Nature's integration in cities' hydrologies, ecologies and societies

M3.1 Co-design of restorative NBS evaluation criteria, constraints and opportunities

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1 Summary

NICHES project aims to advance knowledge on sustainable transformations of cities based on restorative nature-based solutions to enhance water retention capacities to mitigate impacts from floods and combined sewer overflows on aquatic ecosystems. This milestone corresponds to Task 3.1 Community vulnerability assessment (MS3.1) and aims to co-create evaluation criteria for nature-based solutions and identify constraints and opportunities in urban waterscape-wide rehabilitation plans through nature-based solutions. To reach these objectives, a survey and two workshops have been conducted in the Metropolitan Area of Barcelona. The survey and the first workshop asked participants about the importance they attribute to three dimensions for the evaluation criteria of nature-based solutions being vulnerability, multifunctionality and sustainability. A second workshop conducted identified stakeholders' views on the current state and the desired future of the urban water system of the Barcelona Metropolitan Area.

2 Co-creation of evaluation criteria for nature-based solutions and identification of constraints and opportunities

2.1 Background

This milestone corresponds to Task 3.1 Community vulnerability assessment (MS3.1) and aims to co-create evaluation criteria for nature-based solutions and identify constraints and opportunities in urban waterscape-wide rehabilitation plans through nature-based solutions. The study has been embedded within ICTA-UAB's long standing Metropolitan Science-Practitioners' Exchange (MSPE) process. This process has an established pool of local stakeholders and is continued across different research projects run at ICTA-UAB. The exchange has shown to be a trusted forum that supported ICTA-UAB transdisciplinary research (see Langemeyer et al., 2020; De Luca et al., 2021; Langemeyer & Baró 2021 for successful co-creation processes supported by the MSPE process).

2.2 Objective and general approach

The purpose of the co-creation process was twofold, aiming to (a) co-create evaluation criteria (selection, discussion, and weighting) and (b) to identify constraints and opportunities in urban waterscape-wide rehabilitation plans through nature-based solutions.

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 evaluation criteria of NBS can be explored from various viewpoints as well as identifying constraints and opportunities of NBS to improve urban water systems. By incorporating a greater quantity and diversity of knowledge and perspectives, tailored, locally-adapted and more equitable evaluation criteria for NBS can be created.

The co-creation process focuses on generating results based on the exchange of knowledge among participants. To this end, it promotes dialogue between actors with different points of view with the intention of reaching a consensus on social and environmental issues. The work was carried out under these premises and consisted of a survey and a participatory dynamic. The dimensions that have been considered for the evaluation criteria of nature-based solutions are vulnerability, multifunctionality and sustainability.

- **Vulnerability** considered as the exposure to social and environmental risks and the difficulty of individuals, groups or ecological systems to adapt to changes in the environment. The social aspect includes disadvantaged groups such as the elderly or people with motor disabilities.

- **Multifunctionality:** the ability of nature-based solutions to provide a variety of ecosystem services and benefits. These can be of different kinds, such as supporting, by providing natural habitats for animal species natural habitats for animal species, provisioning of fruits and vegetables, regulating, such as runoff, and cultural, which refers to the ability to provide spaces for recreational or spiritual experiences.

- **Sustainability:** Ability to preserve the activities and infrastructure of an area over time without compromising natural resources and biological ecosystems, while maintaining and promoting a good standard of living within society.

The co-creation of evaluation criteria underpins the second step, namely the identification of constraints and opportunities in urban waterscape-wide rehabilitation plans through nature-based solutions. Adopting the 3-Horizons framework (Sharpe et al., 2016), the specific objective consists in identifying stakeholders' views on the current state and desired future of urban water systems and defining transition pathways towards desired future.

3 Case study: Metropolitan Area of Barcelona

Barcelona is a city situated between the Mediterranean Sea and the Collserola mountain range located in the northeast of Spain, in Catalonia. Barcelona belongs to the Metropolitan Area of Barcelona (AMB), a region comprising 36 municipalities and about 3.2 million inhabitants. The AMB has two main rivers, the Llobregat and Besós. Despite their very close proximity to cities, these two rivers and the sea constitute valuable socio-ecological areas of the region. Covering 100 km^2, the Llobregat Delta (wetland) is of international importance for aquatic and wildlife ecosystems and as a freshwater resource for the Barcelona area given its aquifer.

