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REPORT ON THE TESTING OUTCOMES OF THE MITIGATION SOLUTIONS IN THE PILOT SITES

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Deliverable 2.4.1

Project acronym	LocAll4Flood
Project title	Flash flood risk prevention & resilience in Mediterranean area through an Integrated Multi-stakeholder Governance Model, gathering prevention, adaptation and mitigation solutions
Project mission	Protecting, restoring and valorising the natural environment and heritage
Project priority	Greener MED
Specific objective	RSO2.4: Promoting climate change adaptation and disaster risk prevention, resilience, taking into account eco-system based approaches
Type of project	Test
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Partners involved	All

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Terminology	Abbreviation
Nature-Based Solutions	NBS
System Dynamics Model	SDM
Participatory System Dynamics Modelling	PSDM
System Dynamic	SD
Causal Loop Diagram	CLD
Business as Usual	BAU
Social Network Analysis	SNA
Problem Structuring Methods	PSM
Behaviour over Time Graph	BOTG
Sustainable Urban Drainage Systems	SUDS

Executive summary

The document represents the report on the testing outcomes of the adaptation solutions in the nine Pilot sites to support the co-design and co-implementation of Nature-Based Solutions (NBS) for flash flood mitigation. In particular, it illustrates the outcomes of participatory process developed during the third Training and Co-creation Workshop.

The participatory process made it possible to analyse the dynamic evolution of the system in an integrated manner, assessing the effects of NBS not only on reducing flash flood risk, but also on the environmental, social and economic co-benefits that may develop in the medium and long term. At the same time, the process highlighted barriers, trade-offs and resistance dynamics that may limit the effective implementation of the measures.

The results converge into a qualitative System Dynamics Model (SDM) and the construction of two future scenarios, providing a comparative view of the system's evolution with and without the implementation of NBS.

1. Introduction

1.1 Deliverable overview and structure

This deliverable aims to document the participatory modelling process carried out in the nine pilot catchments of the project, designed to support the co-design and co-implementation of NBS as measures for flash-flood adaptation and hydraulic risk mitigation. The entire process is grounded in the Participatory System Dynamics Modelling (PSDM) approach, a methodology that integrates scientific knowledge with local expertise, enabling the representation of socio-ecological system complexity through causal relationships, temporal dynamics, and collective learning processes.

The deliverable is structured into two sections.
The first section, of a theoretical–methodological nature, outlines the foundations of PSDM and describes how the approach is applied. It provides the epistemological framework that guides the transformation of stakeholders' initial perceptions into a shared dynamic model capable of representing feedback loops, policy resistance, and future scenarios.

The second section summarises the results of applying these theoretical steps within the third Training and Co-creation Workshop.

2. Methodology

2.1 Theoretical framework

The methodology presented in Figure 1 summarises a participatory process that integrates the co-design of NBS with the co-design of the SDM following a theoretical and operational framework (Pagano et al. 2019; Pagano et al., 2025). The effectiveness of NBS in contexts exposed to hydrogeological risk depends on the ability to combine knowledge co-production, systemic thinking and iterative modelling as tools to foster dialogue among hydrological, institutional and community-based expertise.

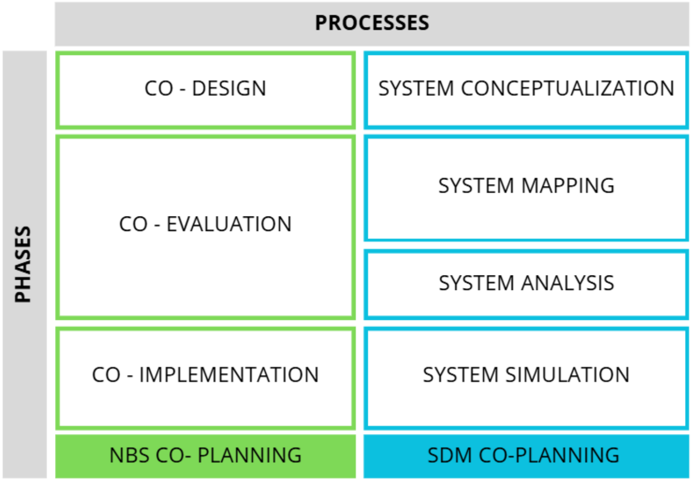

Figure 1 Methodology process

The methodology is structured into three major participatory processes, aligned with policy cycles and with the principles of System Dynamic (SD):

1. Co-design phase that includes baseline analysis, through literature review, existing data, and semi-structured interviews; development of the theoretical qualitative model, representing the first conceptualisation of the socio-hydrological system. This phase is crucial because it enables stakeholders to begin building a shared understanding of the problem, creating a common language between technical and local knowledge (Pagano et al., 2019).

2. Co-evaluation phase. The methodology introduces participatory activities aimed at developing a shared qualitative model, integrating the theoretical model with stakeholder knowledge, a system behaviour analysis, identifying synergies, trade-offs, and critical dynamics. This phase corresponds to the Causal Loop Diagram (CLD) building and the system's feedback structure.

This step represents the core of participatory learning: through causal mapping, actors discover how their behaviours, policies, and hydrological processes interact, generating unexpected outcomes or policy resistance phenomena (Pagano et al. 2019).

3. Co-implementation phase based on the quantitative model building and simulation of scenarios over time, highlighting effects, delays, trade-offs, and potential co-benefits of NBS.

This phase allows stakeholders to compare the Business as Usual (BAU) situation and NBS implementation scenarios. It observe how variables evolve over time, and collectively discusses the strengths and weaknesses of alternative design options.

Each process corresponds to specific methodological components of SDM — system conceptualization, system mapping, system analysis, system simulation — which operate in parallel with the co-design of NBS.

In this context, given the diversity of data across the various pilot cases and the impossibility of defining a uniform process for all of them, the PSDM was developed qualitatively.

The activities carried out during the workshops are summarised in Table 1 and follow Sterman's methodological steps.

Table 1 Workshop activities inspired by Sterman's theory

Sterman's Theory	Description of WS Activities
1. Problem articulation and variable definition	Identification of co-benefits, barriers and trade-offs, and formulation of variables
2. Causal Loop Diagram building	Cause–effect relationships building
3. Dynamic Hypothesis	Selection of key variables
4. Behaviour Over Time (BOT) / Reference Modes	BOT scenario development
5. Iterative learning	Plenary discussion and collective learning

The activities planned in the co-design phases (Fig. 1) were carried out within the framework of task 2.6 *"Multi-stakeholders engagement"* and are described in detail in Deliverable 2.6 *"Report on Multi-stakeholders engagement including Social Network Analysis (SNA) and Problem Structuring Methods (PSM)"* according to the process methodology by Reed (2008) and Luyet et al. (2012) (Fig. 2).

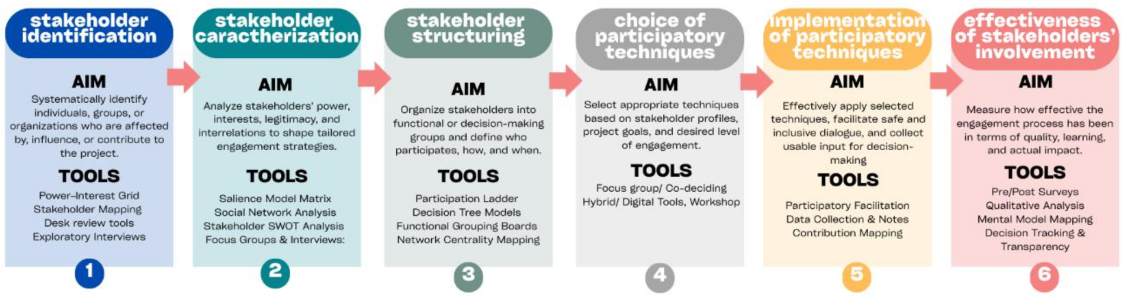

Figure 2 Stakeholders' involvement methodology process

Specifically, stakeholders were identified through tools such as stakeholder mapping and semi-structured interviews, which were used to explore their knowledge and perception of the phenomenon. Subsequently, an SNA analysis was developed for each pilot site in order to understand the network of actors and their interactions.

