et al. 2021; Grima et al. 2020; Jesús Arce-Mojica et al. 2019) or through adapted terracing designs (World Bank 2021). To mitigate deep-seated landslides, NBS might need to be paired with conventional grey infrastructure in hybrid solutions (Turconi et al. 2020). Since landslides are related to runoff and flooding events, NBS targeting these phenomena can also reduce the risk of mass movement (Ruangpan et al. 2020).

3.5.6.1 Exposure to landslides

To map the exposure to landslides I combined datasets prepared for the Małopolska Landslide Protection System (SOPO) into one **landslide risk** indicator. It includes areas of active landslides, periodically active and currently inactive ones as well as areas prone to mass movement (Polish Geological Institute 2015).

3.5.6.2 Sensitivity to landslides

Similar to flooding, landslides can damage critical infrastructures and thus disrupt functioning of society (Assilzadeh et al. 2010; Wells et al. 2022). The same indicator displaying the *density of critical* **infrastructure** was used. To account for the population affected by landslides, the *population density* was included.

3.5.7 Wildfires

Poland experiences more wildfires than the European average, and about 80% of its forest cover is threatened by fire (Grajewski 2017). In the formation of wildfires weather patterns, land-use and fuel management as well as heat sources, play together (Hesseln 2018). While heat sources can be of natural origin, e.g. through lighting, nowadays most fires are caused by human interference (Hesseln 2018). With climate change altering weather patterns the frequency of wildfires is projected to increase (IPCC 2022b). Fires pose a direct threat to life, reduce well-being and health by creating psychological stress and lead to damage and loss of property and infrastructure (Guzewski et al. 2016). It further adversely effect the environment by disturbing ecosystems (Mickler et al. 2013). NBS reducing wildfire risk usually are altered management practices of existing ecosystems. As mentioned the severity and spatial extent of wildfires can be decreased by controlled burning and reducing the fuel load by thinning forests, which also links to incorporating traditional knowledge (Chausson et al. 2020).

3.5.7.1 Exposure to wildfire

The exposure to wildfire is displayed by the *fire weather index* (FWI) that was prepared by Nykiel, Figurski (2020) for the year 2019. The FWI originally was implemented by the Canadian Forest Service and is

now widely used to forecast wildfires (Mandal et al. 2022). It estimates fuel moisture and fire behaviour, more specifically the rate of spread and fuel consumption based modelled meteorological parameters (Mandal et al. 2022). A mean of the daily FWI values was calculated to display the average fire risk.

3.5.7.2 Sensitivity to wildfire

To examine the sensitivity to wildfires, again the indicator *critical infrastructure* is used, since as for the previous two challenges, fire can damage and block critical services and structures (Wells et al. 2022). Besides the *population density* was included to account for the affected population.

The last indicator considers ecosystems with a high conservation value, such as protected habitats, where a fire would cause a major disturbance. While periodic disturbances through fires occur naturally, the increased frequency and severity of wildfires through anthropogenic influences can degrade ecosystems and reduce their functioning (Mickler et al. 2013). The indicator *areas under nature conservation* classifies protected areas according to the IUCN classes (IUCN 2008), assuming more valuable thus more sensitive ecosystems under stricter laws.

3.5.8 Drought

Droughts pose a challenge to the study area, even though it is more prominent in other parts of the country (Małopolska Region 2021). In 2020, Krakow was among 12 Polish cities to sign a declaration on the cooperation in the matter of drought, in order to exchange knowledge and share experiences, which highlights the awareness for the topic (Metropolia Krakówska 2020). Until now no significant increase in drought occurrence has not been observed in Poland (Kuśmierek-Tomaszewska and Żarski 2021), but the frequency of hydrological extremes is projected to increase globally due to climate change (IPCC 2022b).

Drought can pose food security at risk by reducing crop yields (Lesk et al. 2016). The physiological stress induced by droughts can either kill plants, or make them vulnerable to pests or diseases. Next to reducing crop yields, this impacts the ability of plants to serve their function in the ecosystem and to provide ecosystem services such as thermal regulation (McDowell et al. 2011). To maintain the provision of ES, one NBS approach promotes the use of drought tolerant species (Wamsler et al. 2017). This is also applied to maintain agricultural production (Zhao et al. 2022). Another strategy aims at increasing retention capacities storing water from (heavy) precipitation events to make it available during periods of drought, which can be realized for example through retention ponds or wetlands (Oral et al. 2020). To increase the water retention of agricultural soils the application of biochar has been widely discussed (Lehmann and Joseph 2015).

3.5.8.1 Exposure to drought

Drought indices are usually distinguished between meteorological, hydrological and agricultural droughts. For the latter, the soil moisture content especially in the period of crop production is crucial (Liu et al. 2016). Since more comprehensive drought indices would have been available only on a coarse resolution, this study uses the soil moisture content at a depth of 0-10 cm in % which was also provided by Nykiel, Figurski (2020) for the months of May to September 2019. Again a mean was calculated to display the average **soil moisture content**.

3.5.8.2 Sensitivity to drought

As for the previous challenge, the *areas under nature conservation* indicator classified according to the IUCN classes (IUCN 2008) were used to capture ecosystems of high importance, which's functioning could be impacted by drought stress (McDowell et al. 2011). The second sensitivity indicator includes all *areas of agricultural production* as a binary classification. I included annual and permanent crops,

meadows, orchards and also allotment gardens, since they can also contribute to food security (Poniży et al. 2021).

3.5.9 Habitat fragmentation

Habitat fragmentation combines habitat loss and breaking apart of habitats at a landscape scale (Fahrig 2003). While the latter can have weak to positive outcomes on biodiversity, habitat loss adversely impacts biodiversity and ecosystem functioning (Fahrig 2003), which in turn also impacts the delivery of ecosystem services to humans (Egerer and Anderson 2020). In urban areas, the connectivity of green spaces for example impacts of pollination (Johansson et al. 2018). Pollinating insects are crucial for ecosystem functioning. Recent studies indicate that in contrast to their surrounding countryside dominated by intensive agriculture, urban areas with their heterogeneous landscapes including flower-rich gardens and green spaces can provide refuges for pollinator communities (Hall et al. 2017). This turns urban areas into potential pieces for pollinator conservation. Johansson et al. (2018) thus highlight the importance for urban landscapes to “remain well connected and ecologically functional”.

While the amount of green spaces in the MK increases, habitats remain fragmentated and thus lack ecological corridors connecting habitats and allowing for species to (Metropolia Krakówska 2020). A lack of coherent planning among the municipalities facilitated this development (Metropolia Krakówska 2020). NBS strategies to tackle the challenge of habitat loss and fragmentation restore ecosystems especially along important corridors (Kuo et al. 2021) or create new habitats, such as green roofs in urban areas (Orsini et al. 2014), or artificial wetlands in agricultural landscapes (Préau et al. 2022).

3.5.9.1 Exposure to habitat fragmentation

For the exposure to habitat fragmentation I estimate the functional connectivity for pollinators, which describes their possibility to move within or between patches (Andersson 2006). Following a methodology put forward by Johansson et al. (2018) friction values were assigned to different land-uses, to model the ability and willingness of pollinating insects to travel through these spaces. For instance busy roads, buildings and large open water bodies are barriers to pollinator movements, thus high friction values where assigned, whereas grasslands or edges around forests and fields serve as food habitats and being displayed as low values in the *land use friction for pollinators* indicator (Johansson et al. 2018), indicating possibly higher connectivity.

3.5.9.2 Sensitivity to habitat fragmentation

In the making of the Strategy Metropolia Krakowska 2030, potential ecological corridors where mapped to prioritize green space development in these areas (Metropolia Krakówska 2021c). The *major ecological corridors* were used in this study as a sensitivity indicator, assuming that (re-)establishing habitats in these corridors is especially crucial to ensure functional connectivity.

3.5.10 Biodiversity degradation

Human actions, including land-use changes, exploitation of organisms, climate change, pollution and invasive species, lead to biodiversity declining worldwide (IPBES 2019). Around 25% of all species are threatened of which around 1 million faces extinction within decades if current trends are not reversed (IPBES 2019). The loss of biodiversity majorly alters ecosystem functioning and in turn also the provision of ecosystem services (Hooper et al. 2012). In the Małopolska voivoidshop, preserving biodiversity thus is a main goal for spatial development plan (Małopolska Region 2018). While the area of green spaces in the MK increased in the last years (Metropolia Krakówska 2020), the area under protection is stagnating (Małopolska Region 2021). Supporting biodiversity is at the core of the NBS concept, usually conceptualized as a co-benefit in measures targeting other challenges (European Commission 2021).

3.5.10.1 Exposure to biodiversity degradation

To map the currently occurring biodiversity loss, a *biodiversity intactness* indicator (BII) prepared by Newbold et al. (2016) for a resolution of 30 arc sec (~1 km²) was used. The BII was initially proposed by Scholes and Biggs (2005) and models the average abundance of species present, relative to their abundance in an intact pre-industrial ecosystem. Low BII values indicate a high exposure to biodiversity degradation.

3.5.10.2 Sensitivity to biodiversity degradation

While a legal protection status is no definite guarantee for preserving or improving biodiversity (Gatiso et al. 2022), populations of endangered species declined faster in areas not covered by nature conservation regulations (Kajzer-Bonk and Nowicki 2022). The work of Sowińska-Świerkosz and Soszyński (2014) showed that national parks are better preserved than landscape parks, which indicates a gradient according to protection strictness. To display the sensitivity to biodiversity degradation, I thus use the indicator of *areas under nature conservation* differentiated by strictness, though this time assigning higher sensitivity values to areas with no or low protection, assuming that the decline in biodiversity will be even sharper in those areas.

Criteria

The above-mentioned criteria were discussed with stakeholders and their selection was accepted, although some of the suggestions and comments went beyond direct area of criteria (e.g. landslide issue, air-sanitary conditions, issues related to waste and circular economy) or could require adding an additional challenge criterion, ecological - biodiversity (different from fragmentation and degradation of the environment). The list below is the final selection of criteria (Table 5):

Table 5. List of co-created criteria

Criteria for the diagnosis
Lack of recreational opportunities
Air pollution
Noise pollution
Heat
River flooding and runoff
Landslides

Wildfire
Drought
Habitat fragmentation
Biodiversity degradation

Indicators

During the workshop, the selection of indicators was also discussed ending in many suggestions for important new indicators. Here we report the main concerns expressed. Among those with the largest number of votes were: transport accessibility (public transport, use of cars, accessibility by foot), gender (there are studies on a different functioning in the city by gender), measurements of the level of retention and detention in the city.
Within the criterion of "social awareness" doubts were raised by distance indicators from educational institutions and green areas, while at the same time indicators related to demographic and economic structure (income, age, other) were highlighted. An additional indicator, important not only for the areas of the Krakow Metropolis, but also potentially also for other cities of the INTERLACE project, was the risk of landslides. A lot of additional information (mainly related to environmental awareness) can be gained by analysing issues related to waste management and the level of segregation or the location of illegal dumps.

Data

A large part of data is already in resources of SMK (e.g. as elements of Strategy 2030 or its attachments), however, probably there would be no data on sunny/cloudy days for Krakow. Important data is the degree of afforestation, population density, but also population change in given places.
Use of data on existing combined sewage systems or small retention systems (My Water and Krakow Micro Retention programmes).
Additional data on socio-ecological challenges may also be provided by the number of interventions of e.g. fire brigades in given areas, e.g. related to flooding. There are far fewer registered residents in Krakow than actually live here, which may affect the results of the surveys and analyses.

Table 6. Criteria and indicators for the diagnosis

Criteria for the diagnosis	Weight (%)	Indicator	Normalisation	Justification / Reference
Lack of recreational opportunities	*20*	Walking distance to green spaces below 0,5 ha	Min: 0,014 Max: 1	Lack of physical or visual access to green spaces can affect both mental and physical health. Vulnerability to lack of recreational opportunities consists of walking distance to green spaces, visibility of vegetated areas and bodies of water, and density of non-green recreation opportunities. This is combined with population density and the percentage of the population under the age of 14, which is particularly vulnerable, since growing up in an environment without access to green space can have a negative impact on people's mental and physical health throughout their lives. In addition, the percentage of unemployed people of working age and the population on social assistance, who have fewer resources to access recreational opportunities, are in-cluded.
	20	Walking distance to green spaces above 0,5 ha		
	20	Visibility of green		
	20	Visibility of blue		
	20	Distance to ono-green recreation		
	33,33	Percentage of population below 14 years		
	16,67	Percentage of population receiving social assistance		
	16,67	Percentage of unemployed population in the working age		
	33,33	Population density		
Air pollution	33,33	Average concentration of PM10		Air pollution can pose health challenges. To estimate exposure to air pollution, average concentrations of PM10, PM2.5 and NO2 were determined. The % of welfare recipients and the unemployed were taken into account to assess sensitivity, as these groups are more likely to suffer from poor health. The percentage of the population under 14 and over 65 was also taken into account, as these groups are particularly sensitive to exposure to air pollution, as well as the distance from schools, play- grounds, hospitals, doctors and care facilities, where
	33,33	Average concentration PM2,5		
	33,33	Average confrontation NO2		
	12,50	Percentage of population above 65 year		

	12,50	Distance to health and care facilities		there is a higher concentration of these sensitive groups. Finally, popula- tion density was taken into account.
	12,50	Percentage of population below 14 years		
	6,25	Distance to elementary schools		
	6,25	Distance to playgrounds		
	12,5	Percentage of population receiving social assistance		
	12,5	Percentage of unemployed population in the working age		
	25	Population density		
Noise pollution	100	Traffic noise level above 50db		Noise pollution can challenge well-being and health by increasing stress levels. To estimate noise exposure, distances from roads, streetcars and railroads were determined. This was combined with sensitivity to land use, taking into account noise- sensitive areas such as hospitals, residential or recreational areas. In addition, population density was taken into account.
	50	Land use sensitivity		
	50	Population destiny		
Heat	100	Heat islands above 30^{o}C		Hot weather can pose challenges to health and well-being. Heat sensitivity consists of the surface temperature during a heat wave combined with the percentage of the population over 65 and the distance to hospitals and retirement homes, where more sensitive people are expected. The elderly are more likely to suffer serious health effects related to heat stress. In addition, the percentage of welfare recipients and the unemployed, who are less able to adapt to heat stress and are more likely to suffer from poor health, was taken into account. Finally, population density was taken into account.
	16,67	Percentage of population above 65 years		
	16,67	Distance to health + care facilities		
	16,67	Percentage of population receiving social assistance		

	16,67	Percentage of unemployed population in the working age		
	33,33	Population density		
River flooding and runoff	50	Fluvial flood risk		Flooding and runoff can pose a direct threat to life, disrupt society, and pose a current and economic burden. Vulnerability to flooding and river runoff is made up of the risk of flooding and the runoff coefficient, which determines surface runoff gener- ated during heavy rainfall. In addition, the density of critical infrastructure, such as hospitals or major roads, and population density were taken into account.
	50	Run-off coefficient		
	50	Critical infrastructure		
	100	Population destiny		
Landslides	100	Landslide risk		Can pose an immediate threat to life and a challenge to the functioning of society when critical infrastructure is damaged. Landslide vulnerability consists of the risk of landslides combined with the density of critical infrastructure and population density.
	50	Critical infrastructure		
	50	Population destiny		
Wildfire	100	Wild fire risk		Can pose a direct threat to life and a challenge to the functioning of society when critical infrastructure is damaged or blocked. Vulnerability to fires consists of a fire risk index, combined with the density of critical infrastructure and conservation areas to include the most significant habitats. In addition, population density is included.
	33,33	Areas under nature conservation		
	33,33	Critical infrastructure		

	33,33	Population destiny		
Drought	100	Soil moisture content		Can challenge (agro-)ecosystems and thus food security. Drought vulnerability consists of the soil moisture index combined with areas of agricultural production where productivity is critically linked to drought stress. In addition, conservation areas were included to include the most relevant habitats.
	50	Areas under nature conservation		
	50	Areas of food population		
Habitat fragmentation	100	Land use friction for pollinators		Is a major challenge to ecosystem functioning and a threat to biodiversity. To determine sensitivity to habitat fragmentation, a distance for pollinators was determined, which indicates the resistance with which pollinators traverse an area (e.g., large roads are a barrier to pollinators). This was combined with corridors with high connectivity potential
	100	Main ecological corridors		
Biodiversity degradation	100	Biodiversity intactness		Threatens the health of ecosystems and ultimately also affects food security and human well-being. Vulnerability to biodiversity degradation consists of the biodiversity intactness index and the protection status of nature conservation areas.

Table 7. Weighting of the diagnosis criteria

Criteria for the diagnosis	Weighting	Reasons for the weighting/comments
Lack of recreational opportunities	50	
Air pollution	315	
Noise pollution	94	
Heat	205	
River flooding and runoff	205	
Landslides	40	
Wildfire	71	
Drought	135	
Habitat fragmentation	75	
Biodiversity degradation	110	

Mapping and integration

To determine the spatial distribution of vulnerabilities, first of all the indicators were mapped in ArcMap 10.8, ArcGIS Pro and QGIS 3.16 Hannover. After the initial preparations, all vector data was turned into raster format to allow for the integration of different resolutions as also realised in Langemeyer et al. (2020). A cell size of 10m * 10m was chosen as a compromise between accuracy and computing capacity. Raster data with a coarser resolution was resampled. Finally all indicators where scaled from 0-1 to allow for the integration of different scales and units using the equation (1),

$$Xi\ scaled = \frac{Xi - X\ min}{X\ \max - X\ min} \qquad (1)$$

where *Xi scaled* is the rescaled value of the indicator *X* at cell i, *X min* is the minimum and *X max* is the maximum value of the indicator *X* within the study area.

For each challenge, an exposure map and a sensitivity map were generated by creating a weighted sum of the respective indicators. All indicators describing the same phenomenon were clustered, and then in sum weighted equally. For example the sensitivity to the lack of recreational opportunities is composed of the population density, the share of population below the age of 14, the share of people with a low economic status. The latter is described by two indicators, namely the *percentage of the population receiving social assistance* and the *percentage of the unemployed population* in the working age. The sum of these two indicators thus weights as much as the indicators *population density* and *percentage of population below 14 years* respectively.

The exposure and sensitivity maps were then multiplied in the ArcMap Raster Calculator to obtain the vulnerability map for each challenge, following equation (2):

$$Vulnerability_{Challenge\ x} = \sum Exposure\ indicators_{Challenge\ x} * \sum Sensitivity\ indicators_{Challenge\ x} \quad (2)$$

To finally calculate the combined vulnerability map the vulnerabilities for the different challenges where combined using the weightings obtained from the two stakeholder weighting exercises. Two robustness tests were performed: to examine the importance of the population density, the whole analysis was repeated with a binary population layer instead, sorely indicating whether people live in an area but how many. Besides a combined vulnerability map assuming equal weights for all challenges was also prepared, to display the importance of the stakeholder weighting. The integrated vulnerability map is shown in Figure 10.

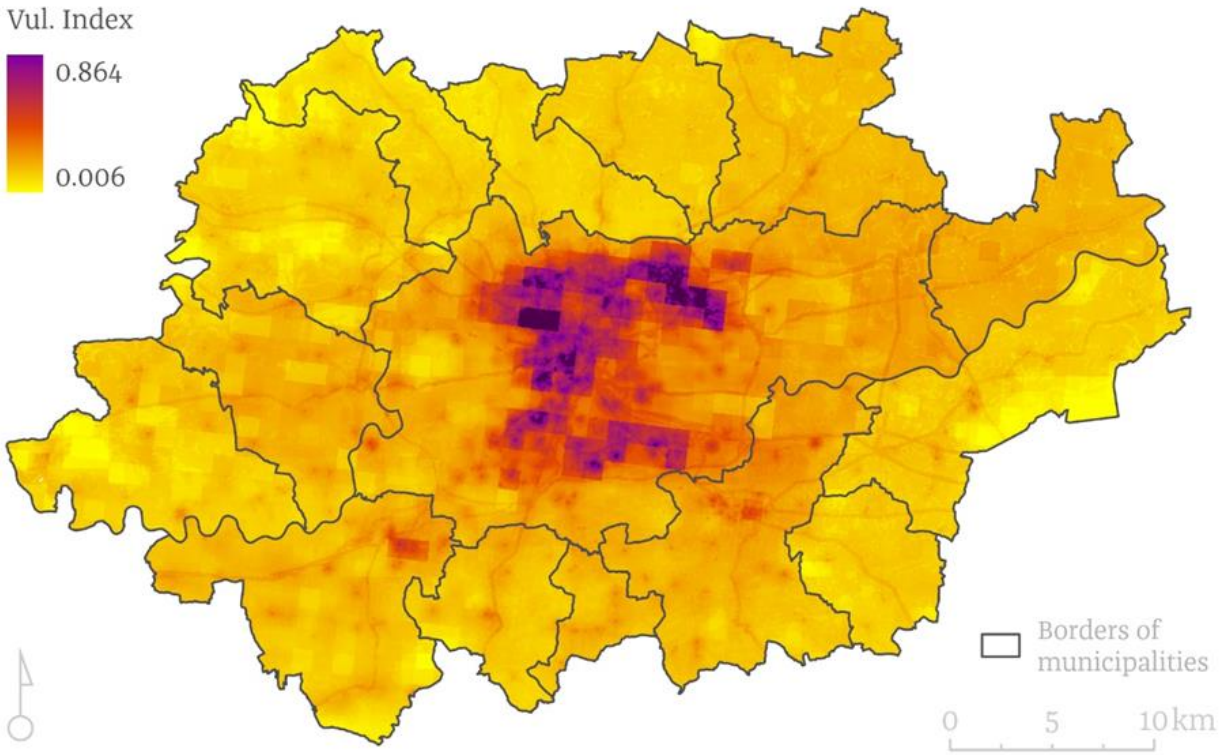


Figure 10. Spatial Screening Results Metropolitan Area of krakow

The overall vulnerability ranges from 0.006 to 0.864 with a mean of 0.153, although the spatial vulnerabilities for the different challenges vary greatly across the MK. For instance, there is a gradient of social-ecological vulnerability scoring lower values in rural parts and higher values in highly populated urbanised areas, where critical infrastructures concentrate. The highest vulnerability index scores are located in densely populated areas of Krakow such as Krowodrza, Bieńczyce and Nowa Huta, where challenges like air pollution, heat and biodiversity degradation are prominent. Local hotspots can be identified also in the denser populated areas of the cities of Skawina and Wieliczka. While here the vulnerability to biodiversity degradation is lower, other challenges including noise are just as present as in the region's capital. Higher scores are also reached along major streets throughout the study area. When averaged on the municipality scale Krakow again shows the highest vulnerability with a mean index value of 0.25, followed at some distance by the municipalities Wieliczka (0.16) and Igolomia-Warzenczyce (0.15).

While in Igołomia-Wawrzeńczyce the population density is low, the share of population receiving social assistance is greatest. In addition the area faces a greater vulnerability to drought, due to its relatively low soil moisture content and high share of agricultural area. The lowest vulnerability is observed in Wielka Wies with a mean of 0.09, followed by Zielonki (0.09) and Niepolomice (0.10). In these three municipalities larger areas are protected under nature conservation regulations, where also the overall lowest vulnerability occurs. When not considering population density but population presence instead, the maximum vulnerability index scores 0.347, and the mean is lowered to 0.1. Still the highest values are observed in urbanised areas of Krakow. In this layer, the areas close to the Vistular river also score relatively high vulnerability, as the sensitivity to flooding and runoff is more homogenous and thus areas prone to flooding and surface runoff impact the overall result more. Besides, the area at the border between Krakow and Igolomia-Warzenczyce gains relative importance in this scenario. Here, no single challenge stands out, but rather relatively high vulnerability values are observed in several aspects. The

relative importance of the challenges determined in the co-creation process visibly alters the results. When weighting all challenges equally, the overall social-ecological vulnerability index reaches only a maximum score of 0.39. The difference between the combined vulnerability and the combined vulnerability with equal weights can be attributed mainly to the vulnerability to air pollution, which is weighted as most important.

4. Corredor Biológico Interurbano María Aguilar (CBIMA)

4.1. Description of CBIMA and the area of intervention

The “Corredor Biológico Interurbano María Aguilar” (CBIMA) constitutes a geographical area in the metropolitan area of San José, Costa Rica. Established in 2009, CBIMA serves as a vital ecological and urban link, weaving through the heart of the region. This interurban corridor encompasses an area of 39 km², a blend of modified and natural habitats, and is home to approximately 400,000 residents.

The corridor of CBIMA is uniquely structured, as it integrates five municipalities, each consisting of several cantons. These municipalities are connected through the María Aguilar River, a tributary of the Virilla River, which itself flows into the Rio Grande de Tárcoles. This natural water network not only provides ecological continuity but also supports diverse urban and natural landscapes within the corridor.

The municipalities included in the CBIMA are:

- La Unión: This area encompasses cantons like San Ramón, Dolce Nombre, San Juan, and Concepción de Tres Ríos. Each of these cantons contributes its unique ecological and cultural characteristics to the corridor.
- Curridabat: Known for its cantons such as Curridabat, Granadilla, and Sánchez, this municipality adds to the diversity and ecological richness of CBIMA.
- Montes de Oca: This municipality includes the cantons of San Pedro, Sabanilla, and San Rafael, offering a mix of urban and natural elements to the corridor.
- San José: As the capital city, it brings a significant urban element to the corridor, with its cantons like Carmen, Hospital, Catedral, Zapote, San Francisco de Dos Ríos, Mata Redonda, Hatillo, and San Sebastián.
- Alajuelita: It includes the canton of San Felipe, rounding off the corridor’s diverse ecological and urban tapestry.

Each of these municipalities and their respective cantons plays a crucial role in the restoration and conservation of the CBIMA. The corridor's design recognizes the intricate balance needed between urban development and ecological preservation, aiming to enhance biodiversity, ecological connectivity, and quality of life for its residents. The CBIMA not only stands as a testament to innovative urban ecological planning but also paves the way for sustainable urban development strategies in other metropolitan regions.