Barcelona's combined sewer system is connected to wastewater treatment plants and is enhanced with a number of large underground stormwater reservoirs. One of the main challenges of the Barcelona sewer system is the overflow into the coastal environment and rivers, as well as floodings caused by heavy rainfall events. The annual average of discharges for the city of Barcelona alone is currently around 19 Hm^3 for a normal hydrological year.

The city has adopted decentralised, small-scale solutions to drainage such as Sustainable Urban Drainage Systems (SUDS) and has an Integral Sanitation Master Plan (PDISBA) to push towards more sustainable solutions. This is a response to growing concerns of climate change induced extreme rainfall events. In parallel, the city has made great effort to promote urban green infrastructure through relevant policy documents such as the government measure "Program to boost urban green infrastructure"; The Nature Plan (2021–2030) and the Action plan for climate emergency (2030). At the AMB level, a Stormwater Master Plan (2005) exists, however, it is not until recently that policy frameworks have incorporated a nature-based solutions perspective to address the challenges of the urban water systems such as the Climate Change Adaptation Plan (2018-2030) and the Metropolitan Urban Master Plan (PDU)

under development. The PDU is a tool that will define the organization and urban planning of the Metropolitan Area of Barcelona for the coming decades. Among its proposals is the development of a metropolitan structure that articulates the urban metropolis and links it with peripheral territories, making use of different elements, among them the structuring of nature-based solutions in form of Green Corridors that will interlace urban spaces and naturalize the environment, through the connection of parks, public facilities, transportation and natural spaces. It is planned to reinforce the existing green infrastructure, while creating new nature-based solutions.

4 Methodology and Results

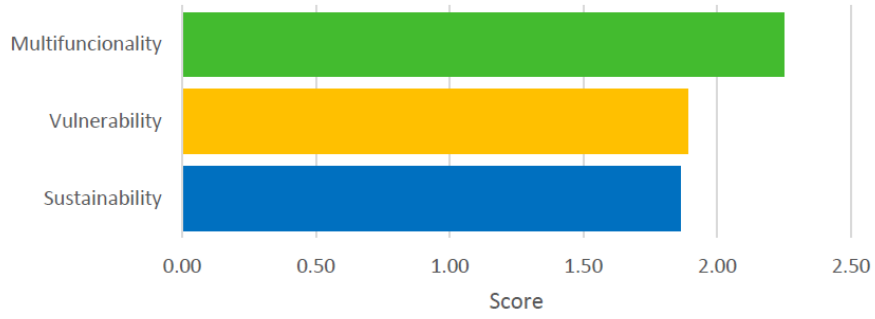
4.1.1 Survey

A survey was sent out to 57 registered participants of the first stakeholder workshop (see 3.2.2) and was answered by 36 of them. It aimed to understand the participants' perspectives on the Green Corridors and their relationship with the dimensions of *Vulnerability*, *Multifunctionality* and *Sustainability*. The most relevant results are shown below:

Question 1: *For you, what would be the main **objective** that the Green Corridors should fulfill?*
Type of question: open-ended. Methodology: coding by Grounded Theory.

Coded responses	Number of responses
Improving ecological and social connectivity	15
Improving quality of life, health and well-being	13
Provision of multiple ecosystem services	10
Promotion and maintenance of biodiversity	9
Promotion and maintenance of ecosystem functionality	4
Urban naturalization	4
Improving urban structure and design	3
Provision of green spaces	3
Provision of environments for connecting with nature	3
Improving urban accessibility	3
Fostering the transition to a sustainable city	3
Climate change protection and mitigation	2
Improving urban mobility	2
Thermal regulation	2
Noise attenuation	1
Urban regeneration	1
Air quality improvement	1
Total	**79**

Question 2: *In this study we considered three dimensions under which to evaluate the Green Corridors, how **important** do you consider each one to be?*
Type of question: ranking. Methodology: Borda method



Question 3*: Below is a list of **criteria for assessing Vulnerability** in the AMB. Please arrange them in order of the level of importance you consider appropriate.*
Type of question: ranking. Methodology: Borda method