The third phase of the process involved the development of CLD models, aimed at structurally capturing stakeholders' knowledge and perceptions. The fourth phase focused on selecting the most appropriate participatory techniques, based on the project's objectives and the desired level of engagement.

In line with the objective of improving flash flood prevention and risk management in Mediterranean basins through a multi-stakeholder governance model, three "Training and Co-Creation" workshops were organized (Deliveralbe 1.5), dedicated respectively to prevention, adaptation, and mitigation.organisedfrom the Locall4Flood consortium prepared specific content and presentations, while each pilot leader organized the participatory session within their respective pilot site.

This document outlines the process followed during the implementation phase of the participatory activities (Phase 5, Fig. 1).

2.2 Workshop design

The participatory modelling process was structured according to the following phases:

- Identification of co-benefits, barriers, and trade-offs, and formulation of variables;
- Construction of cause–effect relationships;
- Selection of key variables;
- BOT scenarios development;
- Plenary discussion and collective learning.

Depending on the specific needs of each pilot, in some case studies not all phases were fully completed; however, the overall process still made it possible to achieve significant and relevant results.

In the preliminary phase of the activities, each case study was asked to develop its own NBS map, defining the allocation of measures based on dedicated hydrological analyses. In some case studies, the allocation derives from hydraulic studies specifically carried out for this purpose, while in others it is based on existing studies already developed within the pilot project. In some cases, this process was further strengthened through active involvement of local stakeholders, who contributed to selecting and positioning the NBS. The NBS considered derive from the results obtained in Activity 1.4." *Mitigation: Adapt, finetune and categorize existing Nature Based Solutions (NBS) tool box to mitigate the negative effects of flash flood events".*

2.2.1 Identification of co-benefits, barriers and trade-offs, and formulation of variables

In this phase, stakeholders explored the system by identifying expected benefits, obstacles, and potential trade-offs related to the NBS implemented in their pilot case study. This process corresponds to Sterman's concept of problem articulation, which requires clarifying perceptions, boundaries and system dimensions before starting the modelling process.

The concepts that emerged were then translated into dynamic variables, meaning quantities that can increase or decrease over time. Sterman emphasises that modelling requires variables to be defined operationally and in coherence with the logic of accumulation and change.

This translation — from concept to dynamic variable — is central to SD because it provides the structural foundation for building the causal model, identifying feedback mechanisms and simulating future scenarios. Without this transformation, the system would remain described in vague, non-modelable terms, preventing a fundamental understanding of the underlying dynamics that drive its behaviour.

2.2.2 Cause–effect relationships

The variables were connected through causal relationships (+/–), forming the first CLD. This step makes it possible to graphically represent the structure of the system and the interdependencies that shape its behaviour.

Once the relevant variables were identified, the workshop guided participants in collectively constructing cause–effect relationships, encouraging them to express in dynamic terms "what each variable depends on" and "what it influences." This step represents the direct application of CLD techniques, which are central in SD (for more details refer to D2.6).

The CLDs developed by the different groups were subsequently aggregated through a model synthesis process, following the approach proposed in the Group Model Building literature. In particular, the collective synthesis of partial models follows the principles described by Vennix (1996), according to which the contributions of individual groups are compared, integrated, and harmonised to produce a single, coherent representation of the system that reflects both the convergences and divergences emerging from the various sessions.

2.2.3 Selection of key variables

From the overall causal structure, the most influential variables are selected. This step corresponds to the formulation of the dynamic hypothesis, that is, the assumption about how the system's structure generates the observed behaviour.

After mapping the causal structure, the workshop guides participants in identifying a subset of key variables on which to build the scenarios.
This step reflects the phase of dynamic hypothesis formulation — a central concept in SD (Sterman, 2000) — which represents the underlying explanation of why the system behaves as it does.

2.2.4 BOT scenario development

The key variables were represented through qualitative time graphs (BOTG) to compare the system's evolution under the "Business as Usual" scenario and the scenario with NBS implementation. Sterman uses these graphs as reference modes to validate or revise the dynamic hypothesis.

The graphs developed during the workshop enabled stakeholders to visualise not only the static outcomes of policies, but also the evolutionary trajectory — including obstacles, accelerations and implications in the short, medium and long term.

2.2.5 Plenary discussion and collective learning

The workshop concludes with a plenary session in which the groups compare models and scenarios. This phase reflects the System Dynamics principle of iterative learning:

comparing, reflecting on and revising assumptions and mental models is an integral part of the modelling process.

According to Sterman, dynamic modelling is an iterative learning process rather than a linear procedure: *"modeling is learning"* (Sterman, 2000). Interaction among actors with different types of knowledge generates double-loop learning, in which not only are existing understandings updated, but mental models themselves are transformed (Argyris & Schön, 1978).

The literature on collaborative governance and NBS (Pauleit et al., 2017; Nesshöver et al., 2017) highlights how participatory deliberation enhances decision quality, policy legitimacy and the long-term sustainability of implemented solutions.

3. Application to the pilot catchment

This section provides a concise and aggregated overview of the main results obtained from implementing the methodology in the pilot case studies.

3.1 Torrent Gros and Na Bàrbara (Balearic Islands,Spain)

The workshop was held in Mallorca on 27 November 2025 and involved 23 participants. During this session, due to limited time availability, it was not possible to carry out the activities aimed at developing cause–effect dynamics and scenarios. Nevertheless, thanks to the results obtained in the previous phases and the discussion held during the plenary session, it was still possible to identify and capture key aspects that characterise the functioning of the system. The following section presents an aggregated report of the testing outcomes.

Figure 3_Training and Co-creation workshop in Mallorca

The aggregated outcome of the participatory workshops led to the adoption of several types of NBS. Within the consolidated urban fabric, NBS are mainly focused on Sustainable Urban Drainage Systems (SUDS). Along strategic infrastructures such as the ring road towards Es Port d'Inca, in urban parks such as Parc de Llevant, Parc de Gènova and Parc des Rafal, and in industrial areas such as Son Rossinyol and Son Morro or sports complex Germans Escales, rain gardens, bioswales, filter strips, infiltration trenches, permeable pavements and de-sealing measures have been introduced. These interventions increase stormwater infiltration, slow down runoff and reduce pressure on sewer networks, transforming rigid and impermeable spaces into more resilient and multifunctional surfaces. In several cases, such as car parks or along urban green corridors, grey infrastructure is progressively replaced or integrated with trees planted in structural tree pits, simultaneously improving the urban microclimate.

Urban wetlands and ponds also play an important role and are located in areas such as Portítxol, Verge de Lluc, Es Molinar and Es Port d'Inca–Coanegra. These solutions promote water retention and reuse, contribute to flood attenuation and support urban biodiversity, while creating new green spaces accessible to the population.

In addition to stormwater management, the NBS system includes sustainable urban water management interventions, such as the treatment of wastewater and industrial effluents through constructed wetlands and integrated systems. In particular, in the EDAR II area, nature-based solutions are planned to reduce the impact of discharges on the coastal environment, while at the Palau de Congressos and in Nou Llevant, green roofs are used as elements for water retention and climate mitigation within the building envelope.

The increase of urban and peri-urban green areas represents another key axis. Through the creation of urban forests, pocket parks, green cycling and pedestrian corridors, and urban agriculture spaces, in locations such as Parc de la Nova Cabana, Parc Krekovic, the area between Son Pacs, Parc Bit and the Son Rossinyol industrial estate, and along the Coanegra corridor, NBS contribute to improving infiltration, providing recreational spaces and strengthening social cohesion. Schoolyards are also transformed into multifunctional green surfaces, capable of acting as climate refuges and small-scale water management devices.

At the river basin scale, NBS are integrated into Integrated River Basin Management strategies. Along the Torrent Gros, in Es Pinaret, Sa Teulera and in upstream catchment areas, interventions include floodplain restoration, channel renaturalisation, meander creation and the use of bioengineering techniques for bank stabilisation. These solutions reduce downstream flood risk, protect strategic infrastructure and restore the ecological functionality of watercourses.