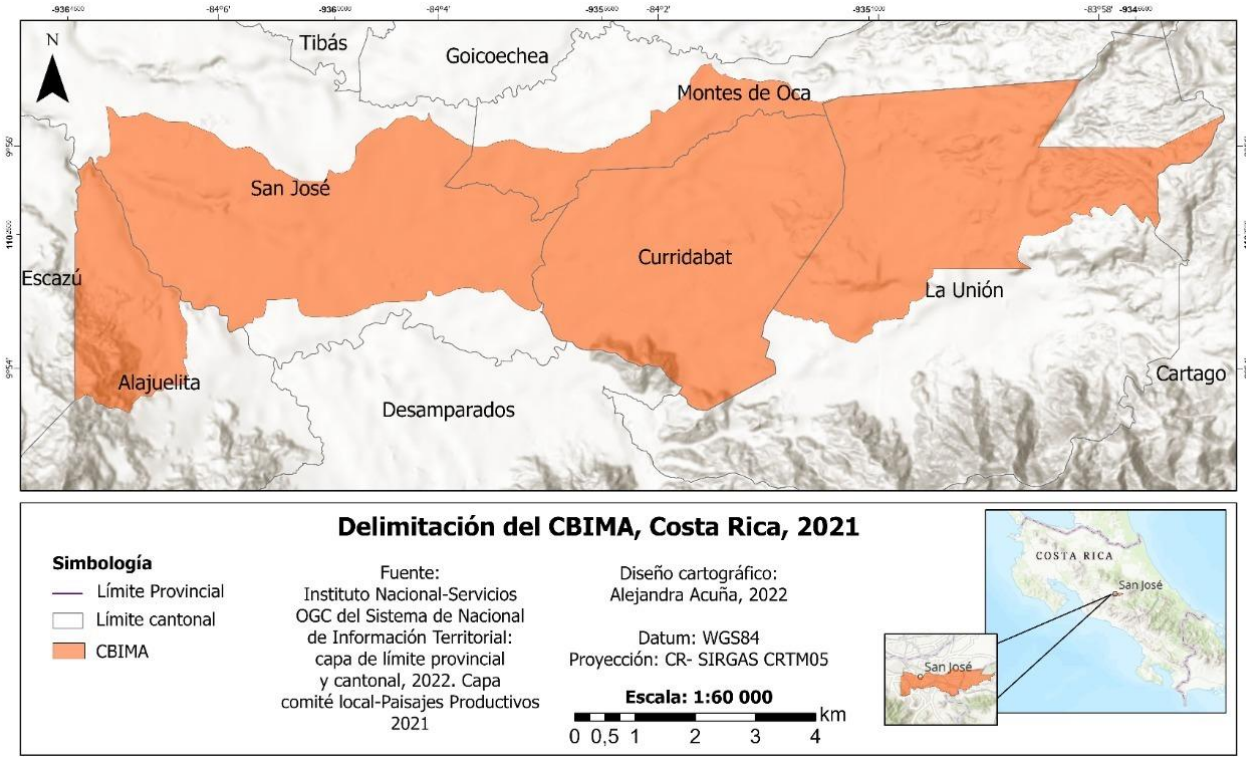


Figure 11. Map of CBIMA (Corredore Biológico Interurbano María Aguilar).

4.2. Status of implementation of the assessment system

The development of the assessment system has reached completion as per the objectives of INTERLACE Work Package 3. Concurrently, local partners from UNA Costa Rica are actively engaged in supporting the utilisation of the generated information by local governments. This follow-up by the UNA Costa Rica team is essential in ensuring the practical application and effectiveness of the assessment system in local governance contexts.

4.3. Module II. Decision Framing

Definition of the assessment system

Describe the challenges to be addressed

1. Environmental Education
2. Information Availability

Describe the objectives of the assessment.

1. To identify vulnerable areas in CBIMA
2. To identify priority areas for the development of NBS interventions.
3. To identify information gaps for the development of an assessment framework

Definition of scale

Define the scale of the intervention, including considering cross-scale implications, Scale n =

CBIMA scale (5 Municipalities, 400.000 people)

Definition of scope and constraints

1. The data availability.
2. Data not available at the municipal level
3. Institutions have many requirements for data sharing and are slow in the process.

4.4. Module III. Co-creation

The co-creation process implemented in the CBIMA project focused on urban ecosystem restoration in San José's metropolitan area. This participatory approach was structured into distinct phases: preparation and co-design, co-creation of criteria, and deliberation of preferences, each incorporating insights from both experts and local stakeholders.

Preparation and Co-Design: This initial phase involved two key steps. Firstly, stakeholders were identified and categorised based on their roles, interests, and potential impact (see Table 8). This step was crucial for engaging stakeholders effectively throughout the project. Secondly, a product vision was created, outlining co-creation goals and engagement objectives to foster a mutual understanding of project aims among all participants. Two online co-design meetings were held, with the first focusing on defining challenges and urban vulnerability criteria, and the second finalising plans for participatory workshops.

Table 8. List of stakeholders

Name of the representative	Organisation	Stakeholder role (select one from list in Table 1)	Stakeholder group (select one from list in Table 2)
1.Alpizar Hidalgo: Distrito Centro 2.Eduardo Vargas: Granadilla 3.Vilma varela: Centro 4.Tracey Calvo: Centro 5.Silvia Paez: Ministerio de Salud 6.Emilia Seco: Centro 7.Rutbeth Ávila: vecina de Tirrases	Civil society Curridabat	Enablers, Interested Public	Civil society
1.Rodrigo Hernandez Jimenez: Catedral 2.Maribell Segura Ceciliano: Hatillo 3.Elizabeth Fallas Gamboa: Hatillo 4.Gerado Lopez Ch: Hatillo 5.Miriam Guzmán Cruz: Hatillo 6.Luz Mary Arias Ocampo: Hatillo	Civil Society San José	Shapers, End-users, Enablers	Local and regional governmental authority

1.Karen Solara Rojas: Municipalidad de San José	San José Municipality	Shaper	Gubernamental Authorities
1.Mariela Gomez Lawson: Uruca, MEP	Ministry of Education	Shaper	Academia, Reserch, Education
1.Helga Zeuner: San Ramón de Tres Ríos 2.Sol Fernández: Dulce Nombre (vecina de San José, pero es voluntaria en el vivero de Dulce Nombre) 3.Seidy Guerrero Anchia: Concepción 4.Lilliana Campos Hernández: Concepción 5.Patricia del Carmen Segreda Rodriguez: La Unión centro 6.Annia Cordero: Tres Ríos, Municipalidad de La Unión 7.Amanda Quirós Montenegro 8.Teresita Solís Richmond: San Rafael La Unión 9.Maritza Zuñiga Cantillo: Concepción 10.Ma. Elena Rodríguez Brenes: Concepción	Civil Society La Union	Shapers, End-users, Enablers, Interested public	Academia, research and education

11.Francisco Rojas: San Juan 12.Sonia Bertsch Hernández: Tres Ríos			
1.Katherine Quirós	Municipalidad de La Unión	Shaper	Gubernamental Authorities
1.Ana Yancy Chavarria Garcia: Alajuelita centro 2. Maribell Gómez: San Felipe 3. Gabriela Bonillla Corrales: Alajueli ta centro 4.Sielbrite: San Felipe 5. Flor Maria Zuñiga Rodríguez: Alaju elita centro 6. Jonathan Arrieta Ulloa: Alajuelita centro 7. Marco Castro: Concepción 8. Jenny Marcela Mora Campos: Centro 9. Rosario Ruiz: Alajuelita centro 10. Norma Camacho Marín: Alajuelita centro	Civil Society Alajuelita	Developers, Shapers, End-users, Enablers, Interested public	Academia, research and education
Liliana Vargas: Municipalidad de Alajuelita	Alajuelita Municipality	Shapers	Gubernamental Authorities
Keily Mena Alfaro:	Alajuelita Municipality	Developer	Gubernamental Authorities

Elizabeth Jiménez: Asociación de vecinos de Barrio Pinto, San Pedro Mario Ruiz Salas: Montes de Oca Accesible, Sabanilla Emilia Rodríguez Corrales	Civil Society Montes de Oca	Interested Public	Civil Society
Francini Acuña Piedra: Especialista geógrafa Adriana Moya Mora: Arq. Paisajista Sofía Richmond Blanco Arquitecta Ana María Lobo Calderón Derecho Ambiental	TEVU (GEF-PNUD Project)	Enablers	Academia, research and education
Erika Calderón	INVU	Developer	Gubernamental Authorities
Mauricio Vega	UNA	Developer	Academia, reserch and education
Miguel Luna	Montes de Oca Municipality	Developer	Gubernamental Authorities
José Retana	Curridabat Municipality	Developer	Gubernamental Authorities
Jenaro Campos	San José Municipality	Developer	Gubernamental Authorities

Randall Retana	San José Municipality	Developer	Gubernamental Authorities
Marcela Gutiérrez	UNA	Developer	Academia, reserch and education
Alejandra Acuña	UNA	Developer	Academia, reserch and education
Gloria Muñoz	La Unión Municipality	Developer	Gubernamental Authorities
Samantha Montoya: San Rafael de Montes de Oca	Biofilica	Developer	Private Sector
Tirsa Aguirre Salazar Ministerio de Salud, área rectora de Hatillo	Ministry of Health	Shaper	Gubernamental Authorities

Co-creation goals

- Civil Society was involved in order to facilitate the environment for collaborative efforts centered on common interests, goals, and principles. An informed society is a key for the development of NBS in the territories.
- Gubernamental Authorities were involved as shapers to make sure the end-results meet their needs.
- Academia, research and education supported the process of criteria selection and provided some of the data

Co-Creation of Criteria: Utilising an Analytical Hierarchy Process (AHP), this phase aimed to integrate place-based stakeholder knowledge to identify specific urban vulnerabilities. The process started with an initial challenge list based on stakeholder input and was fine-tuned through continuous engagement, ensuring equity and social inclusivity in decision-making.

Deliberation of Preferences: This stage employed an agile approach, allowing for adaptability and transformative change based on stakeholder feedback. A series of six participatory workshops (one metropolitan and five municipal) were conducted, focusing on prioritising urban vulnerabilities for future Nature-Based Solutions (NBSs) planning. These workshops involved a "Participatory Weighting

Workshop," where participants used a pebble-distribution method to weigh various urban vulnerability criteria. The workshops included individual and group exercises, moderated discussions, and a final joint discussion to reach consensus on the prioritisation of issues.

Throughout these phases, the process was characterised by continuous stakeholder engagement, collaborative decision-making, and iterative refinement of objectives and strategies. This comprehensive approach ensured that the project's outcomes were aligned with the diverse needs and preferences of the communities involved in the CBIMA region.

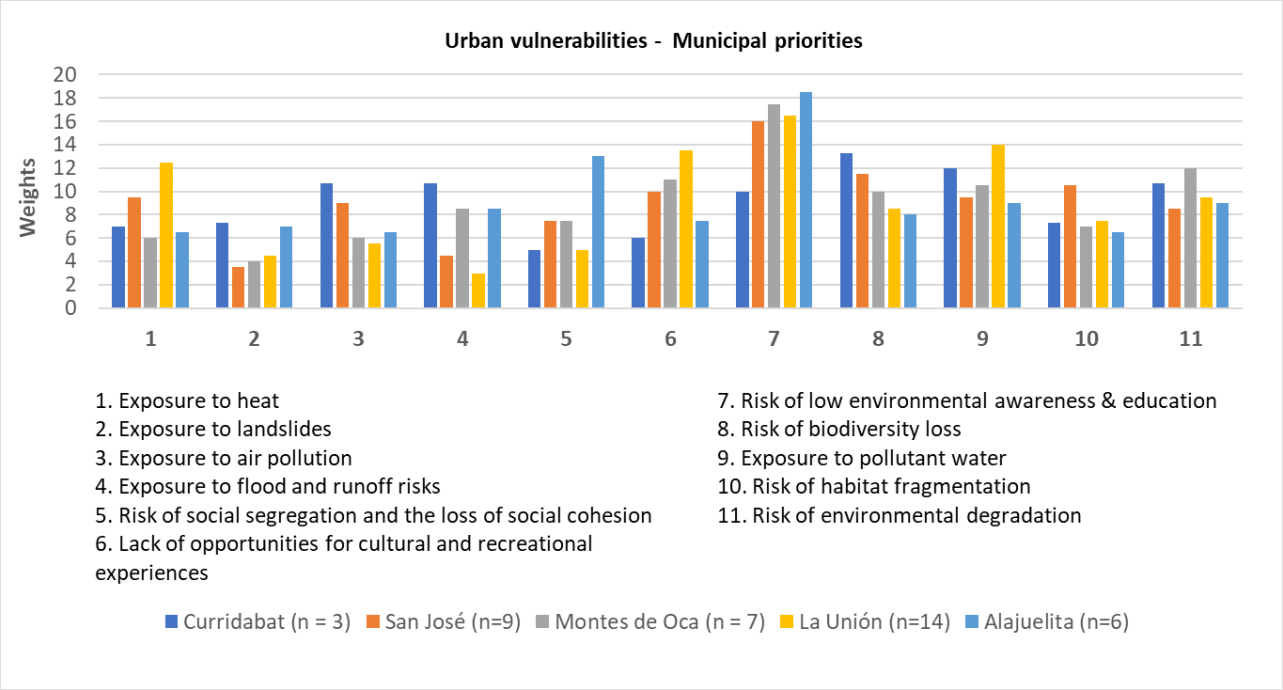


Figure 12. Results of participatory weighting exercise on a municipal scale using a Pebble Distribution method. The consensus weights obtained after final joint discussion are presented in normalised values. The higher the attributed weights the higher importance to be addressed by NBSs.

Table 9. Implementation plan of the engagement activities

Engagement activity	Objective	When to conduct it	Who to involve	Format
Selection of criteria	Choosing the main criteria	February 2022	CNA	online workshop

Selection of indicators	Selecting and matching appropriate indicators to the criteria	February 2022	CNA	online workshop
Weighting	weighting	September 2022	CNA and conference participants	workshops as part of the Cities Talk Nature conference. Survey for the above stakeholders
Weighting and discussion on possible application of the climate change vulnerability maps	final weighting with local stakeholders	October 2023	CNA	workshops

4.5. Module IV. Spatial screening

During the workshop, the criteria for the diagnosis was co-created (Table 10).

Table 10. List of criteria

Criteria for the diagnosis
Lack of environmental awareness- environmental education

Water contamination
Ecological habitat fragmentation
Lack of opportunities for cultural and recreational experiences
Environmental degradation
Heat exposure
Exposure to flood and runoff risks
Exposure to air pollution

Table 11. Weighting of the diagnosis criteria

Criteria for the diagnosis	Weighting	Reasons for the weighting/comments
Lack of environmental awareness-environmental education	11.4375	The reason for this weighting is based on the concept of environment and consciousness, which is associated with both terrestrial and aquatic components. Social aspects are considered where the relationship that individuals have with the environment is valued. Therefore, it is assessed that throughout the cantons that make up the CBIMA there is a serious problem in waste disposal, infrastructure for waste management

		and availability of routes for the collection of recoverable waste.
Ecological habitat fragmentation	4.9375	The assigned weight is due to reasons of habitat fragmentation produced by humans, which causes modifications in territorial dynamics. One of the great challenges facing the CBIMA is poorly planned urban growth, which alters the natural landscape and, therefore, the mobility of species.
Water contamination	11.9375	As in the previous criterion, the inadequate urban planning presented by the Greater Metropolitan Area (GAM) of Costa Rica causes urban rivers to have high levels of pollution. From the results obtained by AyA, it is evident that in 2021 the CBIMA rivers were contaminated by fecal coliforms. Likewise, the sizes of illegal discharges that are present in different cantons of the CBIMA are considered.
Lack of opportunities for cultural and recreational experiences	8.9375	The weighting of this criterion is based on the importance of the presence of green spaces within the CBIMA cities. Although a series of mechanisms have been worked on to reactivate green spaces within the CBIMA, more methodologies and work mechanisms still need to be implemented to strengthen these spaces, in order to maintain the culture of the territory. Furthermore, the restoration of areas that are on the margins of rivers is a challenge that is faced through NbS.
Environmental degradation	8.4375	This criterion is weighted based on the elements of nature and urban elements present in the CBIMA.

Heat exposure	209375	The GAM has presented unpleasant behavior on the issue of heat islands, which is why they are considered indicators of the surface temperature of the earth and buildings, where educational centers and the elderly population are located, because children and older adults They are the population most affected by high temperatures, and in general, most of the CBIMA public educational centers are waterproofed, the classrooms are small and the number of children is quite considerable. It is also considered that children and young people spend most of their time in these places.
Exposure to flood and runoff risks	10.9375	The sewage systems are currently not suitable for the conditions demanded by the population of the GAM, floods caused by these systems are present during the rainy season and during natural disaster events.
Exposure to air pollution	22.4375	The weighting is based on the vehicle demand present in the CBIMA cities, as well as in other cities in Latin America. The concentrations of PM10 are one of the most polluting particles, causing residents to be prone to heart, lung, and cerebrovascular diseases, among others.

Definition of indicators

Indicators are **observable** and **measurable** characteristics that can be used to specify criteria. Once the final list of criteria to be taken into account has been identified, an important technical component is to define the indicators that allow the diagnosis (measure the current state) with respect to each criterion. The definition of spatial indicators for SBN prioritisation is determined by the scientific literature and feasibility in the context of the project (e.g. access to existing data, possibility of creating proxies).

Before selecting the indicator, you must answer these questions to decide whether or not to include the indicator:

- Is the indicator scientifically justified to measure the current situation with respect to the criterion?
- Is the indicator measurable in terms of data availability?
- Do you have the resources (financial, technical and personnel) to have the necessary data to measure the indicator?

While it is key that the definition of criteria is co-produced with stakeholders, the identification of indicators can be done with a smaller group of key actors/experts, based on literature review, or by the implementing team.

For each indicator, the relative weight in its contribution to the corresponding criterion is defined.

In order to execute the final integration, each indicator has to be normalised at the same scale (usually from 0 to 1, or from 0 to 100). The normalisation procedure may vary with respect to different indicators. A standard normalisation would be the min-max normalisation; however this normalisation is not necessarily the most appropriate.

Table 12. Weighting of the diagnosis criteria

Diagnostic Criteria	Weight	Indicator	Normalization	Justification
Lack of environmental awareness-environmental education	*33.3*	*Green Infraestructure*		*The green plot corresponds to the natural green areas within the urban fabric and responds to the concept of green infrastructure, which is defined as a network of green spaces and other high-value natural elements, planned and developed from a strategic perspective in the city (Toribio& Ramos, 2017, who cite Natural England).*
	33.3	*The walking distance to green spaces*		*The walking distance to green spaces is calculated in a range of 300 meters, to know the proximity to green spaces (urban parks) in urban centers.*
	33.3	*Urban parks*		*The urban ones are identified within the CBIMA.*
	33.3	*Amount of Green space per inhabitant*		*Miranda (2021) alludes that "each inhabitant of this biological corridor has 0.95 m2" (p.47). Therefore, a calculation is made of what really corresponds to an inhabitant in relation to the green area.*
	33.3	*Population of Children and population of 65 or older*		*This type of population is chosen because they are the ones that use green spaces the most, whether for recreational activities or social interaction.*

Vulnerability to exposure to air pollution	33.3	PM10 concentration		*Alpízar et al., (2017) highlights that in Central America the concentrations of PM10, which are one of the polluting particles, exceed the parameters imposed by the World Health Organization (WHO).*
	33.3	NO2 concentration		
	100	Population of 65 or older		The population aged 65 and over is considered older adults, and is the most vulnerable to diseases related to air pollution and for which the Costa Rican Social Security Fund (CCSS) has the greatest record
Vulnerability to water pollution	33.3	Population density		Population density helps to understand and analyze which cantons have the highest population concentration.
	33.3	The invasion of springs		The interruption to the springs most of the time is due to concentrations of homes, many in illegal condition, which alters the conditions of the water
	33.3	Number of fecal coliforms Water quality		The Costa Rican Institute of Aqueducts and Sewers carried out a study with different points through the GAM, including the CBIMA, in order to know which are the most relevant contaminants in the waters.

		sampling sites		
	100	Water discharges		In the CBIMA there is a problem with water discharges, however, in this section the sizes of these are considered to relate them to the impact it generates on the environment.
Vulnerability to heat exposure	50	Earth Surface temperatur e		In the GAM, in recent years, unpleasant temperatures have been reported in places with greater population density, highly concentrated infrastructure, l and scarse green spaces
	50	Surface temperatur a of buildings		In the GAM, in recent years, unpleasant temperatures have been reported in places with greater population density, highly concentrated infrastructure, l and scarse green spaces
	50	Location of public educational centers		. Public educational centers are considered because it is where children and young people spend most of their time, also considering that the conditions of some facilities are not adequate.
	33.3	Population of 65 and older		Older adults are considered a vulnerable population.

	33.3	Population density		Population density helps to understand and analyze which cantons have the highest population concentration.
Flood and runoff risk vulnerability	100	Risk of fluvial floods according to the National Emergency Commission		The territories that present the highest risk of flooding are identified according to data from the National Emergency Commission (CNE).
	50	Critical Infrastructure		It is the infrastructure that is vital for society and to economy.
	50	Population density		Population density helps to understand and analyze which cantons have the highest population concentration.
Vulnerability to ecological habitat fragmentation	100	normalized difference vegetation index and land use		These two indicators are used together to analyze the different land uses that are present in the CBIMA and recognize forest vegetation.
	100	protection areas of CBIMA		It is used to define the protection areas that are present in CBIMA

Vulnerability to environmental degradation	50	Protection areas vs invasión areas		Lavell (1996) alludes to the fact that urban environmental degradation occurs because of the way in which a city manages sustainability, and also shows how a society can be vulnerable.
	50	Land use		
	100	Water discharges and dumps in the CBIMA		
Vulnerability to lack of environmental awareness-environmental education	25	Population density		Population density helps to understand and analyze which cantons have the highest population concentration.
	25	Water discharges and dumps in the CBIMA		In the CBIMA there is a problem with water discharges, therefore, the number of discharges and dumps in the CBIMA are identified.
	25	Infrastructure for Comprehensive Waste Management and routes available for waste collection in CBIMA.		The routes available for waste collection in the CBIMA are analyzed, as well as the centers for Comprehensive Waste Management.

	100	Schools that have blue flag recognition		Schools that have blue flag recognition within the CBIMA are identified and thus analyze and understand waste management in institutions.

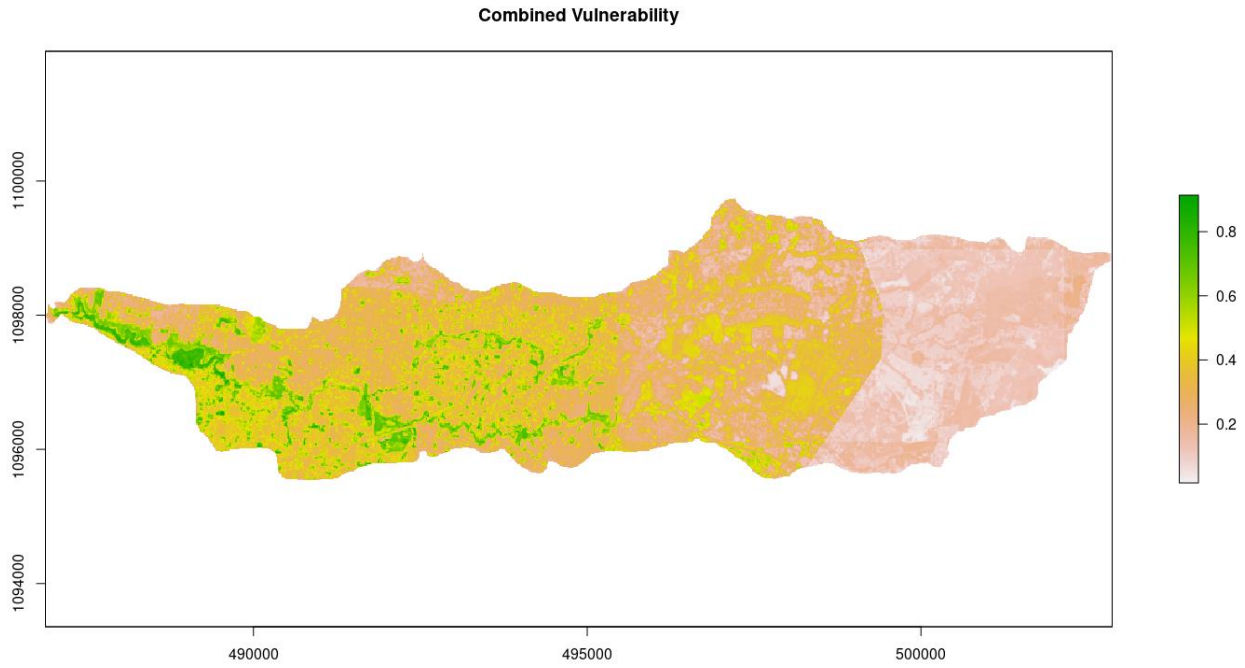


Figure 13. Spatial Screening Results CBIMA

5. Granollers

5.1. Description of Granollers and the area of intervention

Granollers is a city located in the Metropolitan Region of Barcelona, in the Autonomous Region of Catalunya, in Spain. It has a population of 61,983 inhabitants (2022), sits on the fluvial terrace of the Congost River and is the capital of the Vallès Oriental region. Together with Canovelles, Les Franqueses del Vallès and La Roca del Vallès, it forms a conurbation with a total of almost 110,000 inhabitants. Its prime location, just 30 kilometres north of Barcelona has enabled the creation of a prominent communications hub and a powerful industrial and commercial sector.