Vulnerability		
Criteria	Ranking	Score
Exposure to heat	#1	8.71
Exposure to air pollution	#2	8.57
Lack of connectivity between green infrastructures for social functions	#3	7.86
Existence or risk of social segregation	#4	7.57
Exposure to noise	#5	7.43
Lack of opportunities to interact with natural environments	#6	7.43
Neighborhood degradation	#7	7.14
Food poverty and malnutrition	#8	5.86
Lack of connectivity between green infrastructures for ecological functions	#9	5.43
Lack of opportunities for development of cultural and recreational experiences	#10	4.43
Flood, runoff and soil erosion risks	#11	4.29
Fire risks	#12	3.29

Question 4: *Below is a list of **criteria for assessing Multifunctionality** in the AMB. Please arrange them in order of the level of importance you consider appropriate.*
Type of question: ranking. Methodology: Borda method

Multifunctionality		
Criteria	Ranking	Score
Connectivity between green infrastructures for ecological functions	#1	11.00
Thermal regulation	#2	9.47
Connectivity between green infrastructures for social functions	#3	8.47
Reduction of atmospheric pollution	#4	8.18
Provision of environments for connecting with nature	#5	7.53
Reduction of greenhouse gases	#6	7.53
Mitigation of runoff and soil erosion	#7	7.35
Provision of environments for social cohesion/integration	#8	7.00
Promotion of food sovereignty and healthy eating	#9	5.82
Noise attenuation	#10	5.53
Provision of environments for recreational experiences	#11	5.35
Fire risk mitigation	#12	4.12
Improved aesthetics of the territory	#13	3.65

Question 5: *Below is a list of **criteria for assessing Sustainability** in the AMB. Please arrange them in order of the level of importance you consider appropriate.*
Type of question: ranking. Methodology: Borda method

Sustainability		
Criteria	**Ranking**	**Score**
Loss of habitat and ecological functions	#1	7.50
Water pollution	#2	7.33
Water depletion	#3	6.17
Air pollution	#4	5.17
Soil contamination	#5	5.17
Greenhouse gas emissions	#6	4.33
Depletion of material resources	#7	4.00
Economic burdens	#8	3.17
Loss of social functions and negative social effects	#9	2.17

4.1.2 1st workshop with stakeholders

Following the survey, the first stakeholder workshop was organized. Participants were divided into six groups, each working on a different dimension and focusing on two **typologies of AMB cities: dense and sprawled**. The group work consisted of three steps: first, the **selection of the relevant criteria** for the Green Corridors' evaluation under the corresponding dimension/typology, starting from a list of criteria pre-selected by the organizing team that could be supplemented or reduced according to the judgment of the participants (see Appendix 1); the second step consisted of **discussing** the importance of each of the selected criteria, and the third of **weighting** them individually, and then aggregating them to obtain a group total. The first stakeholder workshop was carried out remotely on May 6, 2021, and was attended by 21 participants, including stakeholders from civil society, public administration and the private sector were involved.

Vulnerability

The following is the list of **criteria selected and weighted** by the groups for the evaluation of the Green Corridors under the *Vulnerability* dimension in the dense and sprawled typologies.

Vulnerability		
Selected criteria	**Dense city**	**Sprawled city**
Heat Exposure	45	55
Environmental education/awareness *	35	0
Existence or risk of social segregation	35	20
Exposure to noise	35	25
Lack of opportunities for cultural and recreational experiences	35	11
Lack of opportunities for cultural and recreational experiences	30	43
Exposure to air pollution	30	35
Lack of connectivity between green infrastructures for social functions	30	24
Lack of opportunities to engage with natural environments	20	0
Neighborhood degradation	5	0
Food poverty and malnutrition	0	42
Lack of connectivity between green infrastructures for ecological functions	0	45

*Criteria with rating = 0 indicate that the group did not consider it relevant for the evaluation exercise. *Criteria created by the groups during the participatory discussion.*

Multifunctionality

The following is the list of **criteria selected and weighted** by the groups for the evaluation of the Green Corridors under the *Multifunctionality* dimension in the dense and sprawled typologies.