Finally, the approach extends to coastal areas and the wider landscape. In Ciutat Jardí, NBS are applied through Integrated Coastal Zone Management, including the restoration of wetlands, the use of natural barriers, dunes and living shorelines, with the aim of counteracting erosion and protecting settlements. In the peri-urban and rural landscape, such as between Es Rafal and the Llevant industrial estate and in the Son Reus area, reforestation, green corridors and water retention landscapes help reduce surface runoff, improve territorial resilience and create major green lungs for the metropolitan area.

Figure 4 Activities during Training and Co-Creation workshop in Mallorca

3.1.1 Identification of co-benefits, barriers and trade-offs and their transformation into modelling variables

For the NBS identified through the participatory process and subsequently selected, the main co-benefits, as well as the associated trade-offs and barriers, were systematically identified and assessed. This approach made it possible to go beyond the sole function of flood risk mitigation, highlighting both the added value of NBS and the critical issues that may affect their effective implementation across urban, peri-urban and territorial contexts.

From a hydrological perspective, NBS deliver significant benefits by increasing stormwater infiltration, reducing surface runoff and flow velocities, and consequently mitigating flood risk and erosion processes. These effects are particularly relevant in consolidated urban areas and along watercourses, where impermeable surfaces and channelised flows exacerbate hydraulic hazards.

In addition to hydrological benefits, substantial environmental co-benefits emerge. NBS promote biodiversity enhancement and overall ecological quality through the renaturalisation of urban and infrastructural spaces. The introduction of vegetation and green systems also contributes to lowering urban temperatures, counteracting the urban heat island effect, and improving air quality through CO_2 sequestration and pollutant removal. As such, NBS represent key instruments for both climate adaptation and mitigation strategies.

- **Benefits / Co-benefits**

They constitute another central dimension. NBS improve the quality of public space by creating new recreational and social areas and strengthening the relationship between citizens and their environment. Parks, green corridors and renaturalised schoolyards play a crucial role in supporting public health and well-being, while also functioning as climate refuges during heatwaves. In many cases, NBS also serve as tools for environmental education and for strengthening social cohesion, particularly when combined with participatory processes.

From an economic and functional perspective, NBS contribute to water and energy savings through water retention and reuse, as well as microclimate regulation. At the same time, they help protect strategic infrastructure and reduce economic losses associated with extreme events, demonstrating how investments in nature-based solutions can generate medium- to long-term returns.

- **Trade-off**

However, the implementation of NBS also entails a range of trade-offs and compensations. In some cases, land or built-up areas may need to be expropriated, or existing uses—such as parking spaces—may be temporarily reduced, potentially leading to local conflicts. Construction phases can cause disturbances to residents, while competition with other land uses is a key issue in dense urban areas. Certain solutions, such as urban wetlands, may also pose risks related to mosquito proliferation or require restricted access during emergency situations.

In addition to these trade-offs, several barriers may hinder the effective deployment of NBS.

- **Barriers**

Economic barriers include high initial investment costs and long-term maintenance expenses. Technical barriers relate to the complexity of interventions in consolidated urban areas and the need for continuous maintenance, particularly regarding sediment management and system cleaning.

Social barriers are equally significant, encompassing limited public acceptance, delayed perception of benefits, and opposition from stakeholders affected by land expropriation. For this reason, active citizen engagement and effective communication are essential to ensure the success of NBS. Finally, institutional barriers—such as administrative complexity, lack of coordination between authorities, and long implementation timelines—represent structural challenges that require integrated, multi-level governance approaches.

3.1.2 Ranking of key variables

The classification of key variables highlights the multidimensional nature of Nature-Based Solutions, showing how their performance and feasibility depend on the interaction between hydrological effectiveness, socio-economic conditions, land and governance constraints, long-term management requirements, and ecological and social benefits. This framework allows for a more comprehensive assessment of NBS, beyond their primary hydraulic function.

Hydrological benefits represent the core technical rationale for the adoption of NBS. Measures that promote water accumulation, infiltration and flow attenuation play a crucial role in reducing flood risk, particularly in urban and peri-urban areas characterised by high levels of soil sealing and rapid runoff generation. By slowing down surface flows and enhancing natural drainage processes, NBS reduce peak discharges, improve the performance of drainage networks and mitigate erosion. These hydrological functions are essential not only for flood risk reduction but also for increasing the overall resilience of urban water systems under climate change conditions, where more frequent and intense rainfall events are expected.

At the same time, economic and stakeholder-related factors strongly influence the viability of NBS implementation. Although nature-based solutions often provide cost-effective benefits in the long term, they can involve high initial investment and significant maintenance costs. The willingness of responsible authorities, private landowners and affected stakeholders to support and co-finance these interventions is therefore a decisive variable. Social acceptance also plays a key role, as the benefits of NBS may not be immediately visible, while perceived disadvantages—such as construction disturbances or changes in land use—can generate resistance. Without adequate stakeholder engagement and communication, even technically sound solutions may face delays or opposition.

Land and administrative constraints constitute another critical category of variables. Many NBS require space, which in urban contexts often translates into the need for land expropriation or the reallocation of existing uses. Expropriation processes can be complex and time-consuming, involving negotiations with multiple property owners and legal procedures that extend implementation timelines. In parallel, administrative hurdles—such as permitting procedures, overlapping competencies between institutions and rigid planning frameworks—can limit flexibility and slow down decision-making. The remodelling of existing urban spaces further increases complexity, particularly in consolidated areas where technical, legal and social constraints intersect.

The effectiveness of NBS over time is also closely linked to ongoing management requirements. Unlike conventional grey infrastructure, nature-based solutions are living systems that require continuous care. Clear assignment of maintenance responsibilities is essential to avoid neglect or degradation of created elements. Activities such as sediment removal, vegetation management and system cleaning are necessary to preserve hydrological functionality and ecological quality. In addition, long-term monitoring is required to assess performance, adapt management practices and ensure that NBS continue to deliver their intended benefits under changing environmental conditions.

Finally, ecological and social gains represent one of the most distinctive strengths of NBS. Interventions such as reforestation, green space creation and ecosystem restoration enhance biodiversity and ecological connectivity while contributing to urban renaturalisation. These environmental improvements translate into tangible social benefits, including increased opportunities for recreation, improved public health, stronger social cohesion and the provision of climate refuges during extreme heat events. By improving the overall quality of urban environments, NBS help reconnect people with nature and support more liveable and inclusive cities.

3.1.3 Plenary session and lessons learnt

During the workshop, key stakeholders directly involved in flood risk management attended, including emergency services (112), firefighters from Palma, technical staff from the College of Civil Engineers, the General Directorate of Water Resources, the regional delegate of AEMET (National Meterological Agency) in the Balearic Islands, representatives from diocesan schools (from Palma), and staff from the urban planning departments of Palma and Marratxí, as well as local environmental organisations. Their participation showed a high level of institutional engagement and confirmed that NBS are increasingly recognised as relevant options for flood risk reduction in the Torrent Gros and Na Bàrbara catchments.

Participants agreed that measures with higher investment and implementation complexity are likely to be delayed, whereas lower-cost, more flexible actions could be implemented earlier if regulatory, coordination and maintenance barriers are addressed. They also stressed the importance of combining NBS with existing structural measures, improving inter-institutional coordination, and enhancing communication and awareness so that local communities better understand the benefits of NBS for both risk reduction and urban quality of life.

During the discussion, participants used the measures included in the table and in the card game to reflect on how they might perform under different scenarios, particularly in terms of the time needed to see results and the effort required for implementation. They generally agreed that less costly and technically simpler interventions, such as small-scale sustainable urban drainage projects or targeted revegetation actions in parks and public spaces, could deliver visible benefits in the short term and act as “first steps” to improve risk management. At the same time, they stressed that some more complex NBS with higher investment needs, for example the renaturalisation of stream sections or the creation of large retention areas in the upper catchment, only reveal their full potential when longer time horizons and more integrated planning scenarios are considered, where their ecological and social co-benefits are also valued. **These reflections were not formalised into a complete exercise of cause-and-effect chains and scenarios due to time constraints, but they helped to identify which options could be activated earlier and which ones require a more gradual implementation strategy.**

3.2 Bari (Italy)

The workshop was held in Bari on 14 November 2025 and involved 22 participants, including representatives from universities, research institutes and secondary schools, the Metropolitan City of Bari, the Apulia Region, the Regional Strategic Agency for Sustainable Territorial Development (A.S.S.E.T. – Apulia Region), the River Basin Authority of the Southern Apennines District, cultural foundations, media, and citizens.