As a municipality, Granollers is known for its long history of environmental management and socio-ecological restoration projects. Concerning its green infrastructure, Granollers has implemented a Green Infrastructure Master Plan (*Pla Director del Verd Urbà*) that aims to balance urban mobility with green spaces and recreational areas. However, challenges such as the dominance of motorised mobility and the channelling of the Congost river have influenced the city's configuration. The Congost river traverses Granollers and is the backbone of the municipality's green infrastructure, making it its main environmental characteristic. In 1962, following severe floods, the river was channelized, leading to a drastic reduction in its course and biodiversity.

In this regard, the city has benefited from the Connecta Congost Natura 2025 (CoCoNat25) project, a European Union Next Generation funded project of 3.5 million euros which seeks to renaturalize the river and enhance Granollers' green infrastructure through the application of nature-based solutions. It is an action of great magnitude that fosters the green transformation of the city by opening the river to the city and renaturalizing an urban park and the river path, the development of two superblocks and a green corridor to increase urban biodiversity, enhance the resilience of the city and improve citizens’ well-being.

Figure 14. Picture of the Congost river in Granollers (© Granollers City Council)

5.2. Status of implementation of the assessment system

The development of the assessment system for Granollers is advancing as expected. The workshop to co-create and weight criteria for the design of actions to rehabilitate the Congost river took place on the 21st of March 2023. Concurrently, local partners from ICTA-UAB together with the City Council of Granollers, the Foundation Urban Ecology and Territory and the cooperative EIDOS (the stakeholders in charge of the Connecta Congost Natura 2025 project, CoCoNat25) are actively collaborating in designing and conducting participatory workshops to co-define the green urban transformation of the city together with different types of stakeholders as a scale-out process beyond the interventions of CoCoNat25).

5.3. Module II. Decision Framing

Definition of the assessment system

Describe the challenges to be addressed

The CoCoNat25 project is the first step towards a green transformation of the city. The **global challenges** respond to the need for better adaptation and resilience to the effects of climate change in Granollers. The CoCoNat25 project involves carrying out renaturation and nature-based solutions aimed at increasing connectivity between nature and the city. The project is developed through four specific actions:

B1 Restoration of the Congost River: Recovery of the longitudinal ecological connectivity of the Congost River in its urban section and expansion of ecosystem services through the following actions:

(a) **Green corridor** in the riverbed and on the shore:

- River habitat, defragmentation.
- Hydrogeomorphological study.
- Removal of exotic and mischievous species.
- Wildlife refuges and microhabitats.

(b) **Social corridor**: socio-ecological assessment of the river and its landscape.

(c) **Regulation of the river-river-park-city system**: landscape integration of the existing wall (225 m.)

B2 Naturalization of the Congost Park

The following actions will be carried out:

a) Permeability with vegetation and meadows (450 trees) and water infiltration with natural drainage (800 m2 of shrubs).
b) Promotion of active mobility.
c) Creation of a naturalized viewpoint integrated into the landscape.
d) Reduction of the heat island effect through shaded spaces, climate shelters and asphalt removal.
e) Increase the park's connectivity to the Congost River and nearby neighborhoods by building a bridge integrated into the landscape. Increase biodiversity.
f) Creation of spaces for social cohesion.

B3 Naturalised areas in the Instituts and Primer de Maig neighbourhoods (Roger de Flor, Sant Tomàs d'Aquino, Pius XII and Prat de la Riba streets)

The following actions will be carried out:

a) Start of the new model of mobility and public space (fewer cars, restriction to 10km/h).
b) Change of traffic directions on some roads.
c) Tactical urbanization for social use of public space, ensuring universal accessibility.
d) Creation of permeable and shaded green connectors that reduce temperature, improve air quality, decrease noise and accidents.

B4 Naturalized area of the east-west urban connector (Tres Torres and Emili Botey streets)

The following actions will be carried out:

a) Interconnect neighborhoods with naturalized urban areas.
b) Creation of shaded and permeable areas, improvement of the biotic index.
c) Reduction of air pollution, CO2 emissions and noise reduction.
d) Promote the social use of the space as a place for walking.

Describe the objectives of the assessment

To design in a participatory way the actions of the B1 Restoration of the Congost River.

Define a vision of green urban transformation of Granollers in a participatory way, taking as a reference the actions of the CoCoNat.

Additional Relevant Information

Existence of data derived from the CoCoNat monitoring system/indicators.

Definition of scale

Define the scale of the intervention, including consideration of the implications between scales, Scale n =

The implementation of the NBS assessment framework will be developed at different scales. On the one hand, the scale of the four specific interventions of the CoCoNat25 project as a pilot test of the naturalization process in Granollers:

A) B1. Congost River Area (Natura 2000 Site).
B) B2. Urban green space, Congost Park.
C) B3. Naturalized areas in the Instituts and Primer de Maig neighborhoods.
D) B4. Transverse connection of the green corridor.

On the other hand, the process of participatory debate for the design of the renaturalization of the city of Granollers as a whole.

Definition of scope and constraints

Define the scope and possible initial constraints, e.g. arising from planning frameworks, data availability.

The participatory process cannot have a practical influence on the drafting and execution of the CoCoNat25 actions that are already defined by the project itself that is the object of the Next Generation grant from the European Union, as well as a very strict schedule to have the executive projects of the actions ready, which hinders a substantial participatory process. However, the actions of the B1 Restoration of the Congost River have been designed in a participatory way.

The aim of the participatory SBN design process is to define a vision of green urban transformation of Granollers in a participatory way, taking as a reference the actions of CoCoNat25, for the subsequent design of SBN actions to carry out this urban transformation.

The participatory design of action B1 Restoration of the Congost River may present some limitations to integrate results of the participatory design process due to demands on how the actions of the Catalan Water Agency should be.

5.4. Module III. Co-creation

Several stakeholders were characterized as relevant to be involved in the co-creation of the assessment system (see Table 13).

Table 13. List of stakeholders

Representative's Name	Organization	Role of stakeholders	Stakeholder Group
	Mixed Commission of the Pla de Barris de Primer de Maig	Shapers and interested audience	Civil society
	Schools	Shapers and interested audience	Civil society
	Forum INTERLACE	Shapers and interested audience	Academia, research and education; civil society, political representatives, government

			authorities, citizens, private sector
	Forum l'Arrel de les adolescències	Shapers and interested audience	Civil society
Citizens visiting the 11 fixed information spaces	Citizen Advice Office (OAC), Roca Umbert Library and Can Pedrals Library, GRAJove (Granollers Youth Office), Espai Actiu for the elderly, Can Jonch (Culture Centre for Peace) and the civic centres of Granollers.	Shapers and interested audience	Citizenship
Coordinating Driving Group of the Project	Technicians, area managers and political representatives of the Environmental Service and the Participation Service.	Developers	Government Authorities and political representatives
	Representatives from the public administration at other local and supre-local scales.	Shapers and end users	Government Authorities and political representatives
	Representatives of municipal political parties	Shapers and end users	Political representatives
	City Committee	Shapers and end users	Civil society
Other associations, entities and citizens.	1-Neighborhood Associations 2-Educational Centers	Shapers and end users	Civil society and the private sector

	3-Sports entities 4-Companies and economic activities in the area 5-SIRIUS 6-CIRD 8-Users of libraries and civic centres in the city		
Users of the digital space "Granollers Participa"	The successful bidder is responsible for the content and dynamization of the space on the platform, which must remain updated until the end of the project.	Enablers	Citizens, civil society and the private sector

The following co-creation goals were established:

Setting co-creation goals

1) Define a vision of green urban transformation of Granollers through an inclusive participatory process taking as a reference the four areas intervention of CoCoNat project.

2) Integrate the visions of different relevant actors in the actions of the B1 Restoration of the Congost River.

3)To ensure that the implementation of the NBS evaluation framework is done through an inclusive participatory process, different participatory workshops will be developed for the co-creation and weighting of criteria for the urban green transformation of Granollers that represent the socio-cultural diversity of the city.

The following activities have been planned to co-create the assessment system (Table 14):

Table 14. Implementation plan of the engagement activities

Participation Activity	Objective	When to do it	Who to Involve	Format

Coordination meetings	Coordinate the participatory governance and communication strategy. Joint preparation of surveys.	Different meetings during September 2022; February, March, June, July and October of 2023.	EIDOS, Granollers City Council (Participation Coordinator and Environment and Green Spaces Service) and ICTA-UAB	9 virtual and face-to-face meetings
Participatory workshop to co-create and weight criteria for the design of actions in B1 Restoration of the Congost River	Jointly define and agree on a list of design criteria with different relevant sectors.	March 21, 2023	Participants of the INTERLACE Forum	Face-to-face workshop
Phase 1 of the participatory process. Information: benefits of green transformation.	-Present the CoCoNat25 project and activate citizen participation in relation to the green transformation of the city. - Disseminate the citizen opinion survey of the four areas of action of the CoCoNat.	March-April 2024	1. City Council Plenary 2. Mixed Commission of the Pla de barris de Primer de Maig 3. Public hearing (affected area: includes educational centres, sports entities, companies and economic activities in the area, among others) 4. Citizens at the stable information points in 11 facilities (users of libraries and civic centres in the city, among others) 5. Citizens at the itinerant information points in 11 locations (city area).	Information sessions and information spaces. "Granollers Participa" Platform

Phase 2 of the participatory process. Co-creation and weighting of criteria: Which criteria to consider for the green transformation.	- Present the project. - Consider criteria for the green transformation of the city.	March-October 2024	1. City Council 2. Council of the Infants 3. Youth Roots Forum 'Forum l'Arrel de les Adolescencies' 4. Vulnerable groups (including SIRIUS, CIRD, etc.) 5. Federation of Neighbourhood Associations in Granollers 6. INTERLACE Forum	Face-to-face participatory workshops. "Granollers Participa" Platform
Phase 3 of the participatory process. Return: The most important thing about the green transformation	Disseminate the results of the participatory process related to the weighting of criteria.	November-December 2024	-Plenary of the City Council - Mixed Commission of the pla de barris of Primer de Maig.	Face-to-face meetings. "Granollers Participa" Platform
Phase 4 of the participatory process. Ideation: I have an idea for green transformation	Collection of ideas and proposals to advance in the green transformation of Granollers.	January-April 2025	-Intergenerational workshop: users of the centre for the elderly and students of the educational centres in the area. -Collaborative session between Children Committee (Consejo de Infantes) and Youth Roots Forum (Forum l'Arrel de les Adolescencies)	Face-to-face participatory sessions. "Granollers Participa" Platform

Phase 5 of the participatory process. Summary: How we understand the green transformation	-Define the collective vision of the green transformation of the city and show it through a collaborative painting "Green Granollers". - Disseminate the citizen opinion survey of the four areas of action of the CoCoNat.	May-July 2025	-All participants from the previous phases. -Citizenship in general.	Face-to-face sessions "Granollers Participa" Platform
Phase 6 of the participatory process. Return: How we will make the green transformation.	- Present a report on the decision taken by the City Council in relation to the vision of green urban transformation of Granollers.	August-October 2025	-Plenary Session of the City Council -Comissió mixta del pla de barris de Primer de maig	Face-to-face sessions "Granollers Participa" Platform

Refinement of objectives together with stakeholders

Explain who was involved in refining the objectives and how it was done.

1) Meeting 13 February 2023: discussion about the objectives of implementing the INTERLACE assessment framework with the Environmental Services of the Granollers City Council, Urban and Territorial Ecology Foundation (Fundació Ecologia Urbana i Territorial, members of the CoCoNat project) and ICTA-UAB. The decision made was to carry out a participatory process for the design of the actions of the 4 areas of intervention of the CoCoNat project. We would start with area B1 Restoration of the Congost River.

2) Meeting 20 October 2023: re-definition of implementation objectives of the framework with the Participation Service and Environmental Service of the Granollers City Council together with ICTA-UAB. It is considered that it is difficult to carry out a participatory process for the design of the actions of the 4 areas of intervention of the CoCoNat project due to the limited practical influence on the drafting and execution of the actions of the CoCoNat25. Most of the actions are already defined by the project itself as an object of the Next Generation grant of the European Union. There is also a very strict schedule to have the executive projects of the actions ready. However, the actions of the B1 Restoration of the Congost River have been designed in a participatory way. It was agreed that the purpose of the participation will be the definition of a model of green urban transformation for the city of Granollers, based on the interventions of the CoCoNat as pilot actions that reflect a model that is being discussed with the citizens.

5.5. Module V. NBS Design and comparison

5.5.1. Diagnosis

CLIMATE Conditions	Key parameters of the LOCAL ECOSYSTEM	PERCEPTION/ Landscape design	FUNCTIONALITY of the site	Risk related with the area

The thermal regime of Granollers is temperate, since despite being in an inland valley (plana del Vallés), its proximity to the Mediterranean influences the climate of the area. The average annual temperature of the area (Granollers meteorological station) is 14.9 ºC, with an average daily minimum of 2.3 ºC during the coldest month (January). The warmest month is July, with an average temperature of 23.6 ºC. The rainfall in the area (Granollers meteorological station) shows great irregularity both at an annual and monthly level. The annual average is 647 mm, although the average recorded in the last decade is already less than 600 mm. The maximum rainfall intensities occur during the months of May and September, oscillating around 120 l/h. The average annual relative humidity is around 71%, with	The natural ecosystems of the urban center are basically the river environment of the Congost River, the urban parks located on the river banks and the urban green of public roads. The Congost River as it passes through the urban center of Granollers is a river regulated by various channelling structures that hinder its naturalness. In the last decade, naturalisation actions have been applied to minimise anthropization of the riverbed, which has allowed the partial recovery of riverside vegetation and some fauna populations. Despite the favourable evolution of the water system, there are still some impacts to be resolved, such as wastewater discharges in times of intense rainfall or the effects of invasive species (e.g. Ailanto) or domestic species (e.g. cat colonies). The river promenade parks	The design of the river landscape, and to a lesser extent the urban river parks, aims to recover the ecosystem benefits of the main green infrastructure spaces in the urban center. On the other hand, the natural environments of the streets are practically reduced to street trees and small conventional green spaces, more focused on aesthetics than on the delivery of socio-environmental benefits. Citizen perception of urban landscapes is satisfactory. Despite this, there is still a lack of broader understanding of the interpretation of more naturalised river landscapes and river parks, which are sometimes perceived as left rather than renaturalized.	The functionality of the Congost river as it passes through Granollers is ecological, landscape and educational. River parks have a high recreational functionality that is highly valued by citizens. They have also increased their biodiversity benefits. The urban greenery of the streets is a great ally in minimising the heat island effect, in addition to providing landscape benefits and, to a lesser extent, biodiversity.	The main risk in the area is the artificialization of natural spaces and their connections with urban parks and urban roads. The most traditional visions of conservative citizens and politicians advocate maintaining a clean and orderly landscape that can turn urban greenery into a simple recreational space without providing environmental benefits or resilience for a city that faces the challenges of climate change (heat waves, DANAs, floods…) The main natural risk in Granollers is flooding. The urban expansion of the city and its impermeability make it especially sensitive to pluvial flooding. At the same time, the narrowing of the river and the low drainage capacity of the urban area also affect the risk of river flooding, although abundant actions have been developed on the bed of the Congost River to mitigate

the month with the lowest humidity being July with an average of 62%, and the maximum during the month of November with 77.5%. The predominant direction of winds in the area is from the east, with an average speed of 1.4 m/s. Currently (2023) Granollers is suffering a period of severe drought with total accumulated rainfall below 400 mm per year in the last 3 years.	are large green spaces that have conventional gardening maintenance, although there are increasingly more management actions that seek to promote biodiversity (e.g. differentiated mowing, selection of appropriate plant species...). Unfortunately, these spaces have many elements beyond urban greenery (e.g. parking lots, educational buildings or sports facilities...) that affect both their recreational and biological functionality. The urban green of the streets of Granollers is limited to the alignments of street trees and commonly registers a general absence of small functional spaces with NBS such as pocket gardens or rain gardens.			the effects caused by river flooding.

5.5.2. Co-creation of design criteria

The representative of the Environmental Service and a representative from ICTA-UAB proposed an initial list of criteria for the design of the actions to rehabilitate the Congost river in Granollers (Table 15).

Table 15. Initial decision criteria proposed to local stakeholders

DECISION CRITERIA
Local temperature regulation
Proper management of river floods
Provision of aromatic and medicinal plants
Provision of spaces for recreation
Opportunities for social cohesion and the promotion of a sense of belonging
Opportunities for connection with nature and environmental education
Improvements in landscape aesthetics
Maintenance of biocultural heritage
Improvement of river habitat

Ecological connectivity
Climate change mitigation
Improvement of water quality
Generation of knowledge on the rehabilitation of urban rivers

To create a common understanding, the criteria must be agreed upon by all relevant stakeholders. For this purpose, we conducted an in-person workshop on the 21st of March 2023 with different stakeholders in Granollers to co-create and weight criteria reflecting needs and priorities for the design of actions for the rehabilitation of the Congost River. The workshop comprised three stages. Firstly, participants agreed on a joint understanding about the criteria proposed (see Table 15) and listed those relevant for the rehabilitation of the Congost river (see Table 16). Afterwards, they individually weighted each criterion, assigning a value based on personal reflection without the influence of external perspectives or opinions.

In a third step, a collective evaluation of the same criteria involved two separate groups. Each group had a moderator to guide the weighting session and clarify any doubts about criterion definitions. The phase of collective weighting concluded with a consensus among the two groups on the determined weights (see Table 17). The workshop aimed to attain a comprehensive and collective weighting that incorporated perspectives from both groups. Therefore, the results were presented in a plenary session. During this phase, participants openly discussed and debated differences in the assigned weights. After achieving a consensus, a final review ensured that the obtained weights were socially acceptable to all involved parties. The results highlighted the most important criteria for the stakeholders of Granollers regarding the renaturalization of the Congost River. Table 17 depicts the outcome of the prioritisation process.

The workshop was attended by 17 participants from various sectors, including seven from the technical sector, four from the academic sector, and six from the local sector:

- Vicenç Planas - technician of the Social Economy Service of Granollers City Council.
- Toni Arrizabalaga Blanch - director of the Natural Sciences Museum of Granollers.
- Jaume Coll Gil - representative of the Ponent Neighbourhood Association.
- Quim Comas - head of the Environmental and Green Spaces Service of Granollers City Council.
- Erika Blancas - technician at the Urban Service of Granollers City Council.
- Jordi Morote - ornithologist and citizen of Granollers.

- Johannes Langemeyer - researcher at the Institute of Environmental Science and Technology (ICTA) of the Autonomous University of Barcelona (UAB).
- Oriol García-Antúnez - predoctoral researcher at ICTA-UAB and University of Copenhagen (Denmark).
- Toni Mas - researcher and technician of Territory Department of *Consorci Besós-Tordera* (Consortium in charge of managing the Besós and Tordera rivers where Congost river belongs to).
- Isabel Martínez - technician of the Green Spaces Service of Granollers City Council.
- Marina Andreu - *Fundació Rivus* (Rivus Foundation).
- Marta Chillida - technician of the Environmental Service of Granollers City Council.
- Silvia Escolano - technician at the Local Environmental Planning Department at the Technical Office of Climate Change and Sustainability of *Diputació de Barcelona*. Citizen in Granollers.
- Gemma Merino - student of the gardening and forestry degree. Citizen in Granollers.
- Maria Mas - representative of the Natural Sciences Museum of Granollers.
- Xavier Romero - technician of the Environmental Service of Granollers City Council.
- Sara Maestre Andrés- researcher at ICTA-UAB.

Throughout the deliberation, both Group 1 and Group 2 agreed to exclude the following criteria as relevant factors: “Provision of aromatic plants” (Criteria 3) and “Provision of recreation spaces” (Criteria 4). Both groups rated these criteria with a score of zero out of 100. Participants here argued that the river should not serve as a space for providing aromatic plants and, above all, should not function as a recreation area. They believed that this would detract from the true purpose of restoring and renaturalizing the Congost River.

Table 16. Final list of decision criteria elaborated in a participatory manner

DECISION CRITERIA
Local temperature regulation
Proper management of river floods
Opportunities for social cohesion, for connection with nature and environmental education

Improvements in landscape aesthetics
Maintenance of biocultural heritage
Improvement of river habitat
Ecological connectivity
Climate change mitigation
Improvement of water quality
Generation of knowledge on the rehabilitation of urban rivers
Promoting participatory governance

Table 17. Final weighting of design criteria elaborated in a participatory manner

Design Criteria	Weighting of Group 1 (over 100)	Weighting of Group 2 (over 100)	Total punctuation (over 200)	Reasons for Rating/Comments
Opportunities for social cohesion, for connection with nature and environmental education	14	26	40	Need for the population to engage in educational initiatives to become active agents in decision making. Care and respect for natural environments. Through education and training, aspects such as

				water pollution can be mitigated.
Improvement of river habitat	18	16	34	Relevance and interconnection of this criterion with the rest of the criteria, such as water quality. The intervention project for the Congost River has aimed at habitat improvement, making it a key topic in the discussion and decision-making process.
Ecological connectivity	16	16	33	River rehabilitation would not be feasible without connectivity between different ecosystems.
Improvement of water quality	15	5	20	A key aspect of river rehabilitation is the improvement of water quality
Proper management of river floods	8	9	17	River Congost had some floods so it is essential to management them to minimize the impacts
Generation of knowledge on the	12	5	17	It allows innovation in river rehabilitation as

rehabilitation of urban rivers				well as promotes its scaling-out
Local temperature regulation	3	10	13	The efforts that can be made at the local level are essential, they require much investment, and the impact will be pretty low
Promoting participatory governance (proposed only by group 2)	0	9	9	It is important that citizens are involved in its governance to increase the sense of belonging to the place
Improvements in landscape aesthetics	7	2	8	The river cannot be treated the same way as a garden or theme park. River conservation precisely entails valuing the river as it is, including its vegetation, and promoting the environment to be as natural as possible.
Maintenance of biocultural heritage	5	2	7	Not specially relevant although Granollers is culturally link to the river (many popular stories exist) and this biocultural heritage

				needs to be preserved and disseminated
Climate change mitigation	2	0	2	The efforts that can be made at the local level are essential, they require much investment, and the impact will be pretty low

We aimed to investigate how the participatory approach applied in the Granollers case contributes to urban environmental justice through the interventions, perceptions, and correlations of the actors involved in the transdisciplinary co-creation process to design NBS.

During the participation process, various stakeholders with their respective knowledge systems have engaged in different stages of the NBS design process, expressing their viewpoints and prioritized needs. In this regard, one can observe their valuation of nature and the convergences, agreements, and tensions within deliberative and decision making processes.

Drawing from IPBES (2022) and aligned with the process of renaturalizing the Congost river, while there are several approaches for assessing the values of nature, the most suitable, based on information emerging from deliberative encounters among different stakeholders, is the statement-based valuation. This approach corresponds to people's expressions about the importance of nature and its contribution to deliberative spaces.

Unravelling the difference among stakeholder groups in weighting design criteria

To discern the differences and similarities regarding the weighting of criteria among the stakeholders, a correlation analysis was conducted. Correlation analysis is a statistical technique used to assess the relationship between two or more quantitative variables to understand their degree of association (Johnson & Creech, 1983). This technique aims to determine the direction and strength of the relationship between variables, enabling the identification of patterns, trends, and potential underlying connections in the data. Similarly, it provides valuable insights into how variables are interrelated and how they can influence each other in different contexts.

In participatory processes involving various stakeholders, it becomes essential to determine whether the level of correlation and participation was conducted under democratic and equitable criteria. It is essential to observe whether all actors can express their positions or viewpoints in the decision making process. In this regard, it becomes crucial to identify the weights that specific ideas and stakeholders carry in comparison to other propositions and stakeholders. To achieve this, we propose a quantitative analysis to provide insights on which actors had more significant influence or decision making capacity in relation

to other actors (Edelenbos, et al., 2011). Additionally, we analyse the level of similarity to evaluate the co-creation effect on the final collective outcome.

Following this line of thought, correlation analysis facilitates the extraction of specific values from the prioritisation process of criteria for NBS design. This enables a more profound analysis of initial numerical relationships and the significance of individual and group perspectives in shaping the final decision making process. To this end, we implemented the following strategies:

As a first step, we calculate an average of the individual values assigned to the criteria by the 17 documented participants. This average is then compared with the final agreement reached collectively by all stakeholders. This comparison quantifies the discrepancies and convergences between the average value and the consensus based final value. Correlation analysis allows quantifying the impact of individual assessment on co creation. This approach permits the quantification of the coproduction impact by contrasting it with isolated individual evaluations.

The second step involves categorising survey results based on participants' group affiliations: local, technical, and scientific, generating three distinct vectors for each group. This strategy aims to discern which group aligns more closely with the consensus value and which one deviates further to assess the relative significance of opinions from each group and ensure equity in valuation.

The subsequent step involves observing the variability of values within individual vectors (i.e., scores assigned by each person to each criterion) within the same group. This analysis seeks to determine the level of pre-existing ideas that groups brought into the deliberation exercise. This information allows an examination of the evaluation's effect on the convergence of opinions and final values (Table 17), consistent with the results of the preceding two points.

To carry out the comparisons described in the first and second steps, while there are methods such as Pearson's correlation coefficient to measure the similarity between vectors, we have chosen to utilise the cosine similarity technique in this study. We base this choice on the ability to compare vectors regardless of absolute discrepancies in values that cosine similarity offers compared to other methods, demonstrating its suitability in evaluation studies similar to this research (Boratyn et al., 2023).

Figure 15 show the results of the average value attributed to each criteria by different participants' group affiliations, i.e. local, technical, and scientific, the average weight attributed by all stakeholders and the final consensus value.

Based on this general result, most of the lines exhibit similar patterns, enabling us to establish the existence of a high degree of prior understanding regarding the relative importance of each of the 13 criteria. However, there are instances of significant discrepancy, such as the case of criteria 9 (river habitat improvement) and 10 (ecological connectivity), which were considered less important by the group of scientists in their evaluation compared to the other two groups and the final deliberation exercise. A similar situation is observed with criteria 5 (opportunities for social cohesion) and 6 (opportunities for connection with nature) for stakeholders belonging to the group *technical*.