Multifunctionality		
Selected criteria	**Dense city**	**Sprawled city**
Connectivity between green infrastructures for social functions	70	40
Thermal regulation	50	0
Connectivity between green infrastructures for ecological functions	45	75
Improved aesthetics of the territory	30	0
Provision of environments for social cohesion/integration	30	0
Noise attenuation	25	0
Reduction of atmospheric pollution	20	0
Mitigation of runoff and soil erosion	10	0
Provision of environments for recreational experiences	10	20
Provision of environments for bonding with nature	10	20
Promoting food sovereignty and healthy eating	0	45

Criteria with rating = 0 indicate that the group did not consider it relevant for the evaluation exercise.

Sustainability

The following is the list of criteria selected and weighted by the groups for the evaluation of the Green Corridors under the *Sustainability* dimension in the dense and sprawled typologies.

Sustainability		
Selected criteria	**Dense city**	**Sprawled city**
Water depletion	73	50
Increased density (traffic, people) in nearby areas*	49	0
Loss of social functions and negative social effects	44	0
Economic burdens	38	50
Depletion of material resources	35	0
Contamination of aquifers*	33	0
Loss of alternative uses of space (displaced public transport)*	26	0
Loss of social functions and negative social impacts	25	0
Loss of social functions and negative social impacts	23	57
Greenhouse gas emissions	21	50
Soil contamination	11	0
Air pollution	11	0
Impacts from electromagnetic fields*	11	0
Noise pollution	0	43
Marine pollution	0	75
Water pollution	0	75

*Criteria with rating = 0 indicate that the group did not consider it relevant for the evaluation exercise. *Criteria created by the groups during the participatory discussion.*

4.1.3 2nd Workshop with stakeholders

A second, follow-up workshop was organised by ICTA-UAB to identify constraints and opportunities to integrate nature-based solutions to improve the urban water system of the Metropolitan Area of Barcelona. This workshop also set the scene for the participatory process in the future, with the ultimate goal to co-define transition pathways to foster just, sustainable and resilient urban transformations (T4.3). The second workshop, which took

place on the 6th of March 2023 in the Casa Convalescencia at Barcelona was attended by 32 participants from different academic institutions, public administrations at different scales (local, regional, national), businesses, representatives from NGOs and community group.

The methodology used is based on the 3Horizons framework (Sharpe et al., 2016) and the specific method used is the Focus Group as it allows a deliberative discussion among participants around a specific topic. The workshop started with an explanation of the problem to be addressed, i.e. stormwater management system and the 3 Horizons Framework for the deliberative forum.

Part 1: Stakeholder views and perceptions on the current state of stormwater management at the AMB

Round of presentations: each participant of the groups introduces themselves briefly. Each moderator will have the list of attendees and mark those who are in their group when they introduce themselves. Those interested will respond individually to the questions that appear in Figure 1 and that each moderator has printed on a poster that will be on the table for participants to see. They will answer the questions on post-its and put them on the card (see Figure 2), using as many post-its as they want to express. Each question has a specific part of the card where it must be answered. They will have 5 minutes to think about the questions and answer them individually. For the discussion, each moderator will first ask the first question and let the participants explain their answers. The moderator should promote the discussion by asking, for example, why? Then the same exercise will be done with the rest of the questions. We do not seek consensus, but the exchange of visions.