Participants were organised into three working tables, each addressing specific aspects of the modelling and co-planning process.

Figure 5 Stakeholders during Training and Co-creation Workshop in Bari

The following section presents an aggregated report of the testing outcomes.

The NBS considered in the analysis are derived directly from the main territorial projects currently underway or planned within the study area — including the "Progetto Fiume Verde", "Parco della Giustizia", "Parco della Rinascita" e "Parco Costa Sud". These initiatives represent the strategic frameworks within which various nature-based solutions are already foreseen or can be potentially integrated (Fig.6).

Based on these projects, a set of relevant NBS for the catchment has been defined, covering interventions in urban, peri-urban, and coastal areas. Specifically, the NBS considered include:

- Urban reforestation and increased tree cover
- Riverbank restoration and renaturalisation
- Pedestrian and cycling routes with drainage and shading functions
- Multifunctional coastal parks

- Urban wetlands and natural retention systems
- Vegetated drainage trenches
- Urban gardens and regenerative agriculture
- Permeable parking areas and infiltration pavements
- Green roofs, green walls, and rooftop gardens

Figure 6 NBS project in Bari pilot site

3.2.1 Identification of co-benefits, barriers and trade-offs and their transformation into modelling variables

- **Benefits / Co-benefits**

Environmental: Participants highlighted several key environmental benefits associated with NBS. Vegetation helps improve air quality by filtering pollutants and reducing particulate matter. Expanding green areas and ecological features also enhances biodiversity, promoting more stable and resilient ecosystems.

NBS improve the urban microclimate through shading, evapotranspiration and the reduction of sealed surfaces, helping mitigate the urban heat island effect. They also increase soil water retention, slowing runoff, lowering wildfire risk and contributing to more sustainable stormwater management.

Figure 7 Identification of co-benefits, trade-off and barriers during Training and Co-creation Workshop in Bari

Overall, nature-based interventions act as effective climate mitigation and adaptation tools, reducing hydrogeological risks and strengthening the city's capacity to cope with climate change.

Social and economic: The benefits of NBS extend well beyond environmental aspects. Accessible and high-quality green spaces support physical and mental well-being, improving quality of life and encouraging healthier lifestyles. These areas also become valuable settings for environmental, civic and participatory education, fostering community awareness and engagement.

NBS can drive urban regeneration, transforming degraded or underused areas into recreational or cultural spaces, sometimes even enhancing archaeological heritage. They also promote sustainable mobility, as green networks encourage walking and cycling.

Innovative public–private management models—especially for urban gardens—generate additional co-benefits: reduced public spending, stronger social cohesion, and increased citizen responsibility and inclusion.

- **Trade-offs**

Environmental: Despite their advantages, NBS also present trade-offs that require careful planning. Many green solutions demand significant irrigation, particularly in drought-prone regions, which may undermine sustainability unless systems such as greywater reuse, dual networks or local wells are implemented.

Another issue relates to the potential proliferation of mosquitoes and insects in areas with standing water, requiring appropriate ecological design and monitoring. The introduction of new green infrastructure can also increase technical complexity and require additional support systems.

- **Trade-offs**

Socio-economic On the socio-economic side, major trade-offs concern land use: allocating space to green areas can limit opportunities for development, potentially creating conflicts with real estate interests. Increased use of green spaces also implies higher maintenance costs.

Political will is another source of uncertainty, as administrative priorities can accelerate, hinder or alter NBS implementation. In some cases, increased biodiversity may lead to the presence of wild animals in urban areas, requiring monitoring and management interventions.

- **Barriers**

Environmental and technical: Key environmental and technical barriers include the need for adequate technologies and infrastructure, such as dual water networks, pumping systems and specialised design techniques. Planning errors or limited knowledge of local contexts may trigger negative cascading effects, compromising mobility, public space functionality or NBS performance.

Economic: Economic constraints remain among the most significant issues. Maintenance costs for green areas can be substantial, and accessing funding—although available—often proves difficult due to bureaucratic procedures and political factors that slow decision-making.

Social and cultural: Finally, social and cultural aspects strongly influence the success of NBS. Low environmental awareness can hinder citizen participation and lead to conflicts over the management of shared spaces. Issues such as lack of safety, vandalism and antisocial behaviour reduce usability and increase maintenance burdens. In addition, slow authorisation processes and cultural or regulatory constraints—such as archaeological restrictions—further complicate implementation.

3.2.2 Cause–Effect Relationships

- **Environmental dynamics**

Participants identified biodiversity as a central node in the system. Increasing ecological richness improves air quality, enhances psychophysical well-being, and supports environmental education. More complex ecosystems may also help control issues such as mosquito proliferation, thanks to natural predators.

Vegetation and NBS play a crucial role in microclimate regulation, reducing heat islands and improving outdoor comfort. However, these same interventions can create favourable conditions for insects and require significant water inputs, especially during dry periods, generating delicate trade-offs between environmental gains and resource needs.

This connects to a second critical theme: water management. Urban green areas often depend on dedicated infrastructures such as dual water networks, greywater reuse or local wells. Paradoxically, the same water used for irrigation also helps reduce wildfire risk, reinforcing the overall environmental benefits of the system.

- **Socio-economic dynamics**

On the socio-economic side, education and civic awareness emerged as powerful drivers. Better-informed citizens tend to use green spaces more responsibly, reducing maintenance costs and actively promoting behaviours that mitigate risks such as fires, vandalism or degradation.

Sustainable mobility also plays a key role: transport networks that facilitate access to green spaces enhance public well-being and reinforce a virtuous cycle between quality of life and health. However, increased use of public spaces also leads to higher management and maintenance costs, which need to be properly accounted for.

Participants also highlighted the value of public–private management models, particularly for urban gardens. When citizens take responsibility for maintaining green spaces, public expenditure is reduced, safety perceptions improve and community cohesion is strengthened.

- **Structural obstacles and critical variables**

Despite their potential, NBS face several barriers. These include low levels of environmental awareness, difficulties in securing economic resources, and complex bureaucratic or political dynamics that slow down implementation.

Additional obstacles include archaeological and regulatory constraints, design mistakes and limited knowledge of local contexts, all of which may generate cascading effects affecting mobility, commerce and the quality of public spaces. In some areas, vandalism and petty crime further undermine safety and increase management costs.

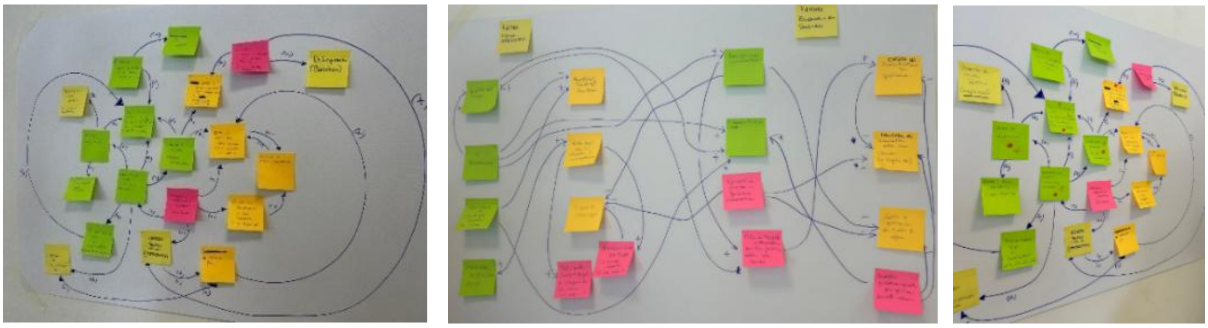

Figure 8 CLD building during Training and Co-creation Workshop in Bari

The CLD developed during the preliminary phase was subsequently enriched with the new variables that emerged from the participatory activities (highlighted in yellow in Figure 9). Many of the concepts that emerged were already present in the preliminary version of the CLD. New variables and related relationships have therefore been identified and included.