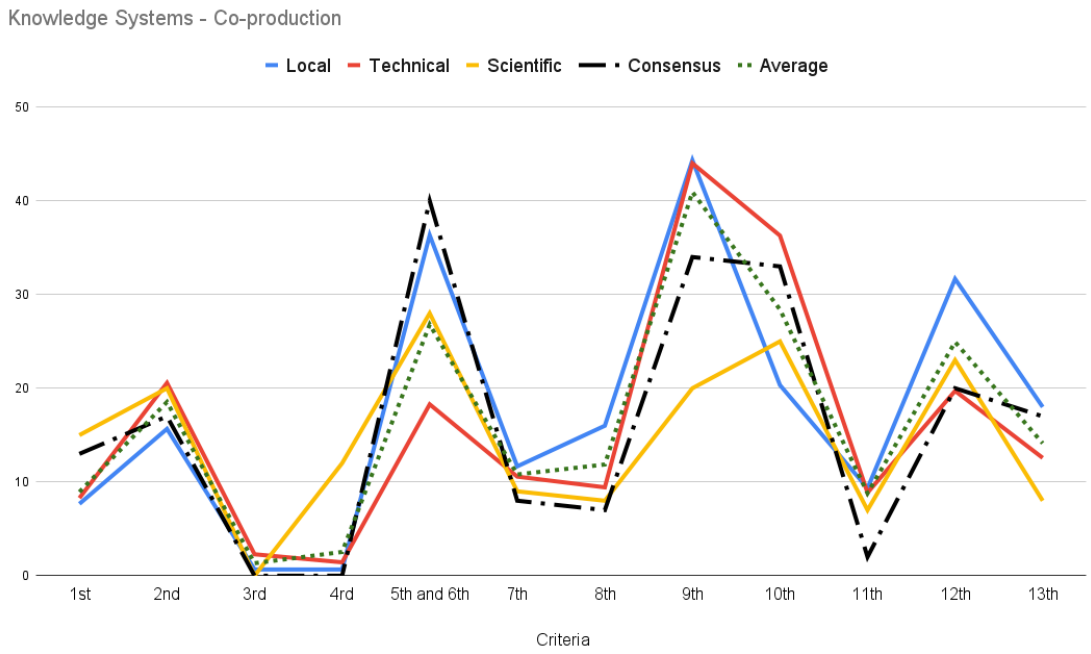


Figure 15. Average weight attributed to each criteria by different participants' group affiliations: local, technical, and scientific together with consensus and average value.

Upon observing the graph, it appears that stakeholder group *Local* initiated the discussion with a prior notion closer to what would eventually become the consensus. Nonetheless, to assert this with certainty, it is imperative to employ a vector similarity comparison tool, such as cosine similarity, which will be conducted in the subsequent analysis.

In this regard, similar to the other values, the overall average, corresponding to the individual evaluation marked with a dashed green line in the graph, did not exhibit significant differences from the value of the final consensus.

The application of the cosine similarity tool, which facilitates the comparison of proximity between criteria vectors with both the average value of individual evaluation and the value resulting from the final deliberative exercise, follows a similar pattern.

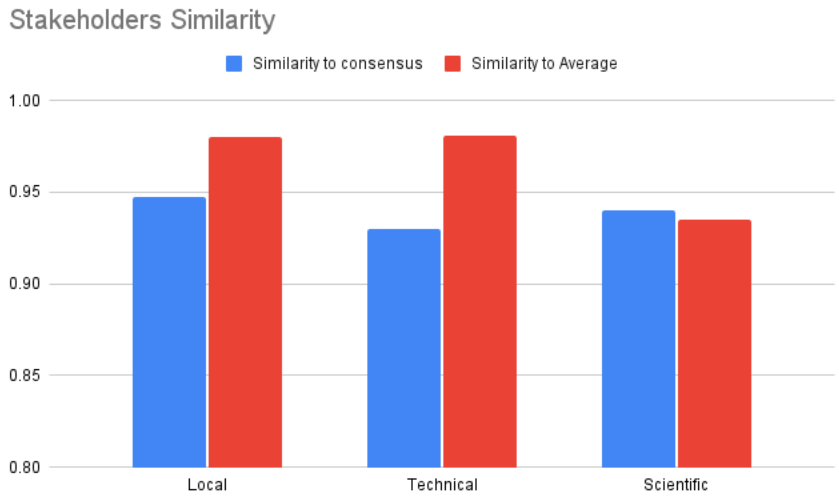


Figure 16. Similarities between stakeholders groups compared to general average and consensus

Table 18. Cosine similarities between stakeholders groups and the general average and consensus

Group	Similarity to consensus	Similarity to average
Local	0.9473	0.9801
Technical	0.9299	0.9808
Scientific	0.9401	0.9353

Based on these results, we can infer that the order of similarity to the final consensus in terms of the match was as follows: local stakeholder, scientific stakeholder, and technical stakeholder. At the same time, the order of similarity to the individual average was local stakeholder, technical stakeholder, and scientific stakeholder. This indicates that local stakeholders interested in the restoration of the Congost River clearly understand the criteria's importance as they are the most engaged with the problem within their environment.

None of the groups exhibit a cosine similarity below 0.9, signifying significant similarity among the values, ensuring that all groups can find representation in the final results. The degree of similarity is lower for the consensus than the general average (i.e., the individual result) because the co-production process generates new opinions, premises, and perspectives, bringing together various stakeholders and refining ideas through discussions, leading to the emergence of different viewpoints, enriching the overall perspective of all parties involved. The following table highlights the average values for each group that closely approached the consensus value in green.

Table 19. Average in stakeholders groups, closest value in green

Criteria	Local	Technical	Scientific	Coproduction
1st	7.666666667	8.285714286	15	13
2nd	15.66666667	20.57142857	20	17
3rd	0.6666666667	2.285714286	0	0
4rd	0.6666666667	1.428571429	12	0
5th and 6th	36.3333333	18.2857143	28	40
7th	11.66666667	10.57142857	9	8
8th	16	9.428571429	8	7
9th	44.33333333	44	20	34
10th	20.33333333	36.28571429	25	33
11th	9.333333333	8.857142857	7	2
12th	31.66666667	19.71428571	23	20
13th	18	12.57142857	8	17

Now, to identify internal value matches within groups in evaluating each criterium, we apply the coefficient of variation method to offer a close perspective on how significant the differences in values are, considering their magnitude.

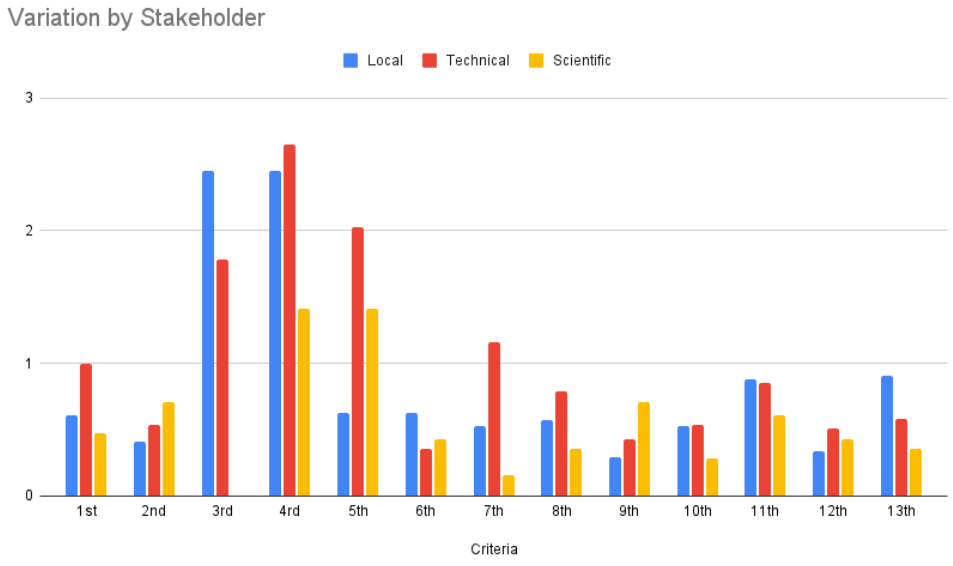


Figure 17. Variation by stakeholder in evaluation groups

When analyzing the coefficient of variation, it is possible to identify that the criteria revealing the highest internal variations within the groups were those associated with lower magnitude values, precisely criteria 3, 4, and 5. Notably, criterion 5 merges with criterion 6 in the co-production consensus. Among the studied stakeholders, the group consisting of technicians displayed the most pronounced internal variations in their opinions, resulting in higher coefficients of variation for each criterion. In contrast, despiteits small size, the group of scientists presented a more substantial initial consensus. Despite the apparent initial disparity within the group of technicians, most groups shared a similar perspective regarding evaluating each criterion.

5.5.3 Evaluating various NBS alternatives against thermal stress under future climate scenarios

A modelling exercise has been carried out in Granollers, for the comparative analysis of various NBS design alternatives against their performance to cope with thermal stress under climate change scenarios and inform decision making towards the most resilient solution.

Thermal comfort simulations are tools used to predict comfort and in some cases to evaluate the impact of nature-based solutions on temperature reduction in urban areas. Overall, simulations are a valuable tool for designers, urban planners and planners to make informed decisions about implementing NBS in urban areas.

Simulation Models are tools that are used to predict and evaluate the impact of different urban designs and solutions on certain variables. These simulations are based on numerical models that consider different factors based on a three-dimensional model of the area. From a baseline, different design alternatives can be simulated to, through a comparative analysis of effectiveness, inform decisions about urban planning.

In general, simulations are a valuable tool for designers and urban planners to make informed decisions about the implementation of NBS in urban areas. Modeling is made through Computational Fluid Dynamics (CFD) calculations. Specifically, with ENVIMet 5.0 software, which allows understanding the complex dynamics of heat distribution in the neighborhood. This 2mx2m evaluation of thermal comfort aids in exploring hot spots and seeing the effectiveness of urban interventions made with nature-based solutions. This kind of adaptive and climate-responsive public space policies are laid by the analysis of heat distribution and how the citizens are affected by it.

EnviMet is a microclimate modeling tool used to simulate thermal comfort in urban and outdoor environments. It enables the creation of 2D and 3D models to conduct detailed simulations of urban climate and the thermal comfort of individuals in public spaces. Building the 3D model involves providing the complete geometry of buildings, trees, and other elements that influence the urban climate. This is done in order to create and export the geometry of objects in the appropriate format for EnviMet and it is made using GIS software. Once the model of the study area is created, input climate parameters such as temperature, wind speed and direction, relative humidity, and other relevant meteorological data. This is done by selecting typical days based on historical climate data.

Urban planners and decision-makers can implement targeted interventions that promote natural cooling, reduce the urban heat island effect, and enhance overall livability and walkability. With the pressing challenges posed by climate change, this assessment holds particular significance in designing sustainable and resilient urban environments. By understanding how different building configurations, land use and vegetation types influence local thermal comfort, decision-makers can make more informed choices. In this context, the relevance of CFD calculations extends beyond immediate comfort considerations, emphasizing the pivotal role of informed design strategies in fostering environmentally conscious and resilient cities.

5.5.3.1. Methodology

Three steps methodology is applied to carry out the exercise:

1. CHARACTERIZATION OF THE SCOPE OF STUDY

Local climatic conditions are analyzed, as well as land uses in the study area. This study characterizes the hourly distribution of different variables such as temperature and humidity and, in turn, determines that types of soil make up the area.

2. COMPUTATIONAL SIMULATION PROCESS

Characterization information is entered into the ENVIMET software. It uses advanced numerical models to simulate atmospheric dynamics and the interaction between buildings, surfaces and vegetation in urban areas.

The climatic or pollutant emission conditions are analyzed, as well as the land uses of the study area. This study characterizes the time distribution of the different simulation variables and, in turn, determines what types of soil make up the area. The characterization information is entered into the corresponding software. Advanced numerical models are used to simulate different scenarios and the role that some of them can play in urban design, such as Nature-based Solutions. The results allow applying effectiveness indices, observing the behaviour of the variables over time, or creating comparisons between different scenarios, including the differentiations between the current climate and a future one with climate change for the variables of thermal comfort and surface runoff.

3. PREPARATION OF INDEXES AND COMPARISONS

The results allow us to apply NBS effectiveness indices, observe the behaviour of thermal stress throughout the day or create comparisons between different scenarios, including differentiations between the current climate and a future one with climate change.

5.5.3.2. Results

In Granollers, an evaluation of thermal comfort in the public space is carried out in Sant Miquel neighbourhood. A current climate scenario and a future RCP 4.5 scenario are used to analyze climate

comfort. The index applied to the definition of people's comfort is PET (Physiological Equivalent Temperature). It assesses the thermal environment's impact on the human body, considering different variables such as air temperature, humidity, air speed, and radiation but also an "average person" physiognomy and clothes characteristics. It represents the equivalent temperature that an individual in a comfortable indoor environment would perceive, given the specific outdoor conditions.

The base scenario with the current climate assumes the conditions of a typical day in the study area. The 13:00h of the typical day is taken to show the results, as it is the hottest during the day. As the Sant Miquel district is dominated by asphalt-type surfaces, this results in the majority of the space being at risk of hyperthermia for people. The PET (>41, considered as the threshold for hyperthermia) is present in 67% of the area. The areas where Nature-based Solutions (NbS) show their effects, such as tree-lined sidewalks or parks and gardens, present lower levels of PET. Thus, there are park areas with PET levels even below 35, and those with trees cover around 29% of the area with PET ranging between 35-41°

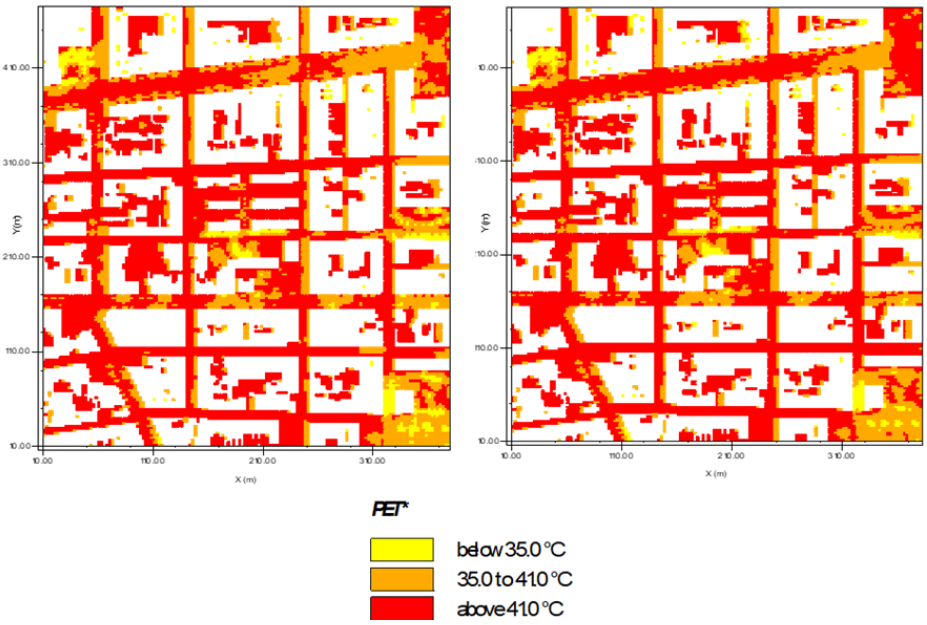


Figure 18. Current (left) and future (right) climate scenario by different levels of PET. Below 35ºC=comfort; 35-41 ºC =discomfort; More than 41ºC=risk of hyperthermia.

The scenario of the future climate represents the neighborhood's conditions under a climate change scenario within RCP 4.5. The future conditions are characterized by an increase in temperature and, consequently, a variation in the surface affected by PET, which implies greater thermal discomfort. The majority of the area will present PET levels >41, specifically 70%. Nature-based Solutions will have a more crucial role in the future, as even though PET generally increases, they manage to prevent it from rising to levels within the risk of hyperthermia where they are located.

When both scenarios are calculated it is time to compare them in order to have valuable conclusions. By contrasting the baseline conditions with the impacts of climate change urban planners and policymakers can better understand and locate the potential risks that communities may face in the future, but also

how the nature-based solutions are going to behave. The comparison at the hottest hour in Sant Miquel shows a worsening of thermal comfort. Specifically, 73% of the area experiences an increase in its PET, although, in the vast majority of the study area, the increase would be less than 2°C, primarily due to a widespread temperature increase. In the current climate, 33% of the space is outside the risk of hyperthermia, a figure that would decrease to 29% in a climate change scenario under the RCP 4.5 model. The areas that generally remain outside of the risk are those that receive shading from NBS. In the current climate, PET indicative of hyperthermia is experienced during the central hours of the day. The daily distribution corresponds to the fact that the lower the comfortable PET, the higher the PET associated with discomfort. In the future climate, discomfort appears earlier and lasts for more hours. A larger portion of the surface faces a PET greater than 41 for an extended period. In the future climate, compared to the present, there is a 20% increase in areas experiencing discomfort in the morning and after the hottest time of the day. The most significant changes would be experienced in the afternoon.

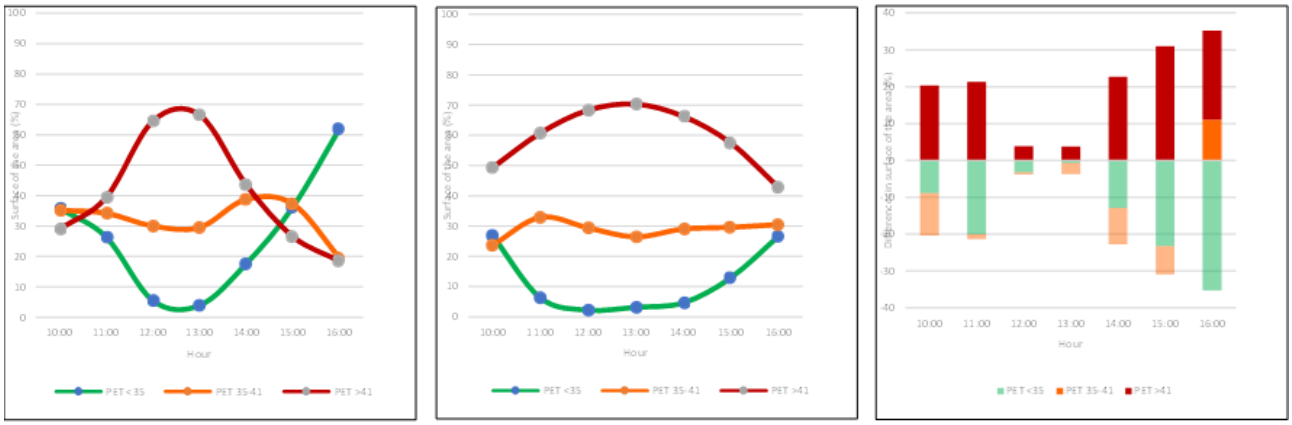


Figure 19. Hourly distribution of different levels of PET under climate scenario (left), future climate scenario (middle), and differences between scenarios (right). Below 35ºC=comfort; 35-41 ºC =discomfort; More than 41ºC=risk of hyperthermia

This analysis underscores the importance of integrating sustainable urban design principles into future planning to create more resilient and adaptable cities. By investigating the data derived from the comparison, stakeholders can make informed decisions about the implementation of climate-resilient strategies. It also helps the integration of green spaces and cooling elements to mitigate the potential risks associated with urban heat.

The importance of simulations is based on the opportunity they represent to detect areas of thermal discomfort in public spaces where to focus decision-making in relation to NBS. Computational simulations based on ENVI-Met have provided thermal comfort results for the different neighbourhoods of Granollers. An increase in thermal stress is expected, which will affect the shading area to a lesser extent. Specifically, the care and improvement of the species that make up the gardens and flower beds will make it possible to avoid the extreme risk of heat to passers-by in a RCP 4.5 scenario.

The application of this methodology not only provided valuable information to urban planners in Granollers to select the most effective NBS design alternative to cope with thermal stress and build a more resilient district. The results of these modelling exercises, could also be upscaled, and inform future planning decisions, for detecting opportunity areas that can be transformed into urban laboratories for testing the NBS effectiveness. Calculations based on CFD offer a greater possibility of climatic contextualization as they not only consider in more detail the shadow but also the mean radiant temperature, humidity and wind speed and direction.

6. Portoviejo

6.1. Description of Portoviejo and the area of intervention

Portoviejo is a medium-sized city of around 300,000 inhabitants on the Ecuadorian coast. The town is crossed by the river that bears its name and which helped to build the town. Since the end of the 20th century, however, the city has expanded considerably without taking this natural axis into account. The municipality of Portoviejo has been working for several years to recover its connection with the river, and in 2020 began defining a specific plan for the urban restoration of the Portoviejo river corridor, partially integrated into its Land Use and Management Plan drawn up until 2035. It is this objective that serves as the main focus for the INTERLACE project.

Within this framework, the town has several development themes, one of which is the restoration of urban public spaces along the river. There is little public urban land in the immediate vicinity of the river, so it is essential to make the best use of those that are available and suffering from under-use.

Figure 20. Picture of the Mamey Park in Portoviejo (© YES Innovation)

It was with these considerations in mind that the municipal team chose to work on Parque Mamey to apply the design module of the NbS assessment framework developed as part of Interlace. This park is

located in a central area, very close to the historic centre, but suffers from partial abandonment, safety problems and a poor connection with the river that runs through it. The Portoviejo river is not very visible or accessible in the town, and this is one of the reasons why the people of Portoviejo have lost interest in the river. To reverse this trend, parks such as Parc Mamey must be able to tell the story of the relationship between the city and the river once again, and recreate a synergy between nature and urban space.

6.2. Status of implementation of the assessment system

The selection of the Mamey Park as the area of intervention was the starting point for the process of applying the NBS design module, which began relatively late due to hesitation in defining the intervention site and major changes in the municipal team (following local elections). Faced with these difficulties, partnerships were established with two local universities (Universidad San Gregorio and Universidad PUCE Manabi). The design work is now halfway through and should be completed by the beginning of 2024 with a co-created proposal for the new Mamey Park.

6.3. Module II. Decision Framing

Definition of the assessment system

Challenges to be addressed

The restoration of the Mamey Park is part of an overall project to rehabilitate the Portoviejo river, which runs through the whole of the city. The river tends to flood the city in winter, and there is a lack of areas that can be used as a buffer. The town has developed in such a way as to lose its link with the river, which is now barely visible and therefore little known. The city has few public spaces along the river, and Mamey Park, with its central position, is a point of great interest that is not used to its full potential. The park's underused space is a source of insecurity and illegal use (drugs). It would be interesting to be able to connect the green spaces of the river with the natural spaces of the neighbouring hill to recreate an ecological corridor between the two ecosystems.

Objectives of the assessment

To understand the issues relating to Mamey Park, both from a global planning perspective and from a local vision. To propose a new design for the park that includes the ecological restoration of the area, the recovery of the relationship with the surrounding urban neighbourhoods, the definition of a new relationship with the Portoviejo river and the use of NBS as a recovery technique.

Definition of scale

Scale of intervention

The primary scale of intervention is that of the park's boundaries, which corresponds to the public land over which the municipality of Portoviejo has a direct possibility of intervention. The secondary scale of analysis, and potentially of intervention, is a wider area around the park, which allows us to understand the urban fabric in the area, and to study the potential relationship of Mamy Park with the town centre on the one hand and with the neighbouring hill on the other.

Definition of scope and constraints

The scope of the intervention is to define a new typology of urban design for green areas along the river using NBS and co-creation processes.
The constraints are the difficulty of reconciling elements of authentic nature with the urban fabric of the town of Portoviejo, the slightly conflicting nature of the intervention site (particularly with regard to current drug-related uses), the pollution affecting the river, its tendency to flood during the winter and the uncertainties over the financial means to effectively implement the designs to be carried out.

6.4. Module III. Co-creation

Stakeholder identification (role and group)

The stakeholders involved in the co-creation process are either part of the neighbours, which are the direct users of the Mamey Park, and the authorities from different departments of the municipality of Portoviejo.

Name of the representative	Organisation	Stakeholder role	Stakeholder group
Ana Belén Suárez	YES Innovation	Developers	Private sector
Daniela Amoroso	YES Innovation	Developers	Private sector
Ligia Vera	Municipality of Portoviejo, Urban planning	Developers	Governmental authorities
Karen Itriago	Municipality of Portoviejo, Urban planning	Shapers	Governmental authorities
Maybe Navarrete	Municipality of Portoviejo, Urban planning	Shapers	Governmental authorities
Presidencia barrial	Neighbours	End-users	Civil society
Club parque puerto Mamey	Local club	End-users	Civil society
Grace Yepez	YES Innovation	Developers	Private sector
Yanko Vasconez Vera	Municipality of Portoviejo, Citizen participation	Enablers	Governmental authorities
Angel Paul Intriago Bermello	Municipality of Portoviejo, Urban planning	Enablers	Governmental authorities
Nelson Bravo Delgado	Municipality of Portoviejo, Urban planning	Shapers	Governmental authorities
Gerardo Xavier Scippa Cedeño	Municipality of Portoviejo, Urban planning	Enablers	Governmental authorities
Peter Bryan Solórzano Véliz	Municipality of Portoviejo, Citizen participation	Enablers	Governmental authorities
Yuly Cerón García	Municipal company Portocomercio	Enablers	Governmental authorities
Teresa Sornoza Araúz	Neighbour	End-users	Citizen
Dioseline Baez	Neighbour	End-users	Citizen
María Sinche	Neighbour	End-users	Citizen
Pepe Pinargote Sinche	Neighbour	End-users	Citizen
Dora Delgado	Neighbour	End-users	Citizen

Gerson Ponce M.	Neighbour	End-users	Citizen
María Galan Celi	Neighbour	End-users	Citizen
Gerardo Farfán	Neighbour	End-users	Citizen
Pabel Villamar M.	Neighbour	End-users	Citizen
Cruz Mera	Neighbour	End-users	Citizen
Alfredo Roman	Neighbour	End-users	Citizen
Yoryi Garcia	Neighbour	End-users	Citizen
Gabriel Obando	Neighbour	End-users	Citizen
Wilson Gregorio	Neighbour	End-users	Citizen
Cinthya Gabriela Samaniego	Neighbour	End-users	Citizen
Yulexi	Neighbour	End-users	Citizen
Ronald Moises Cesar Cedeño	Neighbour	End-users	Citizen
Antonio Pico	Neighbour	End-users	Citizen

Setting co-creation goals

Co-creation goals:

- Diagnosis the actual state of the park
- Identify expectations from the end-users of the area
- Co-design a new proposal for the park
- Define management strategies for maintaining the restored park

6.5. Module V. NBS Design and comparison

6.5.1. Diagnosis

The initial diagnosis allows the definition of the key parameters that will guide the formulation of strategies and the design of solutions, and should consider three dimensions:

NATURE: Natural context: existing natural ecosystems, topography, corridors, relevant natural flows (water, wind, sun, fauna, ...), risks, climate change scenarios; Ecosystem to restore: description (composition, structure, function), level of degradation, restoration potential.