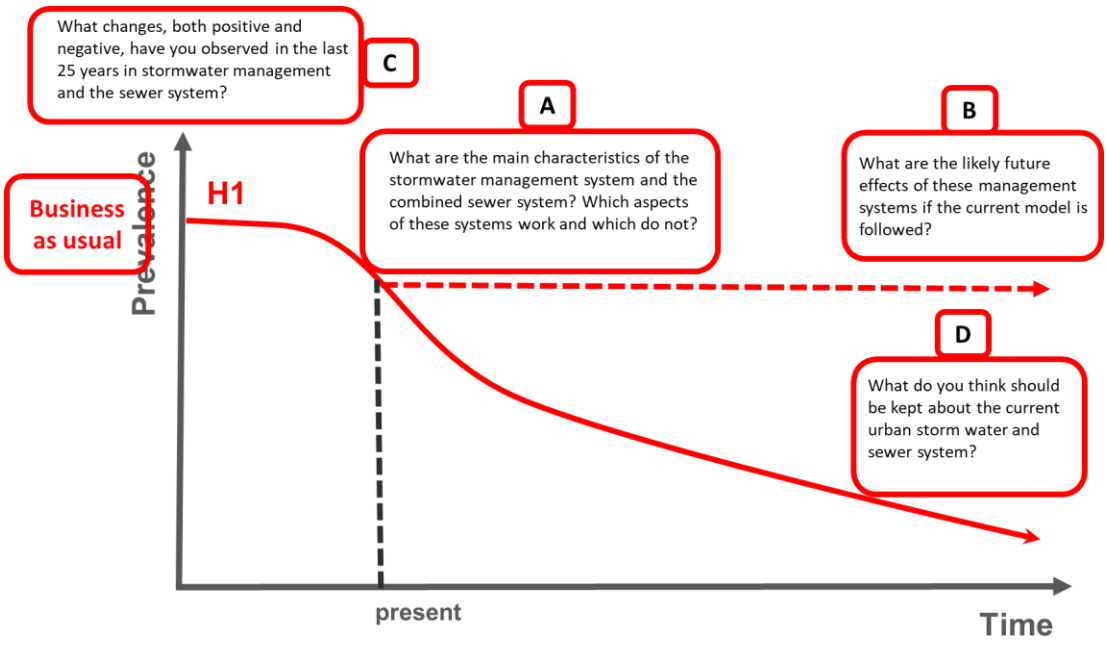


Figure 1. Questions about the current status

	Social, ecological and technological dimensions
Main features	*Things that work*
	Things that don't work
Likely effects for the future	
Changes observed in the last 25 years in the management model	
What do you think should be maintained?	

Figure 2. Cardboard to collect answers about the current status

Part 2. Visions and perceptions of the AMB urban water system for the desired future.

Those interested will respond individually to the questions that appear in Figure 3 and that each moderator has printed on a poster that will be on the table for participants to see. They will answer the questions on post-its and put them on the card (see Figure 4), using as many post-its as ideas. Each question has a specific part of the card where it must be answered. They will have 5 minutes to think about the questions and answer them individually. For the discussion, each moderator will first ask the first question and let the participants explain their answers. Moderators should promote discussion by asking, for example, why? Then the same exercise will be done with the rest of the questions. We do not seek consensus, but the exchange of visions.

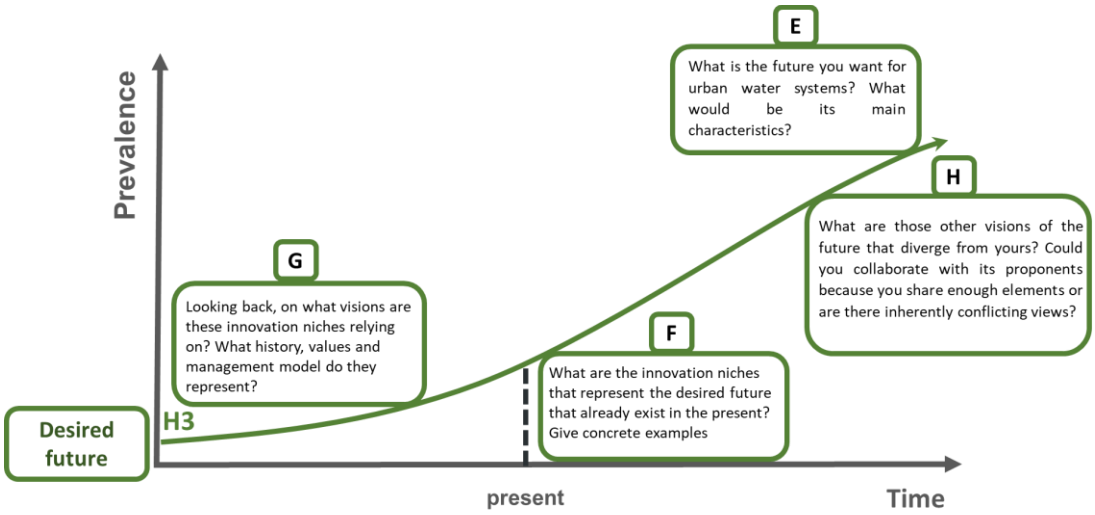


Figure 3. Questions about the desired future

	Social, ecological and technological dimensions
Main features of the desired future	
Existing innovation niches	
Visions, history, values, management model of innovation niches	
Alternative visions of the future - are they contradictory to yours?	