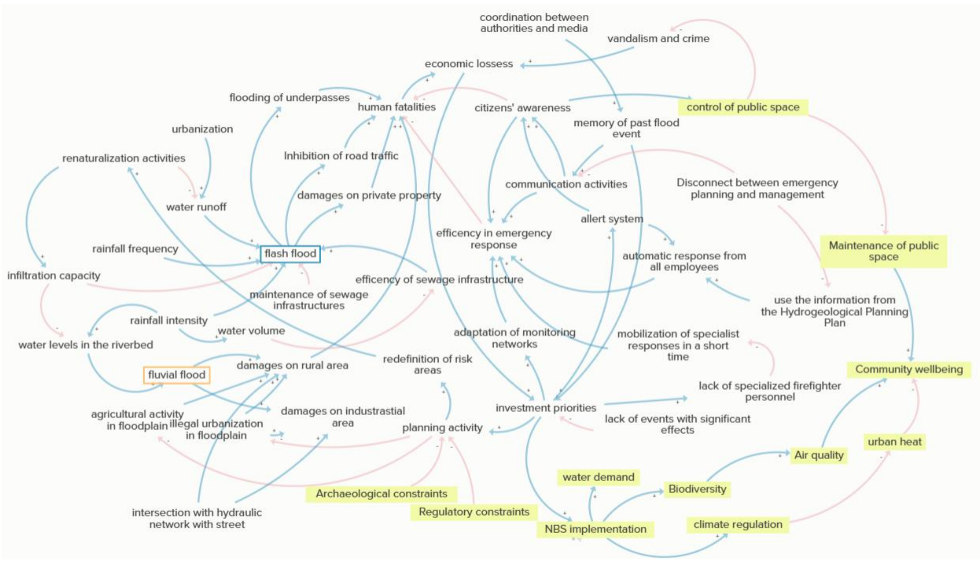

Figure 9 CLD, Bari pilot site

3.2.3 Ranking of key variables

The group work made it possible to identify an articulated set of key variables that describe the functioning of the Nature-Based Solutions system, highlighting the interconnections between environmental, social and governance dimensions. Although starting from different perspectives, the three groups converge in recognising the systemic nature of NBS, in which environmental benefits, social perceptions and institutional capacities mutually reinforce or weaken each other through feedback loops.

Group 1, with a predominantly environmental and infrastructural focus, identified variables closely related to the ecological performance of NBS and their integration into the urban fabric. Environmental benefits—such as improved air quality, increased water availability and enhanced biodiversity—were recognised as high-leverage drivers capable of triggering positive dynamics in terms of well-being, civic participation and climate resilience. At the same time, the group emphasised the importance of ensuring a dedicated water supply for NBS, through greywater reuse or the use of wells, particularly in contexts where irrigation demand increases. From this perspective, management and safety costs emerge as a critical variable, capable of generating trade-offs and negative feedback loops if not adequately planned. Conversely, social benefits related to environmental education, psychological well-being and civic awareness are considered central to activating positive feedback loops, improving space quality and reducing maintenance costs over time. Sustainable infrastructures, such as green mobility and accessibility, complete this framework by acting as enabling factors for public use and the integration of NBS into everyday life.

Group 2, adopting a more socially and culturally oriented approach, highlighted how citizens' perceptions and behaviours represent decisive variables for the success of NBS. Quality of life and citizen well-being emerged as factors with a strong influence on the acceptance of nature-based solutions and on individual and collective behaviours. In this regard, urban regeneration processes and the reuse of degraded spaces play a strategic role, as they are able to generate broad social and economic impacts, strengthening the link between communities and their territory. The socio-cultural level of the population was identified as a key variable for understanding policy resistance and long-term sustainability, while biodiversity enhancement is recognised as a core driver within environmental reinforcing loops. Finally, the valorisation of cultural and archaeological heritage contributes to strengthening local identity and social cohesion, fostering greater appropriation of regenerated spaces.

Group 3, developed to integrate and complement the emerging results, focused on governance dimensions and long-term performance. Institutional capacity and inter-agency coordination were identified as structural factors influencing decision-making processes and the degree of policy resistance, directly affecting the ability to implement and maintain NBS. Maintenance and long-term performance of nature-based solutions are crucial to avoid degradation and to ensure the continuity of environmental and social benefits. Within this framework, social perception of NBS effectiveness plays a determining role in building trust, encouraging space use and strengthening political support. At the same time, local climate resilience emerges as a cross-cutting variable, linking environmental performance with risk reduction and social benefits. Finally, equitable access to green spaces is recognised as a fundamental element for promoting social cohesion, participation and overall acceptance of NBS.

Despite approaching the analysis from different angles — one group focusing more on environmental dynamics, another on social and cultural aspects, and a third on governance and management — the three working groups showed a remarkable convergence on several key elements.

First, all groups agreed that ecological processes, particularly biodiversity, air quality and climate resilience, are central nodes within the system. These elements activate the main reinforcing feedback loops and form the foundation for improving both environmental conditions and the overall wellbeing of the population.

At the same time, the importance of social and cultural dimensions clearly emerged, such as quality of life, environmental awareness and citizen participation. According to all groups, without active community involvement and widespread cultural growth, NBS risk not being fully accepted or properly maintained over time.

Another significant convergence concerns governance: the ability of institutions to coordinate, make effective decisions and guarantee stable resources and maintenance was identified as a structural variable. Weak governance increases policy resistance, slows processes and undermines the long-term performance of interventions.

In addition, the groups highlighted the need for urban regeneration focused on high-quality public spaces, sustainable mobility and equitable access to green areas. These factors not only enhance usability, but also generate additional social and environmental benefits.

Finally, all groups emphasised that water availability, maintenance and financial resources are essential enabling conditions. NBS deliver benefits only when supported by continuous management and adequate funding.

Overall, the synthesis of the three perspectives shows that the most influential variables do not belong to a single domain, but arise from the interaction between environment, society and governance. It is within this intersection that the true levers of change lie, enabling the system to become more resilient and capable of long-lasting transformation.

3.2.4 Behaviour Over Time Scenario

The construction of scenarios represented the final stage of the group work. Its purpose was to translate the complexity of the causal relationships identified earlier into a concrete vision of possible future developments. After selecting the most influential variables — those with the largest number of connections and the strongest feedback effects — participants explored how the urban system might evolve under both a continuation of current trends and improved strategic conditions. Summarizing the results of the three scenarios, some common trends can be defined.

In the **BAU scenario**, groups noted that many existing issues tend to persist: environmental benefits grow slowly and remain constrained by insufficient water infrastructure; management costs rise as green areas are used more intensively and are not always balanced by shared management models; participation and environmental awareness remain uneven, limiting the care of public spaces; sustainable mobility progresses but in a fragmented manner. This scenario is also affected by regulatory constraints, conflicts with real-estate interests, bureaucratic delays and cultural barriers that hinder the recognition of the value of nature-based solutions.

On the other hand, **the NBS implementation scenario** are based on the activation of the previously identified key variables. Here, nature-based interventions significantly enhance air quality, biodiversity and the urban microclimate; the city strengthens its water resilience through dual networks, greywater reuse and smarter resource management; costs decrease thanks to greater citizen participation and innovative public–private management models. Urban regeneration becomes more widespread and increasingly intertwined with environmental, cultural and civic education. Sustainable infrastructure expands, creating smoother and more accessible connections between green spaces and everyday life.

Figure 10 Scenario building during Training and co-creation workshop in Bari

3.2.5 Plenary session and lessons learnt

NBS must be understood as systemic interventions, not isolated measures

Participants realised that Nature-Based Solutions generate chains of environmental, social and economic effects. Their performance depends on feedback loops — some reinforcing, some counterbalancing — that can amplify benefits or create unexpected resistance. Successful NBS planning requires embracing this systemic complexity rather than treating each intervention as a stand-alone project.

Environmental, social and governance variables are interdependent

The workshop showed that the most influential drivers lie at the intersection of ecological processes (biodiversity, microclimate, water retention), social dynamics (awareness, participation, quality of life) and governance capacity (coordination, maintenance, long-term funding). Transformative outcomes emerge only when these dimensions evolve together.