PLACES: public plots, local regulation of land use, urban dynamics, private and public green spaces, public infrastructures (water, transport, buildings, ...), accessibility to green spaces, specific urban challenges (security, memory, heritage, ...).

PEOPLE: social composition and homogeneity, perception of nature, relationship with urban greenery, uses of public areas (type of user, timetables, activities, expectations/added value of the green space), inclusion.

This diagnosis process was realised through the assessment of the data available for the area, site visits, a workshop with the neighbours, and a workshop with local authorities.

6.5.1.1. Initial diagnosis realized by students from Universidad San Gregorio de Portoviejo

Participants

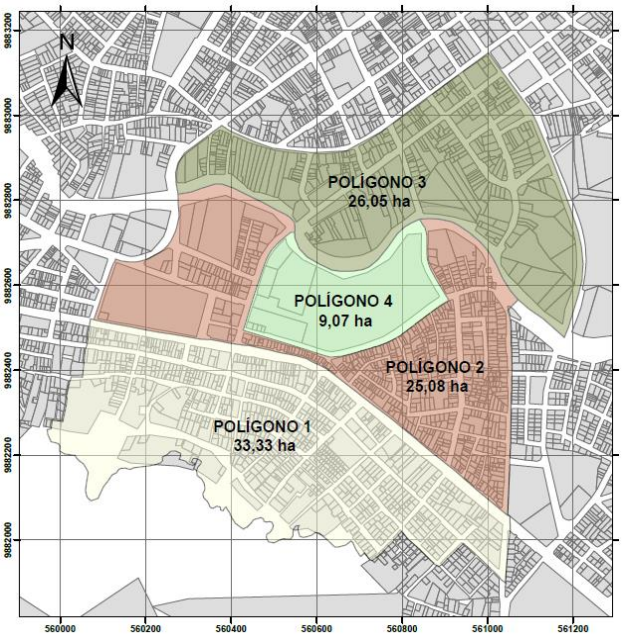
- 15 students from the sixth semester of the USGP architecture course, under the direction of teacher Betsy Marita
- Grace Yepez (YES Innovation)
- Daniela Amoroso (YES Innovation)

Workshops

With the objective of engaging the community in the process, the Interlace team signed an agreement with the Universidad de San Gregorio de Portoviejo (USGP), in which students of architecture would help by collecting data from the site under a teacher's supervision. The interlace team offered workshops for assisting the students, and showed them different programs for collecting and analysing data.

Methodology used

The students were divided into four groups of three to four people. Each group elaborated a diagnosis focused on different areas (scales) and objectives:



➔ **Group 1:** Park inward

Objective: To understand the dynamics and characteristics of the park area. Understand the uses, main issues, strengths, opportunities and natural conditions (species survey).

➔ **Group 2:** Relationship between park and riverside neighborhoods (other side of the river)

Objective: To understand the risks, connections, uses and condition of the relationship between the park and the immediate urban area (right). Analyze the urban regulations governing this area and corroborate if they are being complied with.

➔ **Group 3:** Relationship between park and hills

Objective: To understand the current condition of each individual space and the potential for relationship and connection between them.

➔ **Group 4:** Urban area adjacent to the park

Objective: To understand the risks, connections, uses/activities, deficits, opportunities. To analyze the urban regulations governing this area and whether they are being complied with.

The groups produced a 49-page document with information from the four areas, using primary and secondary sources about the following topics for each area:

- Inhabitants and population density
- Land use (inside and outside the park)
- Height of buildings
- Urban facilities
- Urban greenery
- Coverage of basic services
- Connectivity (road typology)
- Accessibility
- Mobility (Public transport routes)
- Landslide risk
- Flood risk

- Anthropic risk (security)
- Street furniture within the park (benches, lighting, litter bins)

6.5.1.2. Neighbour´s community workshop

Participants

- Ana Belén Suárez (YES)
- Daniela Amoroso (YES)
- Ligia Vera (GAD)
- Karen Itriago (GAD)
- Mambe Navarrete (GAD)
- Presidencia barrial (Neighbours)
- Club parque puerto Mamey, (Community)

The associations that attended were the neighbourhood presidency with some neighbours and the Club Parque Puerto Mamey. A total of 18 neighbours attended.

Of the attendees, the majority were men (67%), and only 6 women attended the meeting (33%) as shown in Figure below. Similarly, the age of all those present was relatively homogeneous, ranging from 45 to 75 years old. Only two people were over 75 years old.

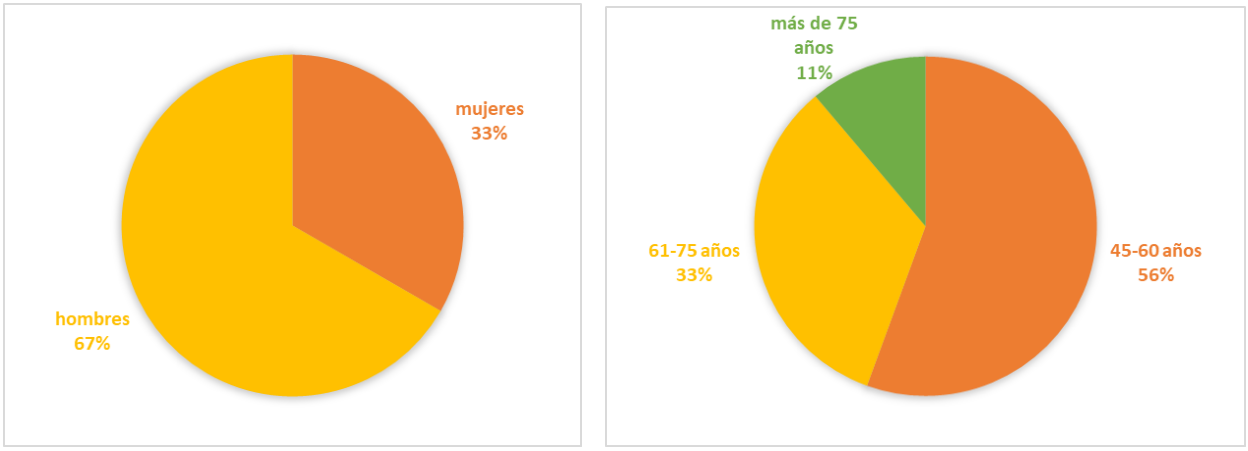


Figure 21. Gender (left) and age (right) of the attendees (© YES Innovation)

Workshop format

A face-to-face meeting was held with residents of Parque Puerto Mamey, facilitated by the Autonomous Decentralised Government of Portoviejo (GAD). The main objective of these workshops was to get closer to the community to understand their needs but also their vision, expectations, and the relationship they currently have with the Mamey Park and the Portoviejo River.

The workshop was held in the chapel inside the Mamey Park with 18 people who live, work, or in some way have a relationship with the park.

Figure 22. Pictures of the workshop held with the local community (© YES Innovation)

Methodology used

The workshop was organised in three moments. During the first moment, the YES Innovation and GAD Portoviejo teams were introduced, a summary of the Interlace project was given and the implications of the SbN were explained, as well as the reason why the Mamey Park is a point of interest and the area of intervention within the framework of the project.

Once the objective of the workshop had been clarified, two round tables were held, led by each member of the YES team and the GAD. The idea of these round tables was to have a more direct approach and conversation with the people, in order to listen to their opinions and identify ideal sceneries.

As a third and final moment, we took a tour through the park, which helped us to better understand what was said earlier during the workshop. We were able to observe key points and actors, as well as potential areas for intervention, as people told us their expectations.

Figure 23. Pictures of the site visit with the local community (© YES Innovation)

Results

1. Currently, the most important concern of the community is the level of insecurity that they and the rest of the city perceive, since the park is no longer visited as frequently by users from outside the area as it used to be.
2. The second point they emphasise is the need to clarify the legal status of the park so that it can be better maintained by the competent authority and so that new projects can be implemented there. Furthermore, accidents caused by fallen branches should be avoided.
3. The park has a historical and cultural potential, which should be exploited and made known in the city.
4. The park has important ecological qualities which could be enhanced to spread this diversity to other areas of the city.
5. There is a design for the park by an urban architect who is part of the community. He wants to present his ideas to the GAD to understand if it is feasible to implement. It is a plan that preserves the ecological qualities of the park and proposes small-scale complementary facilities built with bamboo cane.
6. The people agree and are interested in implementing BNS in the park, as long as it improves the quality of the park and reactivates it. Their unity and interest in improving the park is evident, and they tell us that there is no shortage of hands to work with. On the other hand, they tell us that it is important for them that the new generations get to know the park as it was before and that they take an interest in its care and value its biodiversity.
7. One of the main problems identified is an area where cats are abandoned and fed by people. This can create a major problem in the long term as they are natural predators of wildlife. In addition, these cats become strays and represent a source of diseases transmissible to the population, as they come close to the cats without any qualms about touching and playing with them.

Figure 24. Workshop with the local community (© YES Innovation)

Below, a summary table of the implicit objectives that the neighbours seek for the park, obtained from the analysis of their priority needs. The ideas expressed by the citizens during the workshop have been placed on the following table.

Table 20. List of the objectives as defined by the local community

WANTS	HOW	WHAT FOR
1. Security	More police and homelessness control	The park is more visited and returns to the life it once had.
2. The park is more visited and returns to the life it once had.	Entity in charge of the park or “Portoparques”	Maintain the park well and propose new projects to attract more users. Keep users safe by avoiding accidents due to fallen branches.
3. To raise awareness of the historical and cultural qualities of the park.	Rescue festivities and events that used to take place in the park.	Preventing these traditions from being lost
4. To publicise and promote the ecological qualities of the park.	-	Prevent endemic species from disappearing from the city.

6.5.1.3. On-site data collection with USGP students

Participants

- 13 students from the sixth semester of the USGP architecture course, under the direction of teacher Betsy Marita
- Ana Belén Suárez (YES Innovation)
- Daniela Amoroso (YES Innovation)
- Ligia Vera (GAD)
- Maybe Navarrete (GAD)

Workshop format

The workshop was held in the Mamey ecological park with 13 students from the San Gregorio University of Portoviejo. The objective of the workshop was to carry out a survey with GPS equipment, taking into account the pending information to complement the diagnostic phase of the park. Three groups of students were formed and each one dealt with a particular topic (vegetation; courts and furniture, lighting), while the YES team was in charge of surveying areas of possible intervention, risk zones and access to the river, information that will help us later in the following stages of the project.

Methods used

The activity took about 5 hours and covered the whole park, taking into account that it was not going to be possible to do a detailed survey of each topic due to time constraints. Therefore the following guidelines and conditions were established to mark the points.

- Vegetation: A vegetation survey was carried out with the objective of locating mature trees with high shade projection. Only trees with a diameter of 10m or more and medium to dense foliage were considered, which allows for shade projection due to the size and age of these trees. Special care should be taken in the maintenance of these trees, and counting and locating them will allow for more specific studies in the future.
- Urban furniture: The existing benches, commercial kiosks, toilets and rubbish bins in the park were located in order to determine the best served areas, their condition and the quality of their construction. This survey included a photographic record of 74 benches to assess their quality. It was determined whether the benches are functional, i.e. usable, or non-functional when their poor condition prevents them from being used. This allows the identification and quantification of benches that can be maintained, those that only need a little maintenance and others that will need to be replaced.
- Luminaires: A survey of the existing luminaires in the park was carried out to determine the areas best served, the type of luminaire (pedestrian pole, vehicular, bollard or ground), and their condition (whether they are functional or have been vandalised). As with the furniture, a photographic survey was carried out to qualify and quantify which luminaires need to be replaced, or if only routine maintenance is required.

Figure 25. Pictures of the site visit realised with the students (© YES Innovation)

Results

- Vegetation

Figure 26. Tree inventory realised in the Mamey Park (© YES Innovation)

A total of 79 trees were surveyed, the following graphs show statistics on the size of the trees.

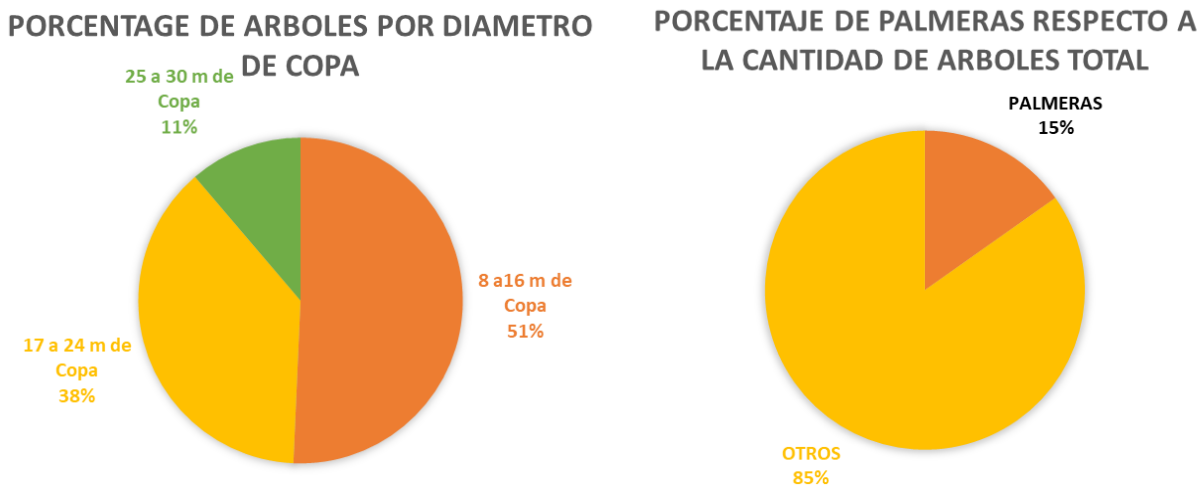


Figure 27. Characteristics of the trees identified in the park (© YES Innovation)

- Urban furniture

Figure 28. Inventory of the actual furniture in the park (© YES Innovation)

Statistical data on the condition of the benches and their material are presented below.

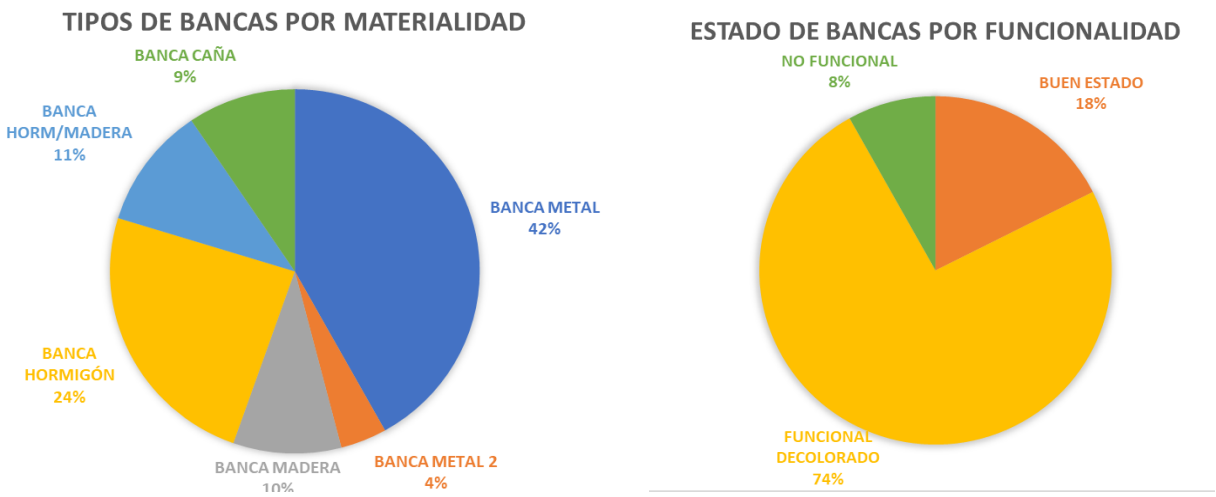


Figure 29. Characteristics of the urban furniture actually present in the park (© YES Innovation)

- ❖ Lightning

During the survey it was found that there are currently only two types of luminaires: pedestrian poles and floodlights for the courts. Of the 69 luminaires surveyed, 62 operate with LED light, while the 7 floodlights are not known to be operational or not, as they are never switched on.

In the project, special emphasis can be placed on unserved areas and on enhancing the more urban areas with luminaires of various types. The statistical results of the type of luminaires and their condition are given below.

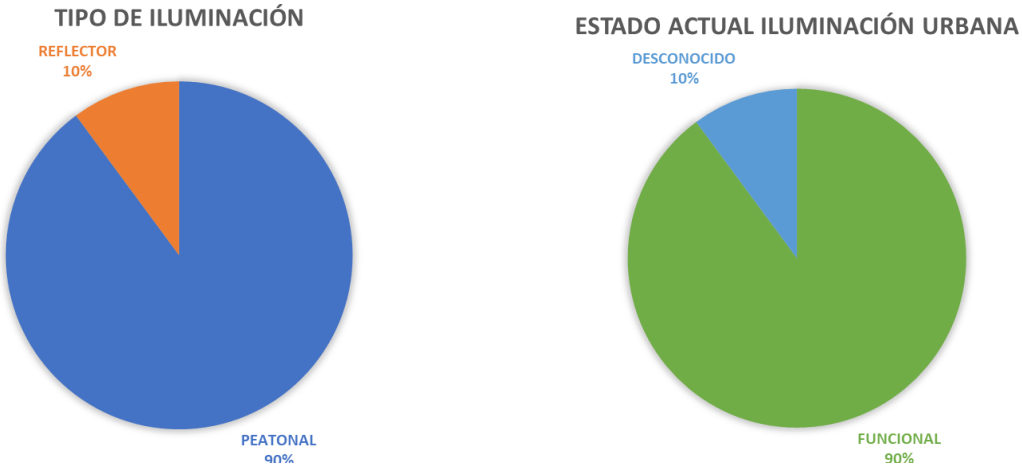


Figure 30. Characteristics of the lightning in the park (© YES Innovation)

6.5.1.4. Summary outline based on USGP information, community workshops and site visits

As mentioned above, the development team decided to elaborate three diagnostic schemes based on the information collected by the USGP students, the community workshops and field visits, to determine potential opportunities, risks and threats to respond to in the design of the park.

To better understand the relationship between the park and its surroundings, a first analysis was carried out at the urban scale. Figure 31 shows the relationship of the park with nearby large-scale facilities as well as with large-scale natural elements such as the Portoviejo River and the Andrés de Vera Hills and potential connections.

Relevant nearby facilities are mapped, such as schools, colleges, hospitals, and in this specific case, the Portoviejo bus terminal which is only 200 metres from the park entrance. This analysis allows us to understand the type of potential users that transit the park on a daily basis.

In terms of green spaces, remnants of native forest were identified at the top of the Andrés de Vera Hills to the south of the Mamey Park, which could be used to propose green corridors from the hills to the park, which in turn connects with the green remnants along the banks of the Portoviejo River. These corridors would allow the flow of biodiversity between these elements, but could also direct the flow of students from Homero Mendoza School, Uruguay School and Medardo Cevallos Educational Unit to and from the park due to their proximity to the corridors.

In addition to these natural areas, four neighbourhood-scale public spaces were identified: Los Botaditos Park (3181m2), and Plazoleta 24 de Mayo (3600 m2) less than 300 metres from El Mamey Park, and Las Vegas Park, with around 10.5ha, only 400 metres from the park. Considering these four green spots in such close proximity, there is a potential pedestrian or cycling circuit to connect them through the urban road, which in turn should include vegetation to provide shade for users and allow for greater biodiversity connectivity.

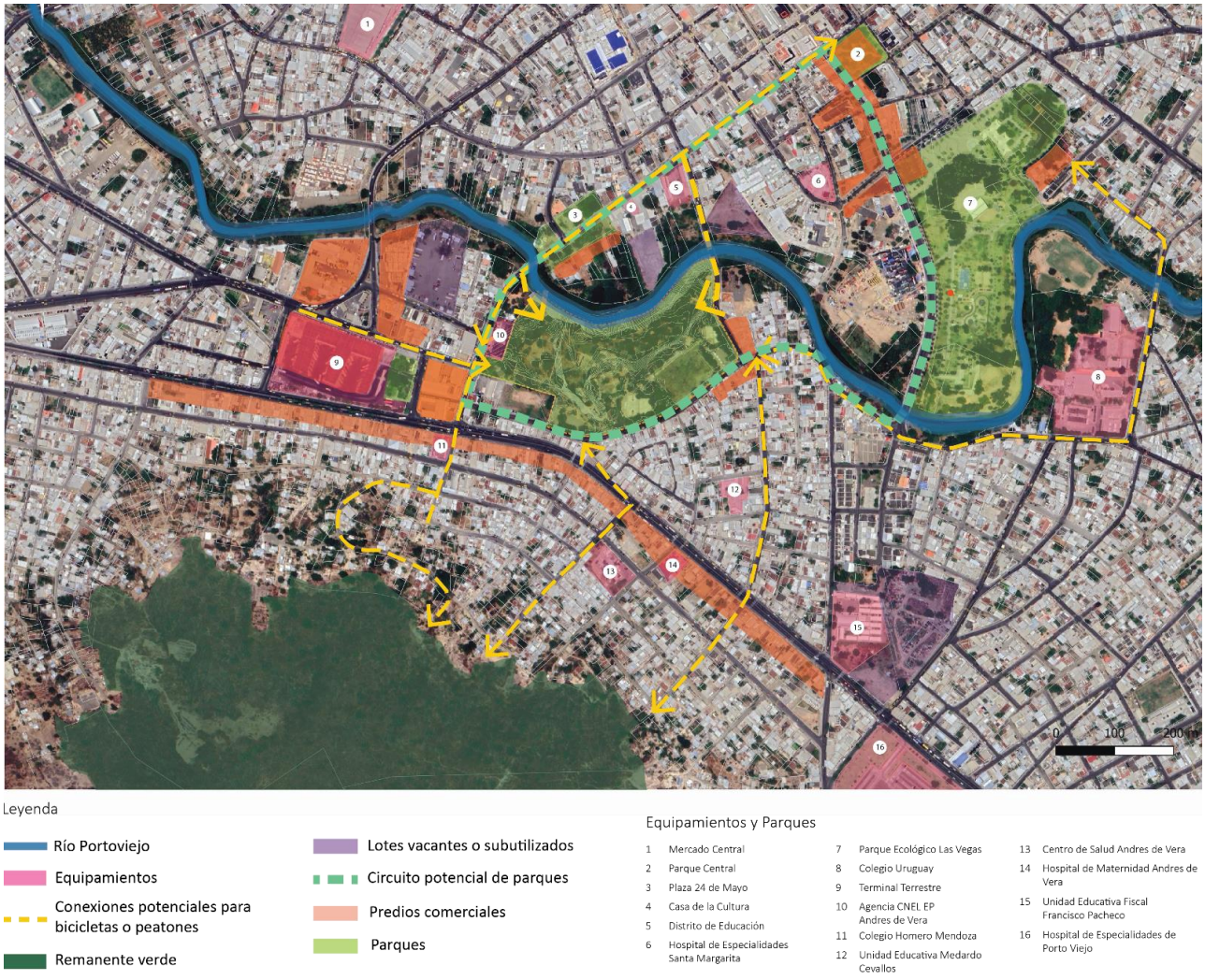


Figure 31. Diagram of the park's relationship with the city (© YES Innovation)

The second diagram (Figure 32) shows the conflicts and risks presented by El Mamey. The level marked in the figure delimits the platform with the highest risk of flooding and corresponds to the least intervened area of the park, and the most ecologically rich. Visits to the site revealed that the soil in this area is very damp. The rest of the park is classified as being at medium risk of flooding, while the highest area, which corresponds to the area of the private plots in the southern sector, is not at risk of flooding.

During the intervention of the park by the Prefecture in 2004, cobblestone walkways, the entrance pool, the food court and other structures were built, where the programme and zones for each activity were determined. However, due to lack of maintenance and disagreements over the legal ownership of the site, the current uses do not always correspond to those initially proposed. For example, the public toilet block is abandoned and the Community Police Unit (UPC) is currently a Porto Parques warehouse. In Figure 32, in the legend, the use that each area used to have has been placed followed by the current situation of the area.