Figure 4. Cardboard to collect answers about the desired future

Part 3. Each group presents its visions

Each group has 3.5 minutes approx. to present their visions. To ensure that we comply with the time, it is the moderators who present the most relevant aspects that have been commented.

UAB is currently transcribing and analyzing the results of this workshop.

4 Acknowledgements

Thanks to all the workshops participants for their input and enthusiasm. Thanks for the ERC-URBAG-project and the Metropolitan Area of Barcelona for hosting the first stakeholder workshop.

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Appendix 1: participatory process

Pre-selection of criteria - Vulnerability

Vulnerability	
Criteria	**Description**
Exposure to air pollution	Presence of pollutants in the atmosphere that are harmful to health and the environment.
Exposure to heat	Presence of heat waves in urban areas and groups affected by its effects.
Exposure to noise	Excess noise produced by human activities that generates negative effects on people's health.
Flood, runoff and soil erosion risks	Accumulation and overflow of water that impacts people's safety, urban infrastructure and soil quality.
Fire risks	Fires that put people and infrastructure at risk.
Existence or risk of social segregation	Social gaps associated with economic, cultural, ethnic, gender, and other differences.
Lack of opportunities for the development of cultural and recreational experiences	Lack of opportunities for cultural and recreational experiences, related to leisure, recreation and maintenance of cultural heritage.
Lack of opportunities to interact with natural settings	Lack of opportunities for linking with natural environments, creating connections with nature and environmental awareness.
Lack of connectivity between green infrastructures for social functions	Lack of vegetation along urban routes for pedestrians and cyclists.
Lack of connectivity between green infrastructures for ecological functions	Lack of ecological corridors that enable the transfer and mobility of species.
Food poverty and malnutrition	Groups of people that for economic, educational or spatial reasons have difficulty maintaining healthy diets.
Neighborhood degradation	Deterioration of spaces, streets, infrastructure and buildings that make up the neighborhoods.

Pre-selection of criteria - Multifunctionality

Multifunctionality	
Criteria	**Description**
Reduction of atmospheric pollution	Improved air quality for health and the environment
Thermal regulation	Temperature reduction during heat episodes
Greenhouse gas reduction	Carbon storage and sequestration or reduction of energy use
Noise attenuation	Reduced noise from human activities (e.g. traffic, building construction)
Runoff and soil erosion mitigation	Increased water uptake, reduction of erosive effects on soil and support to the sewage system (e.g. flood attenuation)
Fire risk mitigation	Reduction of the incidence, intensity or speed of fire propagation
Provision of environments for social cohesion/integration	Meeting points where residents and neighbors can meet, interact and create social bonds.
Provision of environments for recreational experiences	Spaces to develop cultural and recreational experiences related to leisure and recreation.
Provision of environments for nature linkages	Spaces that allow the creation of connections with nature and the development of environmental awareness.
Connectivity between green infrastructure for social functions	Urban paths with vegetation for pedestrians and cyclists.
Connectivity between green infrastructures for ecological functions	Ecological corridors that enable the transfer and mobility of species
Promotion of food sovereignty and healthy eating	Provision of food and environments that promote healthy eating
Improved aesthetics of the territory	Neighborhood beautification through green infrastructures

Pre-selection of criteria - Sustainability

Sustainability	
Criteria	**Description**
Water depletion	Loss of water reserves due to unsustainable consumption (e.g. irrigation of green spaces).
Water pollution	Discharge of pollutants into water (e.g. nitrogen from fertilizers)
Greenhouse gas emissions	Greenhouse gas emissions (e.g. from wetland creation and green infrastructure management)
Soil contamination	Accumulation of pollutants in soil (e.g. nitrogen accumulation)
Air pollution	Release of particulate pollutants into the air (e.g. emissions of pollen and volatile organic compounds from trees)
Economic loads	Costs associated with the creation and management of green infrastructures (e.g. tree pruning)
Depletion of material resources	Construction materials for green infrastructure (e.g. permeable pavements)
Loss of habitat and ecological functions	Replacement of (natural) spaces by green infrastructure and displacement of wildlife (e.g. creation of an agricultural area where a forest once existed)
Loss of social functions and negative social effects	Change of social dynamics due to the transformation of an area (e.g. displacement of residents, increase in crime and perception of insecurity)

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Project partners

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