Cultural and social factors are as important as technical ones

Even the best-designed NBS can fail if users do not recognise their value or if communities are not engaged. Awareness, education and civic participation were repeatedly identified as levers that reduce vandalism, improve maintenance and increase acceptance — confirming that social behaviour strongly conditions NBS effectiveness.

Governance and institutional coordination are critical bottlenecks

Fragmented responsibilities, unclear permitting procedures and limited technical capacity emerged as major barriers. The workshop highlighted that strong, coordinated governance is essential to prevent policy resistance and ensure long-term maintenance, monitoring and adaptation of NBS.

Water availability and maintenance determine long-term performance

Participants stressed that NBS require continuous care, adequate water supply (including greywater reuse or dual networks), and recurring budgets. Without this backbone of support infrastructure, green interventions may degrade quickly or underperform under climate stress.

Shared learning enhances collective understanding and reduces resistance

The workshop demonstrated the value of deliberation: by comparing models and challenging assumptions, participants expanded their mental models and reduced misconceptions. This iterative learning process is crucial for adaptive governance and helps overcome both cultural and institutional resistance.

Co-design strengthens ownership and long-term sustainability

Engaging different actors — citizens, researchers, institutions — increased acceptance, generated new ideas and laid the foundation for collaborative management models. Co-design was recognised as a necessary condition for durability and effectiveness of NBS.

Urban regeneration and green mobility are powerful enablers

Across groups, a recurring insight was that high-quality public spaces, green corridors and active mobility networks enhance the value and usability of NBS, multiplying their social and environmental benefits.

3.3 Dalgopol and Kamchia–Varna (Bulgaria)

The workshop was held in Rosslyn Dimyat Hotel Varna and involved 21 participants from key-stakeholder organizations including the Regional Administration Varna, Fire Safety and Civil Protection Dept, the National Institute of Meteorology and Hydrology, Dalgopol Municipality, Marine Cluster Bulgaria, research institutions, business support organizations and NGOs.

The Bulgarian pilot focused on two catchments: the Dalgopol urban area and the Kamchia–Varna coastal area.

- **Urban area**

The Dalgopol urban area with potential significant flood risk (BG2-APSFR-KA-102) is exposed to compound flood risk driven by the interaction of short-duration intense rainfall, steep surrounding slopes, high water levels in the Kamchia River, and sudden high-volume releases from the Ticha Reservoir during extreme events. These combined processes frequently overwhelm local drainage systems, leading to flash flooding, surface ponding, infrastructure damage, and elevated risks for residents and emergency services. To address this challenge, NBS is considered as an efficient option, bringing also multiple social and economical co-benefits.

During the 3rd training session & co-creation workshop, the LocAll4Flood pilot leader BDCA applied a three-round, stakeholder-driven evaluation process, aligned with the official Flood Risk Management Plan (FRMP) 2022–2027 for Kamchia river basin. The process focused on selecting measures that are effective for flash-flood reduction, feasible for municipal implementation, and coherent with national flood-risk policy. The empasis was put on the measures already included and budgeted in the "National plan for implementation of measures for flood resilience":

M31-B10b – Green, nature-based retention elements, Allocated budget: 120,000 BGN

M34-B19a – Grey–green hybrid drainage channels (as a part of the Sustainable Drainage System SUDS), Allocated budget: 710,000 BGN.

Following a three-round evaluation process (catalogue screening,

from the LocAll4Flood"D1.4 Catalogue of NBS",

FRMP alignment, and feasibility assessment), four complementary NBS were selected:

Final round NBS selection for Dalgopol:

- Terraces & slope stabilisation at the urban edge (NBS 18), combined with small-scale water detention basins (dry ponds)
- Rain gardens & bioswales (NBS 2)
- Rainwater harvesting systems (NBS 11)
- Permeable pavements / green parking (NBS 3)

These NBS were selected in terms of application zoning:

- Upstream / hillslopes: terracing reduces runoff velocity and sediment transport.
- At source: rainwater harvesting removes part of stormwater from the system en tirely.
- Urban surfaces: rain gardens, bioswales and permeable parking infiltrate and d elay runoff.

Together, these measures reduce pressure on the drainage network during both flash floods and river backwater conditions, while remaining coherent with FRMP measures M31-B10b and M34-B19a.

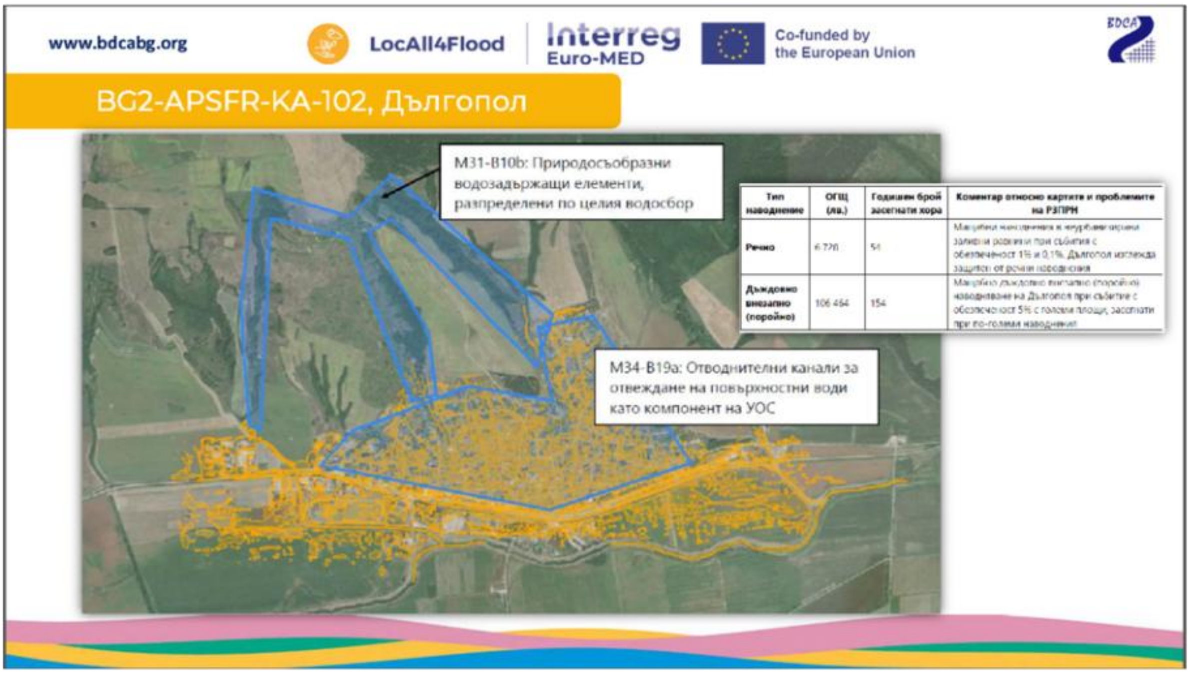

Figure 11 Location of the measures under Bulgarian FRMP for Dalgopol,

M31-B10b – Green, nature-based retention

- **Coastal area**

The objective of this round was to identify all NBS that could be technically and environ mentally suitable for a coastalriver system like the Kamchia estuary, considerin

- the river–coastal flood dynamics,
- the geomorphology of the estuary and dune systems,
- the proximity of residential areas and beach touristic zones,
- the history of destructive events.

Stakeholders were presented to *D2.4 NBS Catalogue, and* 22 NBS measures were reviewed and filtered out only those applicable to:

- riverine flooding,
- coastal surge,
- estuary buffering,
- local runoff management.

This process produced a list of 11 NBS suitable for the Kamchia pilot zone, grouped int o:

I. River-related NBS

1. River floodplain restoration

2. Riparian buffer zones / Bioengineering techniques
3. Natural inland wetlands restoration
4. Terraces and slope stabilisation
5. Natural Water Retention Measures (check dams, retention ponds)

II. Coastal NBS

6. Sandy beach nourishment & dune restoration
7. Living shorelines
8. Floodable coastal parks / coastal wetlands / salt marshes

III. Small-scale urban–coastal interface NBS

9. Rain gardens & bioswales
10. Permeable pavements / green parking
11. Pocket parks / micro-retention spaces

The first selection round formed the potentially viable NBS for the Kamchia estuary BG 2-APSFR-KA-100.