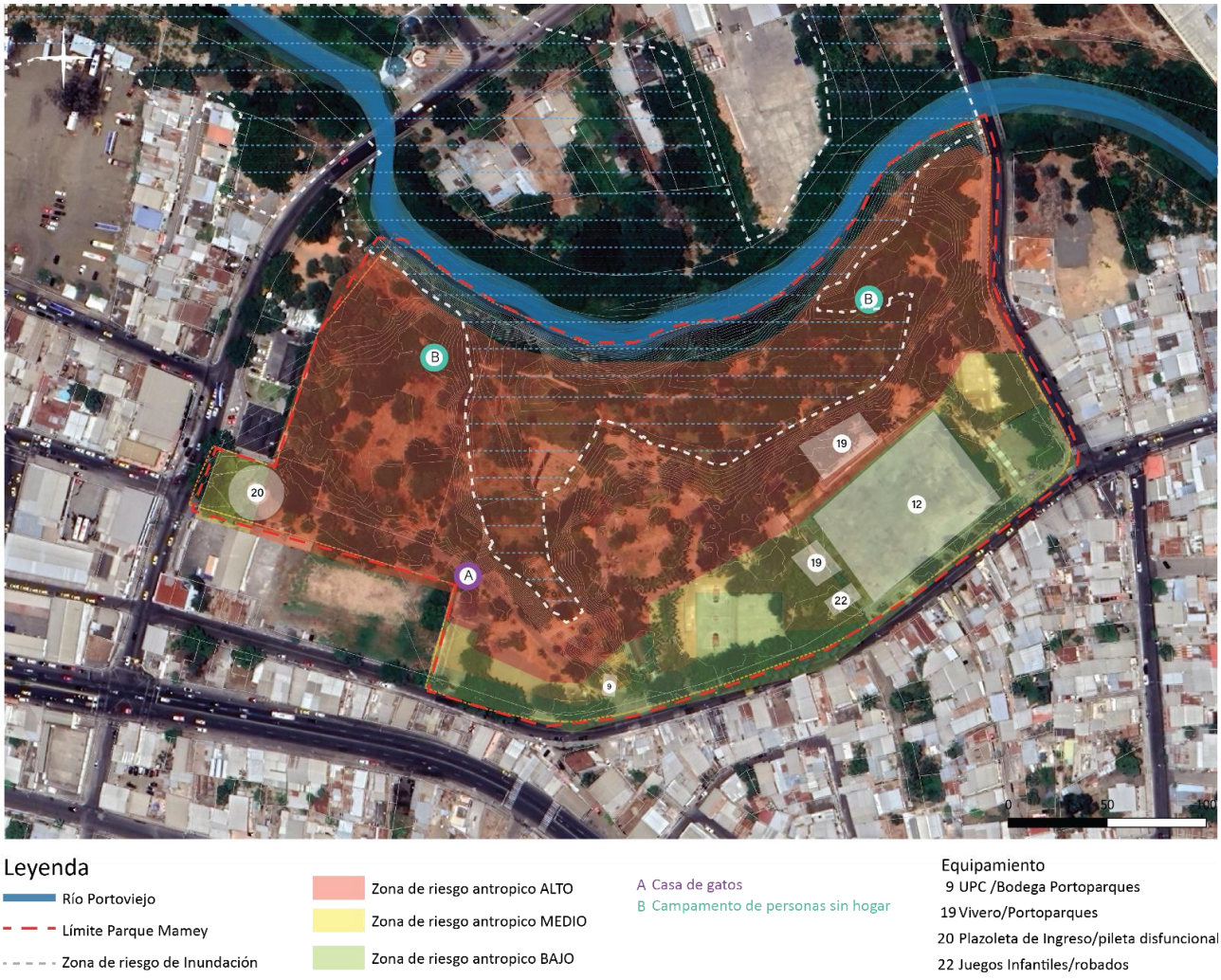


Figure 32. Diagram of conflicts and risks (© YES Innovation)

In the case of the entrance plaza, all the infrastructure for the functioning of the swimming pool and lights have been stolen or vandalised, leaving it dysfunctional.

In another area, it can be seen how the children's playground equipment that used to exist have "disappeared". It is not known whether the theft or municipal intervention was the cause, however, the only remnant is an occasionally used slide.

Figure 33. Pictures of some of the remaining uses in the park (© YES Innovation)

Similarly, uses not contemplated in the original plan were identified, such as the community garden and the municipal nurseries of Porto Parques. The latter use the space to supply the city of Portoviejo with ornamental and native plants, but do not contribute anything to El Mamey Park.

After visiting the site and exchanging information with the community, it was found that the largest football pitch in the park remains closed and is therefore not used. Neighbours say that some years ago a football school for children used to operate there.

In Figure 32, points A and B are located. A corresponds to an area where stray cats are concentrated. A group of charitable people have built small houses for them and a lady feeds them with what little she has left over. However, since this place became known, we are told that there are even people who abandon their pets in this place, so the cat population is constantly increasing. We consider this to be a potential risk point both for the fauna of the park that is to be protected, and for the health of the people who frequent this site and play with the cats. On the day of the visit we were able to count 20 cats at this point and its immediate surroundings alone.

Figure 34. Picture of the cat refugee on a side of the park (© YES Innovation)

On the other hand, points B in the scheme show homeless encampments. According to local residents and police, these are spaces where mainly foreign migrants take refuge at night, it is a park that is close to the bus terminal and easy to access. They also indicate that these are the most dangerous areas of the park, as they say that this is also where thieves take refuge and where drugs and alcohol are consumed. In the mornings these areas are empty, but as the sun goes down, people comment that it becomes more unsafe. On the first day of the field visit conducted by the YES team in the afternoon, four people were observed occupying these places, while the next morning they were found empty (photographs).

Figure 35. Pictures of areas identified as drug taking places (© YES Innovation)

Finally, the third diagram shows the park's programme with the different activities that are carried out, as well as some potential points of intervention and opportunities (Figure 36).

Figure 36. Diagram of uses and potentials of the Mamey Park (© YES Innovation)

Possible area of intervention A:

Possible area of intervention B:

Possible area of intervention C:

Possible area of intervention D:

Possible area of intervention E:

6.5.1.5. Requirements for the project

Based on this contextual analysis, the following table summarises here the essential requirements that should guide the design:

Table 21. Basic requirements for the project

CLIMATE and RISK Conditions	Key parameters of the LOCAL ECOSYSTEM	REGULATIONS AND SURROUNDING USES	FUNCTIONALITY of the site	Social Dimension
Topography Relevant natural flows Flood and landslide risks Climate change scenarios	Green corridors Vegetation cover and its current state	Nearby public lots Local land use rules and regulations Urban dynamics Nearby private and public green spaces	Infrastructure quality within the park (lighting, furniture, rubbish bins, sports areas, etc.). Sewage network Drinking water network Electricity network Public transport network Accessibility to the park	Social composition and homogeneity, Perception of nature, Relationship with urban greenery, Uses of public areas Busiest times Neighbourhood expectations Social inclusion Safety within the park

We complete here with additional contextual elements to be considered for the design:

- ★ It is very important to consider Las Vegas Park, which is a national reference of high quality public space, besides being loved and used by the citizens. It is close to Mamey Park (300 metres approximately).
- ★ Legal regulations must be a requirement to guide the design, so that it can be implemented and built smoothly.
- ★ The regeneration of the park is important from a political point of view because of its strategic location between Las Vegas Park, the river and the historic centre of Portoviejo.

6.5.2. Definition of criteria

6.5.2.1. Initial definition of criteria

We indicate here, in order of importance, which criteria were initially defined as most relevant for the project in the chosen intervention site, to be proposed to the stakeholders:

DECISION CRITERIA
NATURAL DIMENSION Existing natural ecosystems, urban fauna Topography, Green corridors, Relevant natural flows (water, wind) Flood and landslide risks Climate change scenarios Vegetation cover and its current state
SIZE OF THE SITE Nearby public lots Local land use rules and regulations in the surrounding area Urban dynamics Nearby private and public green spaces State of infrastructure within the park (lighting, furniture, litter bins, sports areas...) Public transport network Accessibility to the park Cultural and historical value of the park Sewage network Drinking water network Electricity network
PEOPLE DIMENSION Safety within the park Social composition and homogeneity, Perception of nature, Relationship with urban greenery, Neighbourhood expectations Social inclusion Ownership of the park Uses of public areas Busiest times

6.5.2.2. Workshop for the selection of criteria

Participants in the decision committee

- Grace Yepez (YES Innovation - Interlace)
- Ligia Vera (GAD - Interlace)
- Ana Belén Suárez (YES Innovation - Interlace)
- Yanko Vasconez Vera (GAD) Citizen Participation Specialist
- Angel Paul Intriago Bermello (GAD) Planning Analyst
- Nelson Bravo Delgado (GAD) Territorial Planning Director
- Gerardo Xavier Scippa Cedeño (GAD) Territorial and Urban Planning Specialist
- Peter Bryan Solórzano Véliz, (GAD) Directorate of Citizen Participation, Administrative Analyst
- Yuly Cerón García (PORTOCOMERCIO) EP Control Technician

* 12 people, technicians of the GAD, were summoned, however only 6 attended.

Workshop format

The workshop was conducted virtually through the Zoom platform. First of all, a brief presentation was given on the INTERLACE project, its objectives and how the project has been developed in Portoviejo. The attendees were introduced to the Mamey Park and were asked to participate in a dynamic to prioritise the evaluation criteria in order to focus the diagnosis.

For this purpose, a board of the Miró application was shared, where the dimensions to be dealt with proposed by INTERLACE were found, together with their definitions and some example criteria as a basis for an exchange of experiences with the participants. Each of the participants had an oral participation in which they chose one or several criteria that seemed relevant according to their field experience and specialisation. In some cases, new criteria considered relevant by the participants were included.

Figure 37. Picture from the first virtual workshop about the Mamey Park project (© YES Innovation)

Methods used

Initially, it was planned that each of the participants would log into Miró and vote for the 5 criteria they considered to be priorities in each of the dimensions. However, this dynamic could not be developed because the GAD's internal internet network has blocked access to this type of platform. Another mishap was that not everyone had computers to log in, they were on their mobile phones and could not access the application.

For this reason, the YES team modified the methodology on the fly and opted for an oral intervention by each attendee, while a member of the team posted the criteria and the reasons why these criteria were chosen on the Miró board. This dynamic lengthened the intervention times so that people only choose 1 or exceptionally 2 criteria for each dimension.

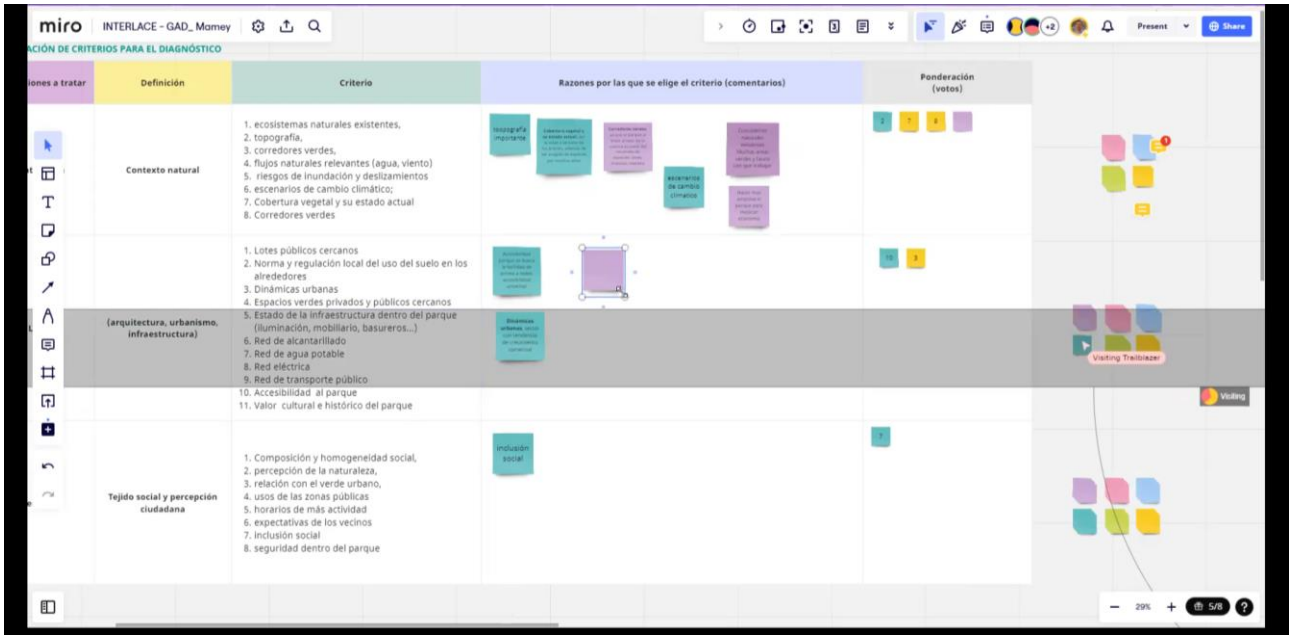


Figure 38. Miro board used for weighting the criteria (© YES Innovation)

Memories of the discussion for the final selection of criteria.

In all the interventions, the participants respected each other's opinions and in no case were there directly opposing opinions; on the contrary, some people chose the same criteria as others because of the importance they represent for everyone.

In view of the short time available to the officials, it was not possible to open a discussion forum on the criteria, but the workshop was limited to arguing personal opinions, based on their experience and expertise in the field.

Results

Table 22. List of the final selection of criteria and a brief note on why each criterion is prioritised

Diagnosis Criteria	Final Score	Justification
NATURAL DIMENSION		
Existing natural ecosystems	3	The current importance of the park on an ecological level in the city is evident, due to the amount of fauna and flora that can be seen with the naked eye. However, it is currently neglected; there is no management, management or maintenance plan, let alone a plan to promote these qualities. A tourism/commercial plan compatible with the natural environment could be proposed.

Vegetation cover and its current state	3	There are no technical criteria to safeguard the state of the vegetation cover that the riverbank should have, and the existing mature trees.
Topography	2	They consider it important to study the topography of the site in view of its location on the banks of the Portoviejo River. It is possible that there could be landslides on the riverbank or floods for which the park should be prepared, even more so in climate change scenarios.
Green Corridors	2	Due to its location on the river bank, it forms part of a natural green corridor that is currently threatened by urbanisation, but where birds, insects and reptiles can still be seen.
SITE DIMENSION		
State of the infrastructure within the park	2	The state of the infrastructure impedes its continued use (especially sports areas) and this in turn makes it difficult to raise funds for maintenance, or to attract new visitors. There is commercial infrastructure that can be improved to attract more visitors.
Local standard and regulation of land use in the surrounding area	1	The urban environment where the park is located was not planned, and is traditionally known as a risky place.
Urban dynamics	1	The sector has a tendency towards commercial growth, which can benefit or harm the park and should be taken into account.
Nearby private and public green spaces	1	The proximity of the park to the river and the Las Vegas Park can be exploited through various types of connections.
Accessibility to the park	1	The public transport network is apparently deficient in the area.
Cultural and historical value of the park	1	It is an added value that can attract a lot of attention and generate income for the park itself.
PEOPLE DIMENSION		
Security inside the park	4	It is necessary to increase security in the park to make it attractive to the public. There is insecurity because of the number of places where criminals can hide. Several assaults have been reported and there are very dark places.

		The general perception of the public is that the park is unsafe and therefore has lost its attractiveness. It is intended to develop a monitoring centre including the area around the park as it is a key connection between Las Vegas Park and the historic city centre.
Social inclusion	1	Need to implement strategies and activities that include all potential users of the park.
Perception of nature	1	The park is several years old and as such requires revitalisation.
Ownership of the park	1	There are problems because no municipal body is responsible for the maintenance of the park. It is also unknown who manages the access to the court, which is always closed.

6.5.2.3. Final decision criteria

To create a common understanding, the criteria must be agreed upon by all relevant stakeholders.

Table 23. Final list of decision criteria elaborated in a participatory manner

DECISION CRITERIA
NATURAL DIMENSION 1. Existing natural ecosystems 2. Vegetation cover and its current state 3. Topography 4. Green corridors
PLACE DIMENSION 5. State of infrastructure within the park 6. Local land use rules and regulations in the surrounding area 7. Urban dynamics 8. Nearby private and public green spaces 9. Accessibility to the park 10. Cultural and historical value of the park
PEOPLE DIMENSION 11. Safety within the park 12. Social inclusion **Perception of nature** 13. Ownership of the park, causing problems with neighbours

7. Envigado

7.1. Description of Envigado and the area of intervention

Envigado is part of the metropolitan area of the Aburrá Valley (Figure 39). It has a population of about 230,000 inhabitants and 70 square kilometres of mixed urban, rural and peri-urban areas. Envigado includes areas of well-preserved forest with high biodiversity, but urbanisation pressures pose a challenge for land-use planning. Among its SBN initiatives are the ecological and cultural restoration of the Ayurá stream, the Envigado Florece program, and SILAPE Evigado's Local System of Protected Areas), which covers 40% of the municipality's surface area.

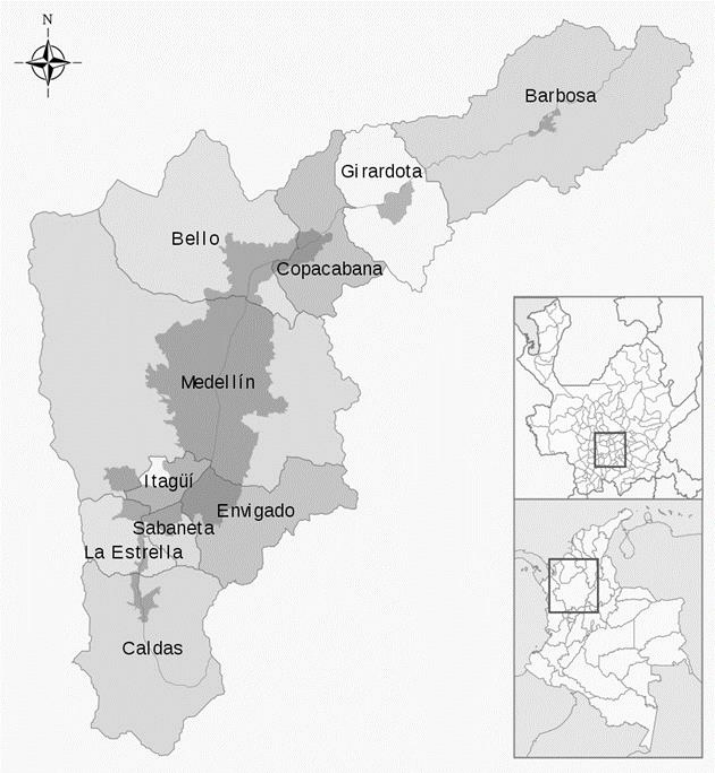


Figure 39. Map of Envigado. Source: Environment Office of Envigado

With the objective of evaluating the impacts of one of its most emblematic NBS. Envigado decided to formulate a monitoring strategy following the monitoring module of the Assessment Framework. Envigado Florece is a programme that the Environmental Office have been implementing for more than two decades. It is an urban space renaturalization programme with a strong participatory component. Its objective is to reduce the heat island effect and improve bioclimatic comfort, through the habilitation, improvement and recovery of green areas. Additionally, it improves urban environmental quality through the generation and increase of soft floors, landscaping and beautification of green spaces. This

programme encourages the transformation of hard areas into soft areas through the planting of native and ornamental plant species. These green areas are designed and managed in a participatory way in which communities are responsible for their maintenance and conservation under the concept of co-responsibility.

Figure 40. Picture of Envigado. Source: Environment Office of Envigado

7.2. Status of implementation of the assessment

In order to implement the monitoring module and formulating the Monitoring Strategy for Envigado Florece programme, The city of Envigado with Humboldt institute have followed the modules of the INTERLACE protocol: Module II. Decision Framing, Module III. Co-creation, and Module VI. Monitoring. Starting at the end of 2022, four workshops and several working sessions have been held to define roles and objectives, identify and weight evaluation criteria, define indicators, among others. These meetings and sessions have been carried out by forming teams as indicated by the protocol. So far, the development team is finishing the strategy to be presented to a wider group of stakeholders involved in the co-creation process.

Modelling exercises have been also applied in Envigado to define the baseline condition and identify potential monitoring variables and location of monitoring devices, regarding the NBS effectiveness of thermal comfort, to inform early warning systems and future planning decisions under climate change scenarios. By the end of this year, the final version of the Monitoring Strategy of Envigado Florece

Programme is expected to be ready. Next subsection describes the process of implementing the protocol and he results obtained up to date.

7.3 Module II. Decision Framing

The decision making module was worked with a small group of people from the City Focal Point, that at a later stage consolidates as *Developers.* An in-person workshop was held in Bogotá were the INTERLACE pilot assessment framework was presented, together with insights to the protocol, the co-creation and the Agile approach. Next to that, a few on-line working sessions took place to work on the Decision Framing module.

Definition of the assessment system

Describe the challenges to be addressed

Envigado Florece main and secondary challenges

Main

- Heat island effect
- Social appropriation, citizen participation.
- Renaturalisation of urban spaces, increase green areas (landscaping) and elimination of hard, impermeable surfaces.
- Biodiversity enhance (pollinators, vegetation, entomofauna, habitat supply).
- Functional gardens - ornamental, medicinal plants, and vegetable gardens.

Complementary

- Intra-urban ecological connectivity (small scale)

Describe the objectives of the assessment

Assessing the impact of actions to renaturalise urban spaces in an active participatory way by formulating the monitoring and evaluation strategy of the programme. Such evaluation will be focused on the impact on the reduction of the heat island effect, the increase of biodiversity, the improvement of the participatory process, and the improvement of people quality of life.

Definition of scale

Define the scale of the intervention, including considering cross-scale implications

The programme is implemented in the urban area of the municipality, which is divided by zones. The actions can be measured in terms of such zones, by neighbourhood or at mico-scale, that is, per garden or implementation.

Definition of scope and constraints

Define the scope and potential initial constraints, e.g. from subordinated planning frameworks, data availability

Possible difficulties and constraints of formulating the monitoring and evaluation strategy of the Envigado Florece Programme:

- Lack of information or updated information about the programme implementations
- The programme has a wide variety of stakeholders responsible for the different implementations, which can make it difficult to generate information about them. For that reason it is important to define wich kind of implementations are going to be included in the strategy:
    - Those implemented by the Environmental Office (EO),
    - Those that are implemented by the citizens, but the EO support with supplies, maintenance, etc.,
    - Participatory budget projects for the transition from hard to soft surfaces,
- Lack of maintenance capacity on the part of those responsible for the gardens can result in the deterioration of the gardens. How do we measure this?

7.4 Module III. Co-creation

After framing the objectives of the assessment, selecting the main Module to follow (which in Envigado's case is Monitoring), the scale, and the other aspects described above. On-line meetings were held in order to follow the co-creation module, in which stakeholders, and a proposed work dynamics were identified.

Stakeholder identification (role and group)

The stakeholders initially identified as potential contributors to the monitoring strategy are presented in the table below. It should be noted that not all of these were ultimately involved in the co-creation workshops. Furthermore, an additional column was added to the original protocol table given that a number of thematic working groups were defined to formulate the monitoring strategy: A=coordination, B= Biodiversity group, C= Climate group, and D = Social group.

Name of the representative	Organisation	Stakeholder role	Stakeholder group	Potential group
Diana López	Environmental Office of Envigado (EO)	Developer	Governmental authorities	A
Sergio Montealegre	SMADA	Developer	Governmental authorities	A
Johanna Tabares	SMADA	Developer	Governmental authorities	A
Isabel Melo	Humboldt Institute	Developer	Academia, research and education	A
Luis Perez	Community	Enabler	Citizen	B
Carlos Restrepo	Ornithological Society of Antioquia (SAO)	Shaper	Citizen	B
Carlos Julio	SAO	Enabler	Citizen	B
Paloma Gonzalez	Community	Enabler	Citizen	B
Robin Bedoya	Community	Enabler	Citizen	B
Gonzalo Abril	Community	Enabler	Citizen	B
Carlos Gonzalez	SMADA	Shaper	Governmental authorities	B
Diana Ruiz	Humboldt Institute	Shaper	Academia, research and education	B

Tecnalia	Tecnalia	Shaper	Academia, research and education	C
Hansel Córdoba	Planning Office of Envigado	Shaper	Governmental authorities	C
Andrés Mejía	EO	Shaper	Governmental authorities)	C
Gloria Inés Uribe	EO	Shaper	Governmental authorities	C
Sara Maestre	Universidad Autónoma de Barcelona	Shaper	Academia, research and education	D
Anny Merlo	Humboldt Institute	Shaper	Academia, research and education	D
Daniel Rivera	EO	Shaper	Governmental authorities	D
John Jairo	EO	Shaper	Governmental authorities	D
Wilfer Ospina	EO	Shaper	Governmental authorities	B
Other leaders from Envigado	various	Shaper	Citizens	na

Setting co-creation goals

Co-creation goals:

- Formulate a monitoring and evaluation strategy of the Envigado Florence Programme to measure, quantify and divulgate its impacts
- Complement the expertise and knowledge of Envigado's technical team with experts from INTERLACE and other key community stakeholders to obtain a robust evaluation framework that incorporates different and varied points of view.
- Promote and facilitate ownership of the EF programme, so that the community appreciates the importance of mitigating these challenges e.g. heat islands, pollination etc.

Implementation plan of the engagement activities

Engagement activity	Objective	When to conduct it	Who to involve	Format
Definition of implementation objectives - internal working session	To define the overall objectives of the monitoring and identify the actions proposed for each implementation. To establish working groups and identify other actors to be involved.	September 2022	CFP, developers	Virtual
Definition of evaluation criteria - internal working session	To define evaluation criteria in the core group (developers) and plan the participatory sessions.	October 2022	CFP, developers	Virtual
Review of co-creation objectives, weighting exercise and groups formation - workshop	To present the objective of the monitoring strategy, perform the criteria weighing exercise, and establish the working groups.	February to March 2023.	Developers, shapers and enablers	In person
Definition of indicators through working groups - Workshops	To identify possible indicators for the evaluation criteria	April - June 2023	Developers, shapers and enablers	one virtual session per group
Writing of the monitoring strategy document - Working sessions	to organise the results from the workshops in a document	July - November 2023	Developers	desk work
Socialisation and reflection of the process and next steps. Workshop	To present and validate the document and formulate next steps.	November 2023	Developers, shapers and enablers, with other stakeholders	to be defined

The refinement of the objectives was performed during the weighting exercises. For that reason, the results are presented in the motoring module section.