Following a structured, multi-round evaluation process using the LocAll4Flood Catalogue of NBS, the Kamchia pilot focuses on a complementary package of large-scale and urban-scale measures:

- Floodable coastal wetlands and salt marsh restoration (large-scale NBS) -These measures restore and enhance the natural capacity of the estuary and adjacent floodplains to temporarily store floodwaters during river floods and coastal surge events. They act as the primary buffering element of the system.
- Dune restoration and creation (NBS14)-the restoration and creation of coastal dune systems through sand nourishment, dune reshaping, and the establishment of native dune vegetation. Restored dunes function as natural barriers that attenuate wave energy and storm surge impacts, reduce coastal flooding and erosion, and enhance coastal ecosystem services.
- Rain gardens and bioswales ((NBS 2) Implemented in urbanised and touristic areas near the estuary, these measures increase infiltration, reduce direct runoff into drainage systems, and improve water quality.

- Permeable pavements and green parking (NBS 3) -These measures reduce impervious surface runoff in critical hotspots, complementing bioswales and supporting sustainable urban drainage.

Together, these NBS form an integrated system, where large-scale retention reduces overall flood pressure and urban-scale measures manage residual risk and local runoff.

Figure 12 Location of the measures under Bulgarian FRMP for Kamchia River Basin, BG2-APSFR-KA-100_M23 "Contemporary methods to improve resistance of residential and non-residential property against floods on the left bank, near the estuary"

Due to time constraints, the activities originally planned to develop cause–effect dynamics not be conducted during this session. However, building on the outcomes of the previous phases and the insights gathered during the plenary discussion, it was still possible to identify and document the main elements that define how the system operates. The following section provides a consolidated overview of the testing results.

3.3.1 Identification of co-benefits, barriers and trade-offs and their transformation into modelling variables

With reference to the selected NBS in the **Urban area** and from the stakeholders' comparison, the following results emerged:

- **Benefits/ Co-benefits**

First, they promote increased water infiltration and retention, helping to reduce pressure on urban drainage systems. This leads to lower peak runoff during frequent storm events, decreasing the risk of flooding and infrastructure overload.

At the same time, these solutions contribute to improved water quality through natural filtration processes and the capture of sediments and pollutants before they reach receiving water bodies.

Another important benefit is urban cooling and the improvement of the local microclimate, which helps mitigate the urban heat island effect and enhances thermal comfort for residents.

Moreover, these interventions support habitat creation and the enhancement of urban green spaces, improving biodiversity and the overall quality of the urban environment.

Finally, their implementation and long-term management generate new local employment opportunities, particularly in construction, landscaping, and maintenance activities.

- **Trade-off**

Despite their many advantages, these solutions also involve some key trade-offs that need to be carefully considered.

One important limitation is their reduced effectiveness during very extreme or compound events, when rainfall intensity or combined hazards exceed the system's design capacity.

Another challenge relates to competition for space in dense urban areas, where land availability is limited and multiple urban functions must coexist.

In addition, these solutions require ongoing maintenance over time to ensure long-term performance, which implies dedicated resources, technical capacity, and clear responsibility for management.

Finally, their successful implementation often depends on effective coordination between multiple types of nature-based solutions, as isolated measures may be less effective than integrated systems. This highlights the need for holistic planning and cross-sectoral collaboration.

- **Barriers**

A major challenge is municipal maintenance capacity, as local authorities may lack the staff, skills, or organizational structures needed to manage these systems over time. Another barrier concerns technical design and construction expertise, since nature-based solutions often require specialized knowledge that is not yet fully mainstreamed in standard engineering practice.
Budget constraints for long-term operation and maintenance also represent a significant obstacle, as funding is frequently focused on initial construction rather than lifecycle costs.
In addition, regulatory and permitting procedures can slow down implementation, especially when existing frameworks are not well adapted to non-conventional approaches.
Finally, limited public understanding and acceptance of non-traditional solutions may reduce political support and social uptake, highlighting the importance of communication, engagement, and co-design with local communities.
With reference to the selected NBS in the **Coastal area** and from the stakeholders' comparison, the following results emerged:

- **Benefits/ Co-benefits**

A key benefit of NbS is the **enhancement of water retention and buffering capacity.** Through the restoration of floodplains, wetlands, and river spaces, water can temporarily spread during intense rainfall events, reducing flood peaks and alleviating pressure on downstream urban areas and infrastructure. This natural buffering mechanism is especially effective in territories increasingly exposed to extreme events.

Closely linked to this function is the **infiltration capacity of the soil.** Permeable surfaces, renaturalized soils, and green systems promote rainwater absorption, reducing surface runoff and contributing to groundwater recharge. In agricultural and peri-urban areas, this function is crucial for restoring the balance of the hydrological cycle and limiting erosion and flooding phenomena.

NbS also contribute significantly to **water quality improvement.** Wetlands, riparian buffers, and phytoremediation areas act as natural filters, retaining sediments, nutrients, and pollutants originating from agricultural and urban areas. This process not only reduces water pollution but also improves the ecological status of aquatic ecosystems, in line with the objectives of the Water Framework Directive.

Another important benefit concerns **urban and coastal cooling.** The presence of vegetation, moist soils, and water bodies promotes cooling through evapotranspiration and shading, mitigating urban heat island effects. In urban environments, this contributes to improved human well-being, reduced energy consumption, and greater resilience to increasingly frequent heatwaves.

Finally, NBS play a crucial role in **habitat and biodiversity support.** The renaturalization of rivers, wetlands, and green corridors creates favorable conditions for flora and fauna, enhances ecological connectivity, and strengthens ecosystem resilience. This ecological value is not a secondary benefit, but a core component that underpins the long-term effectiveness and stability of the other functions.

- **Barriers**

Key barriers identified include regulatory constraints related to Natura 2000, institutional coordination across river, coastal, and urban authorities, funding availability, and long-term maintenance capacity. Rather than being treated as obstacles, these factors are recognised as critical leverage points for successful implementation.

Effective governance, sustained financing, and clear communication with stakeholders are essential to ensure that NBS deliver their full potential over time. Integration with early warning systems and monitoring further enhances adaptive capacity and decision-making.

3.3.2 Behaviour Over Time Scenario

The Business-as-Usual (BAU) scenario in the **Urban area** highlights uneven short-term developments. While modest greening efforts and environmental actions may lead to slight improvements in certain ecological and visual aspects, fundamental hydrological processes—such as infiltration, water storage, and flood attenuation—are expected to gradually deteriorate. This decline is driven by ongoing soil sealing, uncontrolled runoff from surrounding hillslopes, and the constrained performance of the existing drainage infrastructure, particularly during high river stages and emergency discharges from upstream reservoirs. Consequently, flood mitigation capacity is projected to weaken over time, with flooding events becoming more frequent and more damaging during intense rainfall.

By contrast, the Nature-Based Solutions (NBS) implementation scenario shows stable and positive trends in infiltration and water retention, resulting from the integrated application of slope terracing, rainwater harvesting, rain gardens, bioswales, and permeable surfaces. These interventions limit surface runoff, attenuate flood peaks, and reduce stress on the drainage system, especially during frequent and moderate events. Benefits related to greening, urban cooling, and ecological performance are expected to increase progressively as vegetation establishes and maintenance practices become routine. Flood risk—considered as an inverse indicator—therefore declines steadily, shifting from higher toward lower theoretical levels, although very extreme events may still exceed the local capacity of NBS.

Overall, despite challenges related to implementation timelines, spatial constraints, and maintenance requirements, the long-term co-benefits and enhanced climate resilience delivered by NBS clearly outweigh the associated trade-offs. This supports their strategic integration into local flood risk management frameworks.

Taken together, the Dalgopol and Kamchia pilot sites illustrate how context-specific NBS portfolios, aligned with existing Flood Risk Management Plan (FRMP) measures and reinforced through stakeholder co-creation, can effectively respond to diverse flood risk mechanisms while generating multiple long-term benefits in a changing climate.

Under the Business-As-Usual (BAU) scenario in the **Coastal area**, no coordinated large-scale NBS strategy is implemented. Flood management continues to rely primarily on conventional grey infrastructure and fragmented local actions.