7.5 Module IV. Monitoring

After pre-defining the main criteria, an in-person workshop took place in Envigado, with the Developers, and other stakeholders in order to present and validate them, perform the weighting exercise, and define next steps. In such workshop the objectives of the Envigado Florece monitoring strategy were presented and participant shared their experience with the programme and their perception. Then pre-selected

criteria were presented and the criteria weighing discussion took place. The monitoring module protocol guided the process for defining and weighting the criteria, as well as identifying the indicators. For the results of this module, see below:

NBS criteria selection

NBS name **Envigado Florece**

Initial list of evaluation criteria and actions/interventions for the nature-based solution

N	Evaluation criteria	Action / intervention
1	Climatic comfort	Planting trees, and implementation and maintenance of community gardens in neighbourhoods, in residential units and on private land.
		Moving from hard to soft soil surfaces through the Presupuesto Participativo Programme
		Renaturalisation of urban spaces
		Production of plant species in the plant nursery for distribution, and provision of planting inputs
2	Social appropriation of the territory and promotion of citizen participation	Envigado Florece contest
		Gardening courses and workshops
		Implementation maintenance community activities
		Personalised advise sessions
		Art activities and tours associated with changing hard to soft surfaces within the Presupuesto Participativo programme.

		Plan distribution
3	Human wellbeing	Inclusion of ornamental, medicinal and edible plants in the programme
		Gardening workshops with an emphasis on health and wellbeing
4	Biodiversity (pollinators, vegetation, entomofauna, habitat supply)	Planting of trees and implementation and maintenance of community gardens, in residential and private units.
		Entomological and plant species studies for inclusion in gardens
		Plan distribution
		Renaturalisation of urban spaces
5	Intra-urban ecological connectivity (small scale)	Planting of trees and implementation and maintenance of community gardens, in residential and private units.
		Renaturalisation of urban spaces
6	Green space management	Planting of trees and implementation and maintenance of community gardens, in residential and private units.
		Renaturalisation of urban spaces
7	Social cohesion	Implementation and maintenance activities in the community

Figure 41. Pictures of workshop held in Envigado.

Criteria weighting exercise

Workshop participants had a first round of individual voting on the criteria. This was followed by a round of debate and discussion in which each participant voted and, at the end, the scores from this debate were totalled.

Evaluation criteria	Final score
Social appropriation and participation	23
Biodiversity enhance	20
Climatic comfort	10
Ecological connectivity	6
Human wellbeing	2
Green spaces management	1
Social cohesion	1

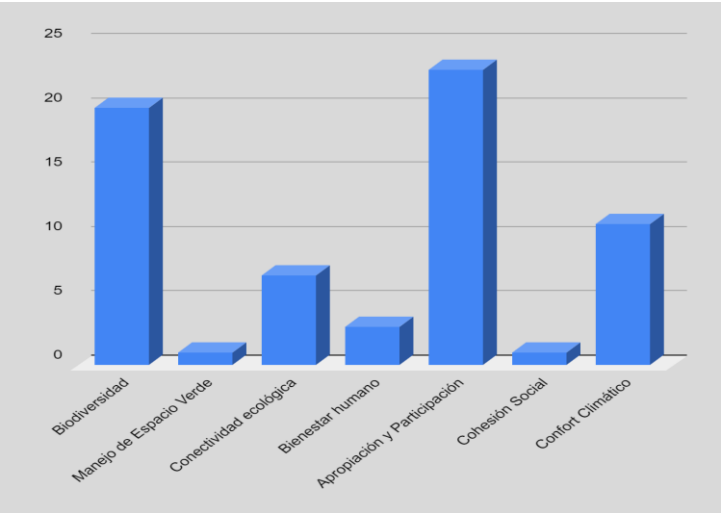


Figure 42. Weights obtained by each criteria

After the workshop, three working groups were defined: Biodiversity, Social, and Climate. Each group had the task of defining indicators to be included in the monitoring strategy. For Biodiversity and Social indicators, a desk review was performed and on-line meetings with participants of each group. For Climate aspects, a number of online meetings were held during between Tecnalia´s team and members of the Environmental Office of Envigado, in which simulation modelling exercises at micro-scale were identified as valuable tools for monitoring and evaluation of NBS performance under climate change scenarios. After that, modelling exercises were applied in order to define the baseline condition and identify potential monitoring variables and location of monitoring devices, regarding the NBS effectiveness of thermal comfort, to inform early warning systems and future planning decisions under climate change scenarios. the advances of each group is shown below.

7.5.1 Identifying biodiversity indicators for the Envigado Florece Programme

First step was to define a monitoring question for biodiversity aspects. This was done on-line, in a meeting with the biodiversity group participants. There, two questions were defined, included potential indicators and initial guidelines. Next steps will include to define specific guides to collect and analyse the information for each of the indicators.

First biodiversity question

Are planting interventions associated with increased diversity and abundance of Lepidoptera, Hymenoptera, Hemiptera, Coleoptera and birds in the municipality of Envigado?

Biodiversity enhance indicators

- Change in the number of plant species
- Change in the number of birds
- Change in the number of lepidopteran species (butterflies and moths),
- Change in the number of species of Hymenoptera, Hemiptera (bugs, rooks, etc),
- Change in the number of coleopteran species (beetles and related).
- Change in the number of species of concern (Conservation objects or with potential use)

Ecological connectivity question

How do planting interventions increase the amount of green space reflected through the square metres implemented in each zone?

Based on the assumption that by increasing green areas in a micro scale, (structural) ecological connectivity will be assessed by measuring new areas and relating it with biodiversity indicators.

Indicator

- Change in the green areas available (square metres) in the different neighbourhoods where gardens/planting are implemented in the city of Envigado.

7.5.2 Identifying social indicators for the Envigado Florece Programme

Initially, an on-line meeting of the social group was held to guide the identification of possible social indicators based on the actions and challenges addressed by Envigado Florece Programme. After that, a desk search was performed to identify specific indicators and methods. Next steps will include to define specific guides to collect and analyse the information for each of the indicators.

Social cohesion indicators

- Perception of the impact of NBS on social cohesion.
- Trust and solidarity among community members.

Social appropriation and participation

- Willingness to carry out community work.
- Perception of security.
- Willingness to participate in the future.

Human wellbeing indicators

- Perception of security
- Connection with Nature

7.5.3 Modelling exercises in Envigado to evaluate NBS effectiveness against thermal confort with Envimet

Simulation Models are tools that are used to predict and evaluate the impact of different urban designs and solutions on certain variables. These simulations are based on numerical models that consider different factors based on a three-dimensional model of the area. From a baseline, different design alternatives can be simulated to, through a comparative analysis of effectiveness, inform decisions about urban planning.

In general, simulations are a valuable tool for designers and urban planners to make informed decisions about the implementation of NBS in urban areas. Modelling is made through Computational Fluid Dynamics (CFD) calculations. Specifically, with ENVIMet 5.0 software, which allows understanding the complex dynamics of heat distribution in the neighbourhood. This 2mx2m evaluation of thermal comfort aids in exploring hot spots and seeing the effectiveness of urban interventions made with nature-based solutions. This kind of adaptive and climate-responsive public space policies are laid by the analysis of heat distribution and how the citizens are affected by it. Urban planners and decision-makers can implement targeted interventions that promote natural cooling, reduce the urban heat island effect, and enhance overall livability and walkability. With the pressing challenges posed by climate change, this assessment holds particular significance in designing sustainable and resilient urban environments.

EnviMet is a microclimate modelling tool used to simulate thermal comfort in urban and outdoor environments. It enables the creation of 2D and 3D models to conduct detailed simulations of urban climate and the thermal comfort of individuals in public spaces. Building the 3D model involves providing the complete geometry of buildings, trees, and other elements that influence the urban climate. This is done in order to create and export the geometry of objects in the appropriate format for EnviMet and it is made using GIS software. Once the model of the study area is created, input climate parameters such as temperature, wind speed and direction, relative humidity, and other relevant meteorological data. This is done by selecting typical days based on historical climate data.

By understanding how different building configurations, land use and vegetation types influence local thermal comfort, decision-makers can make more informed choices. In this context, the relevance of CFD calculations extends beyond immediate comfort considerations, emphasising the pivotal role of informed design strategies in fostering environmentally conscious and resilient cities.

The exercise in Envigado had four calculus areas which comprehend four neighbourhoods with different characteristics. Mesa, Flores, the central area and Alcalá were the ones selected. Mesa and the central area share homogeneous characteristics as they have an orthogonal street pattern, are dominated by asphalt, and share mix land use (commercial and residential). Flores and Alcalá are different ways of residential neighbourhoods both dominated by green areas.

Figure 43. Four districts selected for the assessment of NBS effectiveness against thermal stress in Envigado, namely Mesa, Flores, the Central area and Alcalá

Methodology

Three steps methodology was applied to carry out the exercise: scope of the study, computational simulation processes, and preparation of indexes and comparisons.

Regarding the scope of the study, local climatic conditions are analysed, as well as land uses in the study area. This study characterises the hourly distribution of different variables such as temperature and

humidity and, in turn, determines that types of soil make up the area. Regarding computational simulation processes, characterization information is entered into the ENVIMET software. It uses advanced numerical models to simulate atmospheric dynamics and the interaction between buildings, surfaces and vegetation in urban areas. The climatic or pollutant emission conditions are analysed, as well as the land uses of the study area. This study characterises the time distribution of the different simulation variables and, in turn, determines what types of soil make up the area. The characterization information is entered into the corresponding software. Advanced numerical models are used to simulate different scenarios and the role that some of them can play in urban design, such as Nature-based Solutions. The results allow applying effectiveness indices, observing the behaviour of the variables over time, or creating comparisons between different scenarios, including the differentiations between the current climate and a future one with climate change for the variables of thermal comfort. And for preparation of indexes and comparison, the results allow us to apply NBS effectiveness indices, observe the behaviour of thermal stress throughout the day or create comparisons between different scenarios, including differentiations between the current climate and a future one with climate change.

Results

2D thermal comfort maps were made for each of the districts analysed in Envigado, that allowed to identify areas where adverse thermal conditions occur and areas where optimal thermal comfort is achieved. These maps can be useful in identifying areas of high risk of heat stress, which may be particularly important for planning urban design and public health risk management. The comparison allows evaluating the effectiveness of the improvement measures implemented. The scenario with future climate assumes the conditions of a typical day in the study area under a temperature increase of 1.95ºC with the help of CORDEX models. The simulation with the future climate is a great opportunity to know in general terms the consequences of the acceleration of climate change in the area. The future scenario has been carried out by increasing a delta of 1.95ºC to the temperatures of the baseline climate file. This was done using three CORDEX models. As Envigado is located in a mountainous area, the spatial resolution has taken precedence over the number of models available, finally using the “South America” region of CORDEX.

The Mesa neighbourhood is a central space with a mix of commercial activities and residential uses. The buildings provide low levels of shading, and it is the natural solutions that play a fundamental role. Thermal comfort varies from one street to another significantly since there are streets without trees compared to others that do. 76% of the area is under PET levels compatible with heat stress and there exists a noticeable differentiation between tree-shaded areas and asphalt ones. There are cases in which there is a 19ºC difference. The future climate will affect the Mesa neighbourhood, generally increasing the PET of the neighbourhood by between 1-3ºC. There are increases in all streets, especially in those that do not have trees. In 90% of the surface the PET will increase but tree areas can even reduce it by 0,5ºC. This shows the effectiveness of nature-based solutions even when the general temperature increases. This may be due to factors such as blocking the direct solar radiation, evapotranspiration, or implication in the air circulation. These maps of PET changes with future climate become a very interesting tool to find opportunity spaces to apply urban design policies.

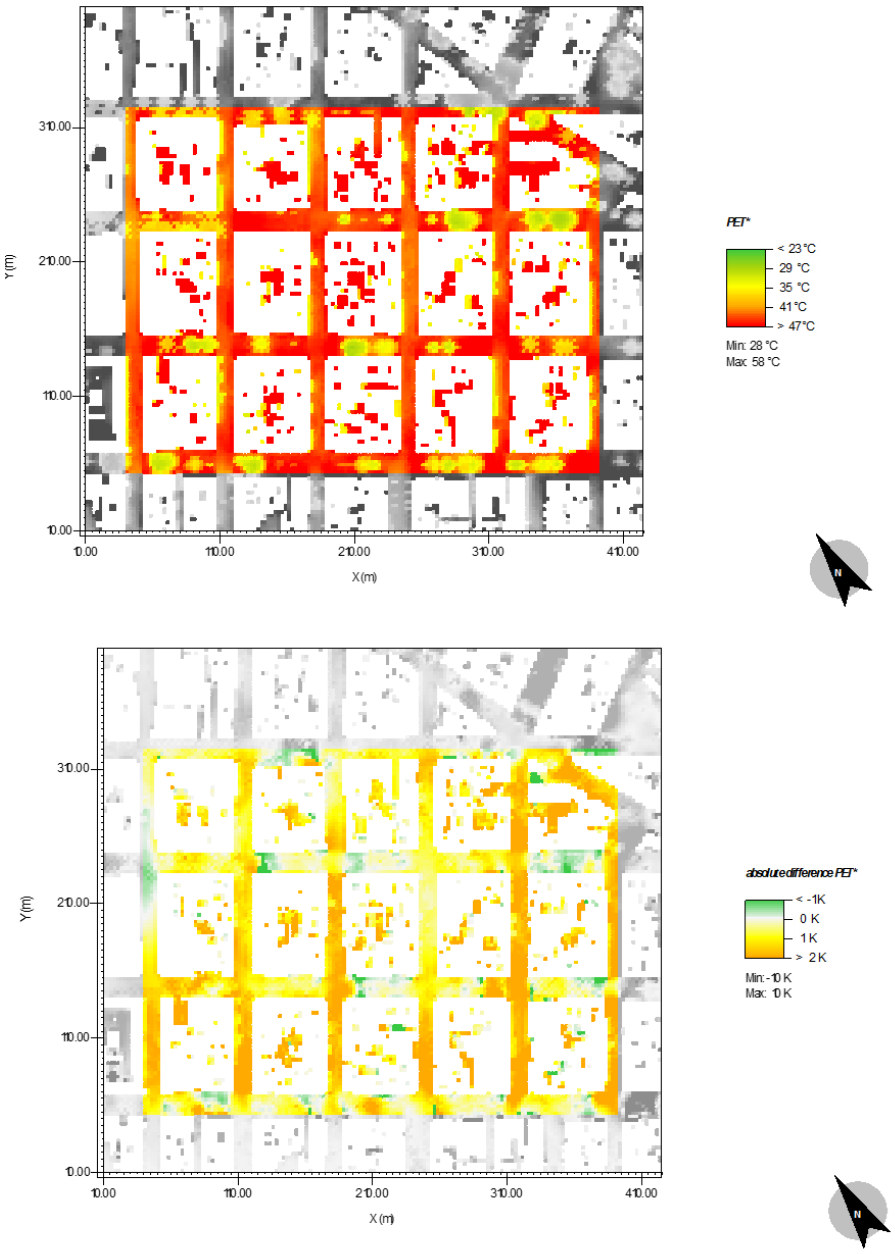


Figure 44. Baseline scenario and different PET levels / Differences in ºCPET between baseline scenario and climate change scenario (RCP 4.5) in Mesa neighbourhood.

Figure 45. Opportunity areas identified in Mesa, based on modelling exercise.

The Flores neighbourhood in Envigado is a small residential area dominated by paved spaces and large trees of different species. Homes usually have three floors with limited shading capacity, so solutions based on nature are the only ways to improve thermal comfort in the current space. 71% of the area is under PET levels compatible with heat stress and there exists a noticeable differentiation between tree-shaded areas and asphalt ones. There are cases in which there is a 21ºC difference. The future climate in the Flores neighbourhood will show an increase of between 1ºC-2ºC of PET in paved spaces while in

areas with trees, it will remain the same or decrease to 1ºC. In 86% of the area, PET will be higher but nature-based solutions can even lower the temperature by 3ºC if comparing both scenarios.

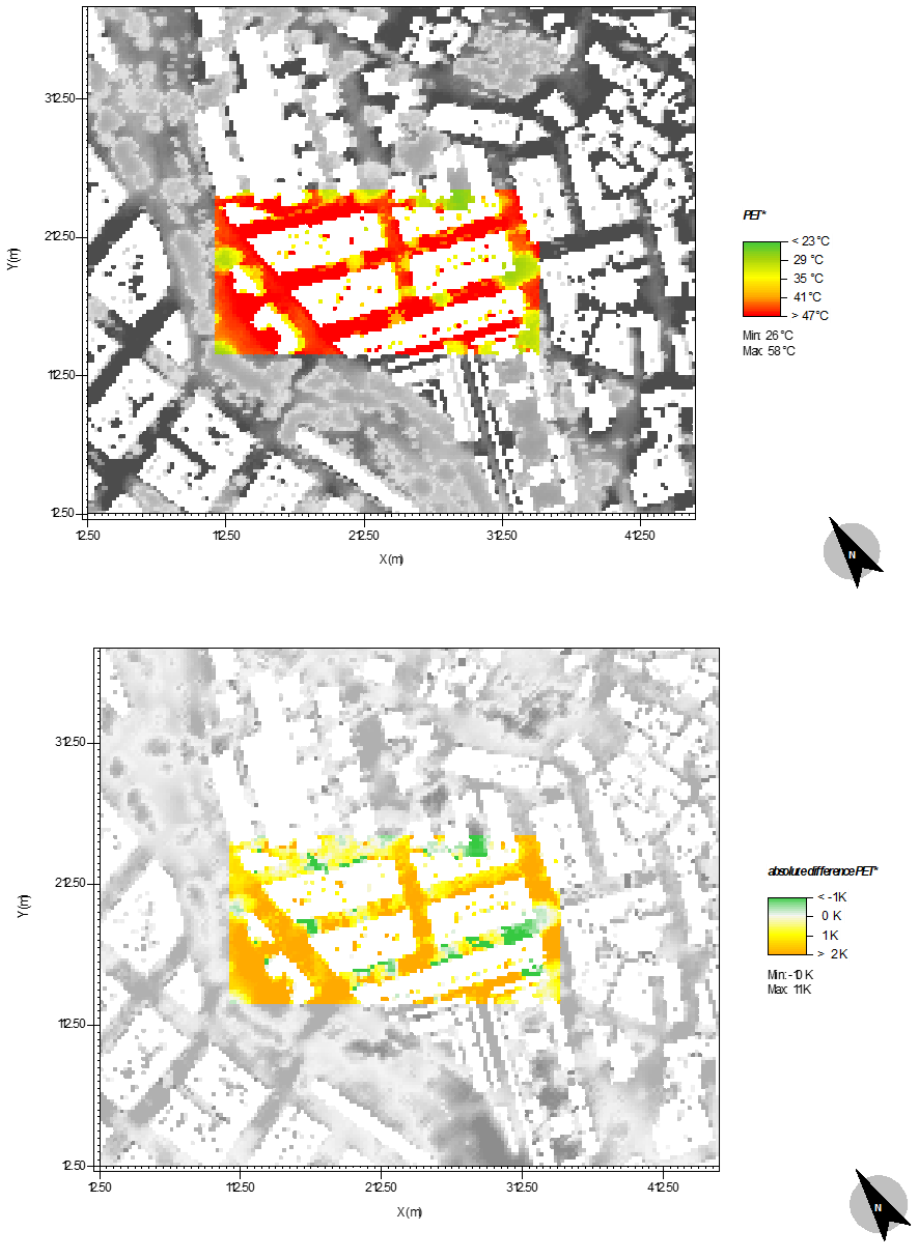


Figure 46. Baseline scenario and different PET levels / Differences in ºCPET between baseline scenario and climate change scenario (RCP 4.5) in Flores neighbourhood.

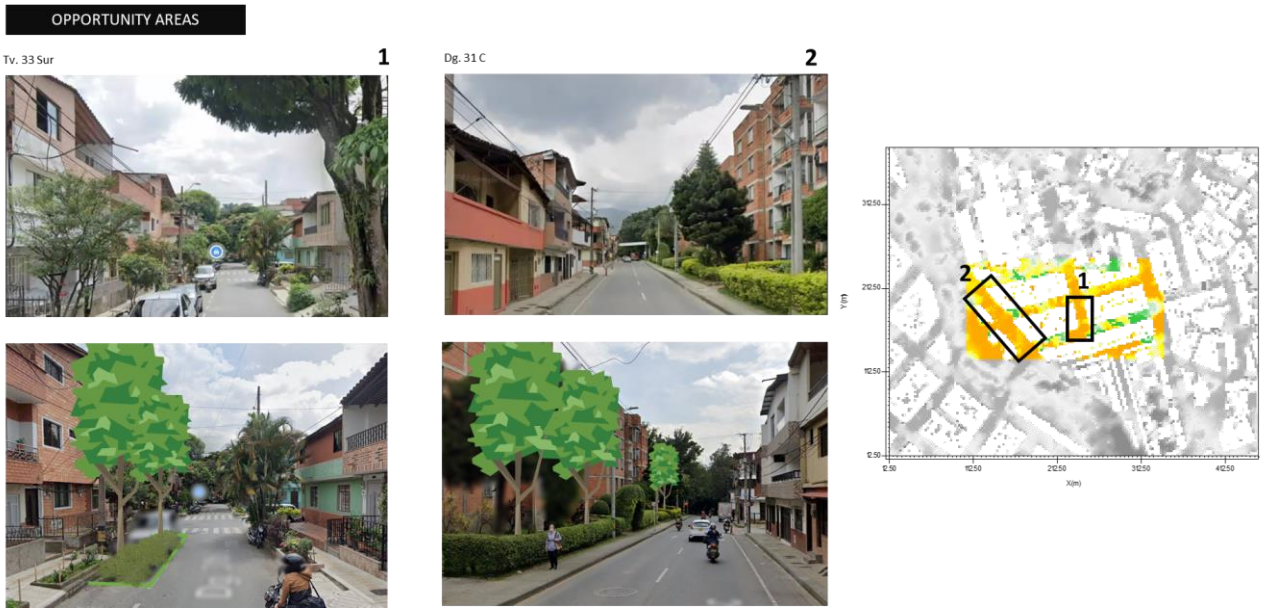


Figure 47. Opportunity areas in Flores based on modelling exercise.

The central neighbourhood of Envigado is a commercial and residential area in square blocks dominated by asphalt and narrow sidewalks. Sometimes there are trees that provide shade, but in others, their canopy is not dense enough or does not exist. There are great variations between neighbouring streets. Taller buildings provide shading on sidewalks, producing a differentiation in 16ºC of PET between sidewalks. The future climate will affect the central neighbourhood, generally increasing the PET of the neighbourhood by 1ºC. There are increases in all streets, although the effect of trees is present in some blocks. In 90% of the area, PET will rise, but in half of it, the increase will be below 1ºC.

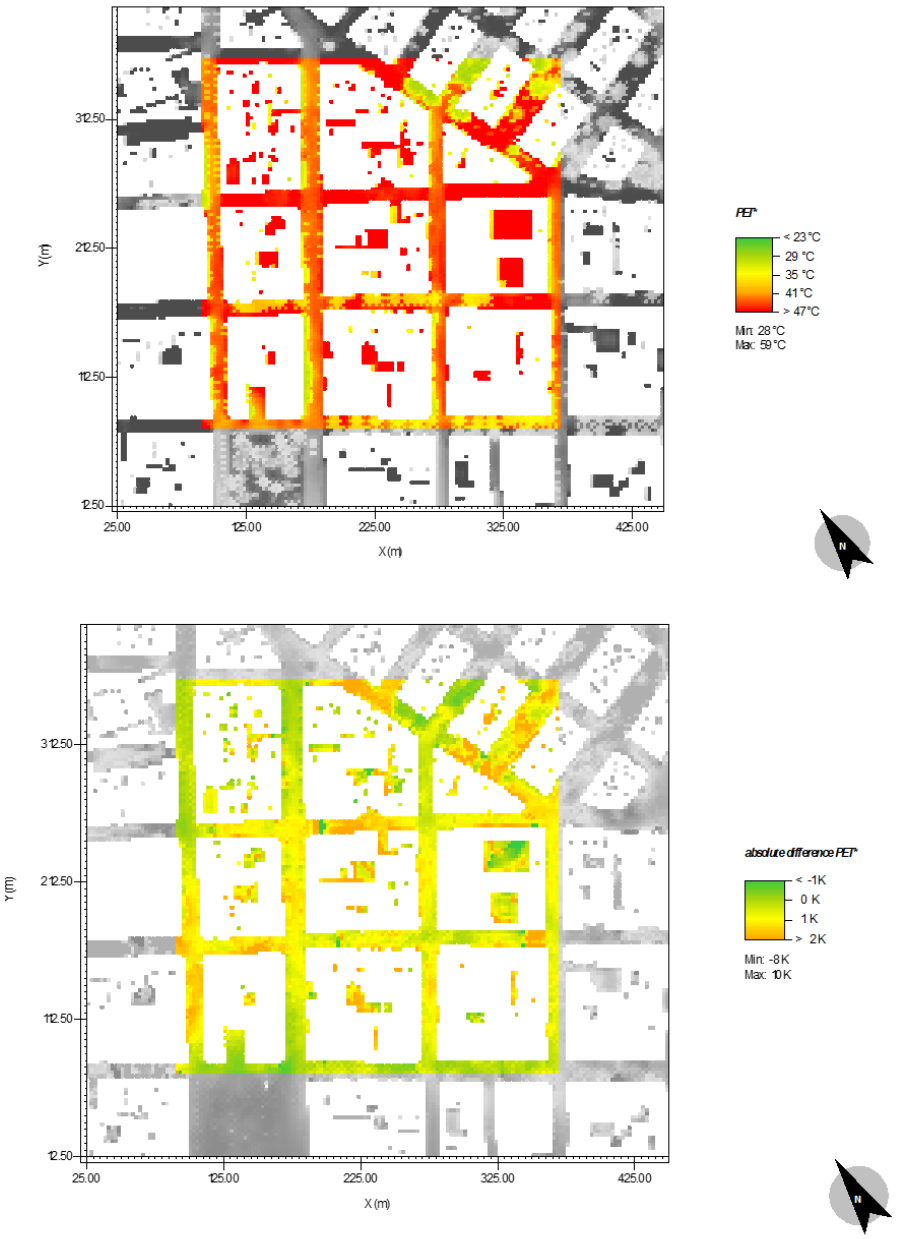


Figure 48. Baseline scenario and different PET levels / Differences in ºCPET between baseline scenario and climate change scenario (RCP 4.5) in central neighbourhood.

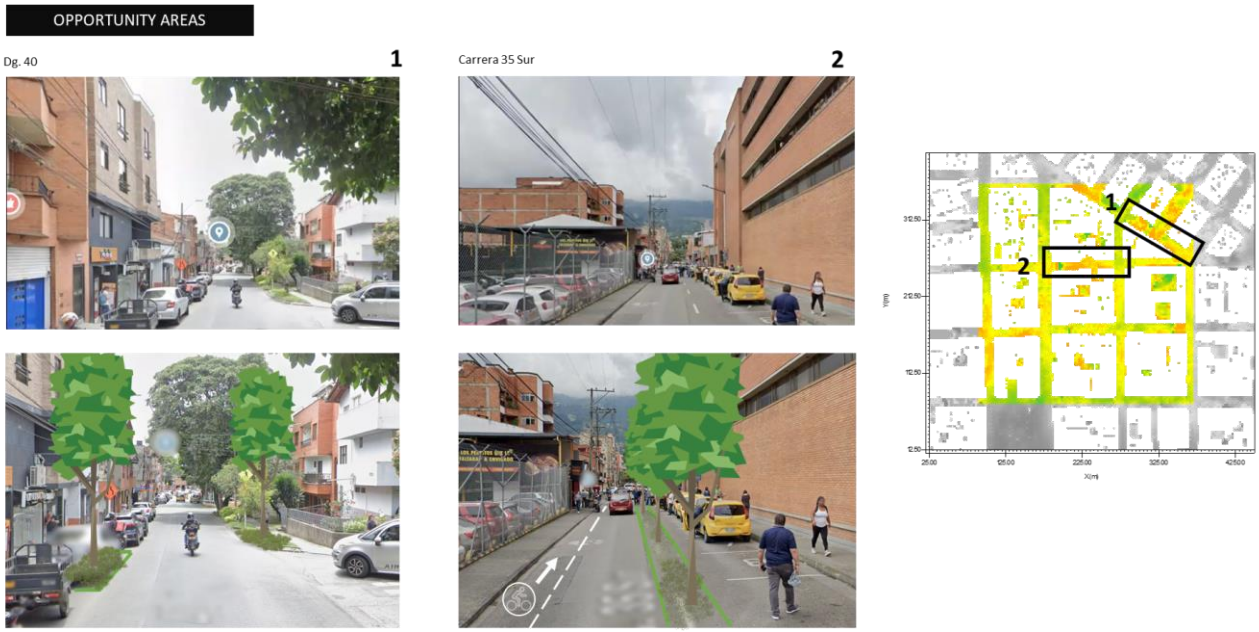


Figure 49. Opportunity areas in Area Central based on modelling exercises.

The Alcalá neighbourhood is a residential area in rectangular blocks with generally three-story homes. It accuses a lack of nature-based solutions in most streets that is compensated on some sidewalks with the shading of buildings. The main arteries, on the other hand, do have comfortable public space. Areas compatible with levels of risk of heat stroke are the majority in space. Specifically, 66% of the area is under those PET levels. Nevertheless, spaces on main avenues tend to be more comfortable. Differences

in PET between places on the sidewalk of a main avenue and places on the sidewalk of a residential street within the neighbourhood can have differences up to 17ºC of PET.

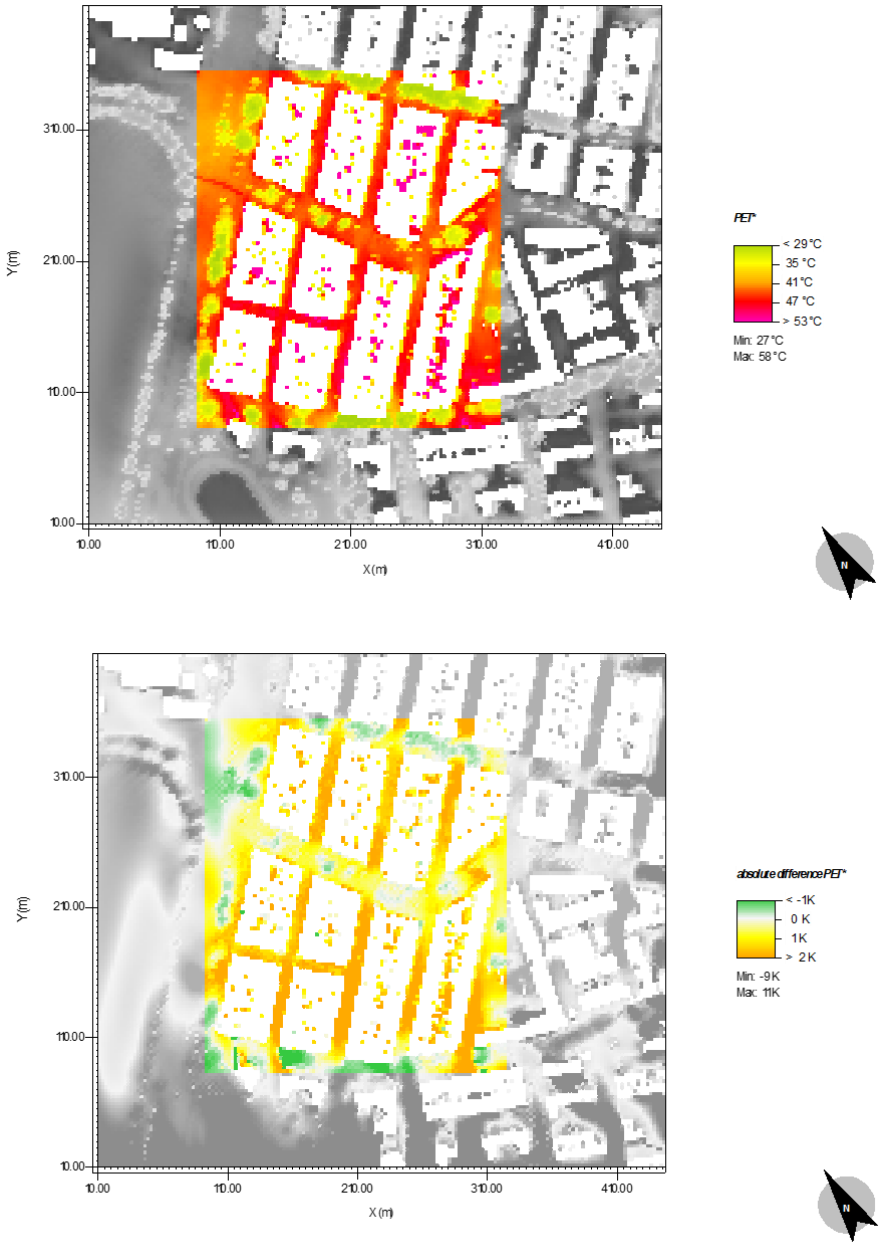


Figure 50. Baseline scenario and different PET levels / Differences in ºCPET between baseline scenario and climate change scenario (RCP 4.5) in Alcalá neighbourhood.

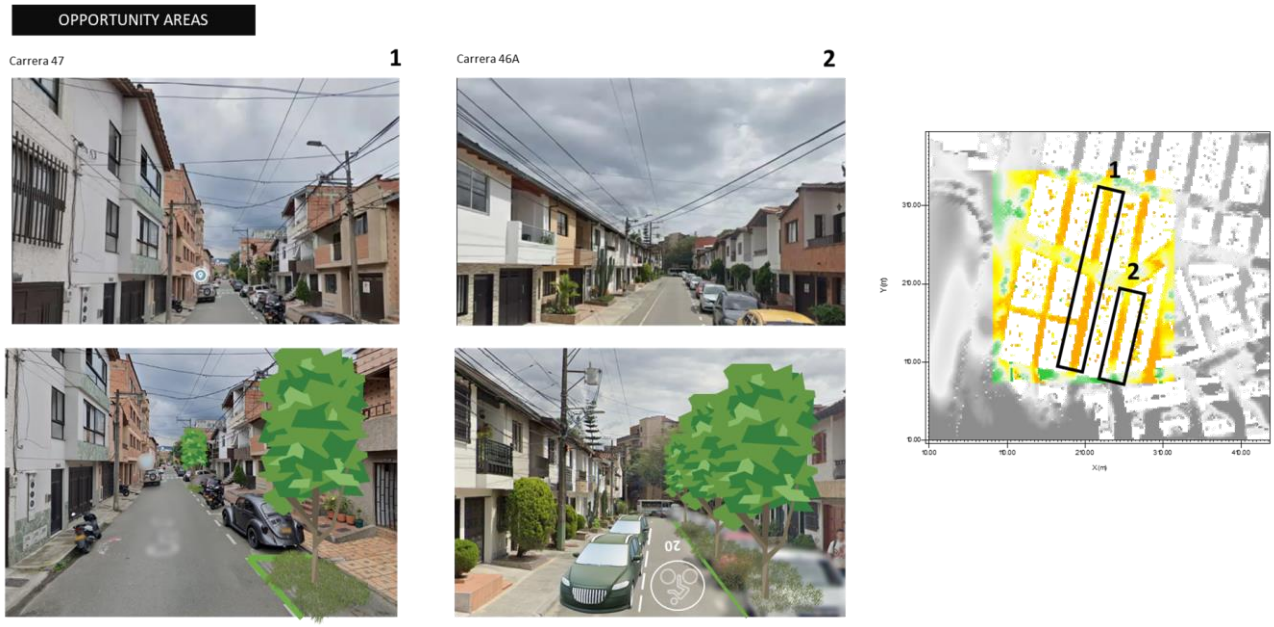


Figure 51. Opportunity areas in Alcalá based on modelling exercises.

In Envigado, local stakeholders and city planners are provided with spatially explicit information that can contribute to early warning systems in relation to heat stress. By monitoring meteorological variables and using predictive models to forecast future conditions, it can provide advanced warning of dangerous heat waves and other extreme heat events. This information can be used to develop targeted interventions such as cooling centers, provisional drinking fountains, public education campaigns, and emergency response plans.

8. Chemnitz

8.1. Description of Chemnitz and the area of intervention

The Old River Bath in Altchemnitz is one of the intervention areas of the European Capital of Culture Chemnitz 2025. The project is part of the "City on the River" project, in which various flowing waters in the city are to be brought back to life.

River bathing has a long tradition in Chemnitz. At least since the opening of the municipal "river, air, sun and swimming pool on the Chemnitz in today's Altchemnitz district in 1922, the place has enjoyed extreme popularity among bathers. For decades, the Flussbad was one of the most frequented outdoor pools in the city of Chemnitz. Today - almost 20 years after the complete dismantling of the bathing facilities, which were severely damaged by the floods of 2002 - nothing reminds us of this tradition, a place seemingly forgotten. As part of the "City on the River" project, which will culminate in the European Capital of Culture 2025, the river is to be brought back to life. The leisure and recreational potential of the floodplain will be enhanced on both sides of the river and the accessibility of the area improved by a new bridge. The bridge is not only a connecting element, but also an architectural attraction and a vantage point on the Chemnitz, which is being redesigned in a near-natural way at this point by the state dam administration.

The two banks of the Chemnitz are no longer connected since the demolition of the former footbridge. On the right bank of the river is the building of the former river baths, which was erected in 1926 and is now a listed building; on the left bank are the alluvial meadows of Chemnitz City Park, which are a listed garden. In addition, the southern city park has been protected since 1996 as a protected landscape feature to promote the interconnection of biotopes. This area was formerly also home to the 50-metre swimming pool built in 1928 as an addition to the river bathing area and the extensive sunbathing lawns. In order to reconnect both sides of the Chemnitz River as well as the adjacent urban spaces, a new bridge will be built at the site of the former footbridge.

Figure 52. Picture of the Old River Bath in Altchemnitz in Chemnitz (© Chemnitz City Council)

Figure 53. Area of intervention for the rehabilitation of the Altes Flussbad Altchemnitz in Chemnitz (© Chemnitz City Council)

8.2. Status of implementation of the assessment system

To develop its assessment system to monitor the interventions in the Old River Bath in Altchemnitz, the city of Chemnitz guided by WP3 members has followed the modules of the INTERLACE protocol: Module II. Decision Framing, Module III. Co-creation, and Module VI. Monitoring. The city has conducted the participatory workshop to co-create and weight criteria for the monitoring of the interventions on 18th of September of 2023. The following steps will be to define indicators for each criteria and elaborate the

monitoring plan. By beginning of next year, the final version of the Monitoring Strategy of Chemnitz is expected to be ready.

8.3. Module II. Decision Framing

Definition of the assessment system

Describe the challenges to be addressed

Improve biodiversity

Fluvial biodiversity, improve water quality, increase in population (birds, insects) on land or in the river.

Ecological connectivity

Through the planting of new trees and shrubs and the ecological restoration of a short section in the Chemnitz river an improvement of the ecological connectivity is projected.

Human health & wellbeing

Through missing meeting and recreational points in this area of the Stadtpark the park is behind its potential for human health and wellbeing for neighbours of the park and potentially other inhabitants of Chemnitz.

Green space management

The maintenance of the intervention area is currently on a low level, through the development of the area the maintenance of the area will be improved.

Social cohesion

The area of intervention lies in between two socially and economically lower neighbourhoods, the development of this area could improve cohesion and exchange between them and other neighbourhoods since it would work as a meet and exchange place.

Social equity

The Stadtpark in this area is vast and destinations for daily visits are further downstream. The bridge will allow access to the Stadtpark. The development of the area could be beneficial for social equity.

Describe the objectives of the assessment

To monitor social and environmental aspects before and after the development in order to understand the usefulness of specific developments.

To re-use the monitoring plan for other development sites of the Green Space Office.

To monitor social criteria: hard (number of visits, benches, information plates) and soft (perceived social quality of the area, increased social cohesion and equity, perceived wellbeing).

To monitor environmental criteria: hard (number of species/plants, temperature) and soft (perceived quality of nature/quality of biodiversity)

Additional relevant information

The area to be monitored is an intervention site of the European Capital of Culture 2025. The revitalization of the “Altes Flussbad Altchemnitz” includes the construction of the bridge, paths between the bridge and the existing path system of the park, sundecks, art sculptures, information boards, new tree and shrub plantings and a newly created access to the river. Originally the place was used as a summer bath with the option to also use the river as a bathing place.

Definition of scale

Define the scale of the intervention, including considering cross-scale implications

Sub-area of the river (area of intervention), the bridge and the paths along the riverside for environmental criteria.

Up to neighbourhood-level for social criteria.

Possible cross-scale implications for, e.g. social equity, human health & wellbeing.

Definition of scope and constraints

Define the scope and potential initial constraints, e.g. from subordinated planning frameworks, data availability

Scope: Environmental and social monitoring aspects of the development for this area. Deliverable in the bid book for the European Capital of Culture 2025.

Environmental impact assessment is being developed (birds, dragonflies, plants). There is more information about aquatic fauna from the “Landestalsperenverwaltung (LTV)”, that are in charge of monitoring the quality of the river. Data collected in Autumn 2023.

The construction works will start early 2024.

There may be little data about social aspects.

8.4. Module III. Co-creation

Stakeholder identification (role and group)

Name of the representative	Organisation	Stakeholder role (select one from list in Table 1)	Stakeholder group (select one from list in Table 2)
Florian Etterer	Green space office - City of Chemnitz	Developer, End-User	Governmental authorities
Max Krombholz	Urban Planing office - City of Chemnitz	Developer	Governmental authorities
	European Capital of Culture	Shapers	
General public		Shapers	Citizen
Jacqueline Drechsler	AWO Soziale Dienste Chemnitz und Umgebung	Shapers, Interested public	Civil Society

	gGmbH - Citizen Platform Mitte		
Katharina Keller	AWO Kreisverband Chemnitz und Umgebung e. V. .- Citizen Platform Süd	Shapers, Interested public	Civil Society
Thomas Rosner	AWO Soziale Dienste Chemnitz und Umgebung gGmbH - Neighbourhood Management	Shapers, Interested public	Civil Society
Janette Wilfer	Neue Arbeit Chemnitz e.V. - Community Management	Shapers, Interested public	Civil Society
Elke Uhlig	Local water authority (UWB) - City of Chemnitz	Shapers	Governmental authorities
Jens Börner	Local nature conservation authority - City of Chemnitz	Shapers, End-Users	Governmental authorities
Water maintenance authority (LTV)	Water maintenance authority (LTV)	Shaper, End-Users	Governmental authorities
Melanie Hartwig	Environmental center (Umweltzentrum) - City of Chemnitz	End-Users/ Shapers	Governmental authorities/ Civil Society
Heidi Enderlein	BUND - NGOs for nature conservation	End-Users/ Shapers	Civil society
Lutz Röder	NABU - NGOs for nature conservation	End-Users/ Shapers	Civil society

Setting co-creation goals

For the co-creation part of the monitoring the developers will ask local experts (shapers) about possible criteria and the weighting of the criteria in order to increase the value of the monitoring.

To adapt the assessment framework to the end-users need, they will be involved as shapers in order to ensure a useful product.

For aspects of Biodiversity: UNB, Nabu, BUND, ehrenamtliche Naturschutzhelfer, Umweltzentrum.

The interested public is involved in the co-creation to increase the awareness of such projects and to support the bottom-up process for further NBS.

For social aspects: Citizen platforms and district managers will be involved.

Engagement activity	Objective	When to conduct it	Who to involve	Format
Criteria selection and weighting	Selection of the criteria and weighting of those by local experts	Early September	Local experts (citizen platforms, district managers, environmental NGO's), related governmental authorities, green space office, core group	Workshop at the area of development
Indicator identification	Indicator selection for the prior defined criteria	Early October	Experts of UAB, core group	Online Meeting
Feedback on monitoring action plan	Collect feedback on the monitoring action plan	end of October	Local experts (citizen platforms, district managers, environmental NGO's), green space office, core group	Workshop in tba

Refinement of the objectives together with stakeholders

Explain who participated in the refinement of objectives and how it was done.

The refinement process was done by the internal team of the INTERLACE Assessment Framework in Chemnitz (Florian Etterer from the Green Space Department; Sarah Arnold from the Environmental Department; Isabel Melo from Humboldt Institute; Sara Maestre Andrés from ICTA-UAB and Max Krombholz from the Urban Planning Department.

In a first round Florian Etterer and Max Krombholz defined the objectives of the engagement. In a second round the whole internal Assessment team for Chemnitz refined the objectives.

8.5. Module IV. Monitoring

Selection of the criteria for the nature-based solution

Name of the nature-based solution: **Revitalization of the old river bath in Altchemnitz, Chemnitz**

Initial list of evaluation criteria and actions/interventions for the nature-based solution

N	Evaluation criteria
1	Water quality: Degree of water quality.
2	Occurrence of vegetation/plant species: Number of plant species present (invasive/indigenous).
3	Occurrence of animal species: number of animal species present (invasive/indigenous).
4	Functional biodiversity: Degree of functional biodiversity. (Describes the relationship between biodiversity and ecological processes. The main focus is on the

	characteristics that are functionally significant - both for the "functioning" of the organisms themselves and the ecosystem in which they occur).
5	Terrestrial ecosystem protection and restoration: enhancement of terrestrial habitats that contribute to increasing functional biodiversity and species diversity.
6	Protection and restoration of riparian ecosystems: Enhancement of riverine habitats that contribute to increasing functional biodiversity and species diversity.
7	(Functional) habitat connectivity: Defragmentation of the river and creation of ecological corridors that enable species mobility along the river and in the rest of the urban area.
8	Exposure to nature: degree of use that visitors:inside experience in the area.
9	Access to nature (accessibility): Realistic accessibility and distance from urban green spaces.
10	Sustainable green space management: Adapted management and maintenance of green spaces to the use objective.
11	Recreational potential: Ability of the area to function as a place for recreation or leisure.
12	Landscape aesthetics: Changes to the urban and environmental scenario that are pleasing to residents and better adapt the intervention to the landscape.
13	Further criteria

In total five people participated and did the weighting exercise of the criteria for the monitoring of the Revitalization of the old river bath in Altchemnitz:

- Elke Uhlig from the Lower Water Administration Chemnitz
- Jacqueline Drechsler from a citizen platform from Chemnitz-Center
- Sarah Arnold from the Environmental office
- Florian Etterer from the Green Space Office
- Max Krombholz from the Urban Development Office

The workshop was held in the green space next to the location of the “Altes Flußbad” in the neighbourhood Altchemnitz. At first, a short presentation of the INTERLACE Assessment Framework and an overview of the planned intervention “Altes Flußbad” was presented. In a second step, each participant had the chance to fully understand and familiarise with the proposed criteria, discuss it in the group and propose changes on each definition and on the final list of criteria to be weightened on. In the third and final step, the weighting of each criteria was done in the group. On a printed spinning wheel with all the final criteria listed, the collective weighting was undertaken. To distribute the available 100 points, corn kernels and oak nuts were used. One corn kernel was one point and one oak nut was 10 points worth. Clockwise every participant had the chance to weigh on one criteria of their choice until all criteria were weighted on. After the initial weighting phases a collective and deliberative weighting started discussing the final weight of each criteria and switching around corn kernels and oak nuts.

Through the initial discussion of the criteria and the individual definitions rough ideas about the individual weighting have been obtained. Already in the individual weighting a focus on the development of the ecosystem on land and water as well as the useability for recreational activities was of importance for the participants.

Table 24. List of evaluation criteria and their weight

Evaluation criteria	Final weight	Reason of the weighting
Vorkommen von Vegetation/ Pflanzenarten - Occurrence of vegetation/plant species	5	This will be affected automatically with the ecological development of the area
Vorkommen von Tierarten - Occurrence of animal specie	5	This will be affected automatically with the ecological restoration of the area
Entwicklung des terrestrischen Ökosystems - Development of the terrestrial ecosystem	20	Important to support the development of the terrestrial ecosystem
Entwicklung von Flussufer-Ökosystemen - Development of riverbank ecosystems	20	Important to support the development of the water-bound ecosystem
(funktionale) Lebensraumvernetzung - (functional) habitat networking	4	This will be affected automatically with the development of the ecosystem
Naturerfahrung - nature experience	20	The intervention is a good opportunity to foster the awareness about nature in the city
Erholungspotenzial - recreational potential	22	Main purpose is for recreational activities

Landschaftsästhetik - landscape aesthetics	4	aesthetic is like art: some like it and some not

9. Next steps

The four cities that are still developing their assessment framework, i.e. Portoviejo (EC), Chemnitz (GE), Granollers (SP) and Envigado (CO), are expected to finish in the following months. WP3 will support them following a train-the-trainer approach. As a follow-up process and with the aim to evaluate the implementation of the assessment framework in the six INTERLACE cities, several actions will be done in the coming months: i) an analysis of the protocols that each city together with their knowledge brokers have filled in with the aim to systematically describe the different steps and processes of implementation of the AF focusing on tracking the what, how, who and when; ii) semi-structured interviews conducted to members of the City Focal Points with the aim to have a subjective evaluation of the processes and steps of co-designing the AF focusing on what worked and what did not and why certain decisions were made; and iii) semi-structured interviews with members of the H2020 project Connexus to get external feedback on the assessment framework.

The lessons learned through this evaluation of the implementation of the INTERLACE pilot assessment framework will lead to a generalised assessment framework.

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11. Appendices

Appendix A. Questions to collect stakeholders feedback based on Participant feedback form for INTERLACE events

1. How would you rate the engagement activity in terms of content? (provide a Likert scale response ranging from 1 to 5, where 1 means “poor” and 5 means “excellent”).
2. What did you find most interesting?
3. Have you learnt anything new? And if so, what?
4. How would you evaluate the structure/format of the engagement activity? (provide a Likert scale response ranging from 1 to 5, where 1 means “poor” and 5 means “excellent”).
5. In case you evaluated the format as ‘poor/fair’ (1 or 2), please indicate why. In case you particularly liked a specific format, please indicate it.
6. On a scale from 1 to 5, in your opinion, to what extent did the moderation promote an open and respectful discussion? (provide a Likert scale response ranging from 1 to 5, where 1 means “closed-minded, fixed viewpoints” and 5 means “open, respectful, consensus-oriented”).
7. How would you rate the opportunities for networking and exchanging idees at the event?

8. How would you rate the heterogeneity of the workshops participants (in terms of expertise, affiliation, views, background, gender)? (provide a Likert scale response ranging from 1 to 5, where 1 means “poor” and 5 means “excellent”).
9. In case you evaluated the group as unbalanced, which group do you consider to be underrepresented (e.g. city government/administration, urban planners, business/industry, universities/research centres, NGOs/civil society organisations, women, other underrepresented groups)?
10. How would you rate this event’s logistical organisation? (provide a Likert scale response ranging from 1 to 5, where 1 means “poor” and 5 means “excellent”).
11. What would you have done differently in terms of event organisation?
12. Other general comments

INTERLACE

RESTORING URBAN ECOSYSTEMS
RECUPERANDO ECOSISTEMAS URBANOS

INTERLACE is a four year project that will empower and equip European and Latin American cities to restore urban ecosystems, resulting in more liveable, resilient and inclusive cities that benefit people and nature.

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Project Partners

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