In the short term, limited greening or maintenance activities may lead to stable or slightly improved environmental conditions in some locations. However, over the medium to long term, the capacity of the system to buffer floods progressively decreases due to loss of natural floodplain function, continued soil sealing in urban and touristic areas, and increasing climate pressure.

As a result, compound river–coastal flood events increasingly exceed existing protection capacity, leading to higher flood risk, longer inundation periods, and growing damage potential. Ecological quality and cooling benefits gradually decline, further weakening overall system resilience.

Under the NBS implementation scenario, restored floodable wetlands and salt marshes significantly increase the system's ability to store and delay floodwaters during river floods and storm surges. Urban-scale SuDS, including rain gardens, bioswales, and permeable parking, complement this by reducing runoff at source and improving infiltration and water quality.

Over time, water retention, infiltration, and flood buffering capacity increase, while flood risk steadily decreases. Although extreme compound events may still exceed the capacity of individual measures, their cumulative effect reduces flood magnitude, duration, and damage, improving overall resilience.

Co-benefits related to biodiversity, water quality, and microclimate regulation strengthen gradually as vegetation matures and maintenance routines are established. These benefits reinforce public acceptance and support long-term governance and maintenance, creating a virtuous cycle for adaptation.

3.3.3 Plenary session and lessons learnt

In the **urban** area, the implementation and assessment framework developed for the CW3 Dalgopol pilot highlights several key lessons for the effective deployment of Nature-Based Solutions (NBS) in complex flood risk contexts.

A first lesson concerns the **importance of measurable and operational indicators** to support adaptive management. Monitoring parameters such as peak water depth at critical street low points, duration of surface ponding, drainage times of rain gardens, and the frequency of blocked inlets and culverts proved essential for linking NBS performance to hazard reduction, exposure, and vulnerability. These indicators enable continuous feedback, allowing design and maintenance strategies to be adjusted based on observed system behaviour rather than assumptions.

A second lesson is the central **role of maintenance in ensuring long-term effectiveness**. Indicators related to sediment accumulation, maintenance completion rates, and post-event performance underline that NBS functionality is highly dependent on regular inspection, cleaning, and vegetation management. Without adequate maintenance planning and resourcing, performance can degrade rapidly, reducing risk reduction benefits.

From a financial perspective, the experience demonstrates that **initial investment** funding alone is insufficient to guarantee sustained performance. While FRMP funding effectively supports design and construction costs, long-term success depends on securing stable municipal co-financing for operation and maintenance, as well as aligning NBS implementation with routine road and drainage upgrades to reduce lifecycle costs.

Another key lesson relates to the **value of diversified and hybrid financing approaches**. Incentives for rainwater harvesting systems and the gradual integration of NBS into broader urban stormwater management strategies can enhance uptake and distribute costs more evenly over time, improving economic sustainability.

Finally, the Dalgopol pilot confirms that integrated NBS portfolios can effectively address multi-source flood risks, including hillslope runoff, river flooding, and dam-release events. The four selected NBS demonstrate technical feasibility, policy coherence, social co-benefits, and adaptability, providing a solid foundation for long-term flood risk reduction and climate resilience when supported by robust monitoring and sustainable maintenance frameworks.

Figure 13 Co-creation Workshop Wrap-Up in Varna

In the **coastal** area, the implementation and assessment framework developed for the CW3 Dalgopol pilot highlights several key lessons for the effective deployment of NBS in complex flood risk contexts.

Integrated, multi-scale planning is essential
The Kamchia pilot shows that effective flood-risk management in complex coastal–river systems requires interventions at multiple spatial scales. Large-scale ecosystem restoration in upstream and coastal zones must be combined with targeted urban and peri-urban measures to address both fluvial and pluvial flood dynamics in a coherent way.

Alignment with existing Flood Risk Management Plans enhances effectiveness
Integrating Nature-Based Solutions within existing Flood Risk Management Plans (FRMPs) ensures regulatory coherence, facilitates implementation, and increases institutional acceptance. NbS are most effective when they complement, rather than replace, established planning and risk management frameworks.

Nature-Based Solutions are well suited to compound flood risks
The pilot demonstrates that NbS can simultaneously address multiple hazard drivers—such as river flooding, coastal surge, and intense rainfall—making them particularly appropriate for areas exposed to compound and cascading flood risks exacerbated by climate change.

Ecosystem restoration delivers long-term risk reduction
Restoring wetlands, floodplains, and coastal ecosystems increases natural water retention, buffering capacity, and adaptive flexibility over time. These benefits tend to grow as ecosystems mature, providing more durable flood protection compared to single-purpose grey infrastructure.

Urban NbS strengthen local resilience and social acceptance
Targeted urban interventions, when designed as multifunctional public spaces, enhance local flood resilience while delivering visible social benefits. This dual function improves public acceptance and supports long-term maintenance and stewardship.

Cross-sectoral coordination is a critical success factor
The Kamchia experience highlights the importance of coordination among water

authorities, spatial planners, environmental agencies, and local governments. NbS implementation benefits from governance structures that facilitate cross-sector collaboration and shared ownership.

Transferability depends on principles, not replication
While site-specific ecological and hydrological conditions vary, the Kamchia pilot offers a transferable model based on principles—multi-scale integration, ecosystem-based design, and policy alignment—rather than fixed technical solutions. These principles can be adapted to other coastal and riverine contexts facing climate-driven flood risks. Beyond flood risk reduction, the pilot confirms that NbS generate ecological, social, and economic co-benefits, including biodiversity enhancement, improved water quality, recreational opportunities, and climate adaptation. Recognizing and valuing these co-benefits is key to securing long-term political and financial support.

3.4 Anthemountas (Greece)

The workshop was held in Thessaloniki on 21 November 2025 and involved 29 participants,

Figure 14 Training and Co-creation Workshop in Thessaloniki

The analysis of the choices made by the two groups reveals a multifaceted picture of Nature-Based Solutions (NBS) adoption across the territory, showing several areas of overlap as well as some notable differences in priorities and proposed locations.

Figure 15 Identification of NBS during Training and Co-creation Workshop in Thessaloniki

Both groups converge on a core set of NBS considered strategic: green roofs, green walls, and vertical gardens are widely recognized as effective interventions in densely built urban areas, with proposed applications in Peraia, Intersalonica, and the airport area. A similar level of coherence is found for rain gardens and bioswales, which both groups selected for Vasilika, with Group 2 additionally proposing their implementation along the "New Road Demokratias," indicating heightened attention to distributed stormwater management along road infrastructure.

Likewise, permeable pavements were selected by both groups in Galarinos, reflecting a clear consensus on their potential to reduce runoff in low- urbanized areas. The groups also agree on river floodplain restoration in Vasilika and on Natural Water Retention Measures (NWRM) in both Vasilika and Galarinos, underlining the relevance of basin-scale water retention solutions.

In coastal areas, both groups proposed Natural Coastal Barriers in Peraia and the Macedonia airport area, recognizing the need for protection against extreme marine events. A similar alignment emerges for living shorelines, although Group 1 locates them in the Airport Area and the Anthemountas discharge outlet, while Group 2 extends their application to the Agrokthma areanewly assigned Thess-Intec location.

Other solutions display a more differentiated distribution. Group 2 recommends bioengineering techniques in Galarinos and Sourwti, whereas Group 1 does not consider them a priority. Pocket parks and natural playgrounds are selected only by Group 2 and located in Peraia, suggesting a stronger focus on neighborhood-scale recreational spaces. Conversely, Group 1 attributes greater importance to urban and regenerative agriculture, recommending it for Nea Raidestos, while Group 2 does not include it.

Sustainable mobility is another point of convergence: both groups highlight the value of cycle and pedestrian green routes, locating them in Livadaki (Group 1) and Peraia (Group 2), signalling a shared interest in multifunctional green corridors.

Group 2 also introduces a criterion of territorial feasibility for rainwater harvesting systems, suggesting their implementation "in small communities and where possible," whereas Group 1 does not include them. Regarding coastal protection, Group 2 additionally proposes floodable coastal parks/coastal wetlands in both sides of the Airport area, indicating a stronger emphasis on the capacity of coastal zones to buffer extreme events.

Both groups identify Sustainable Land Management techniques as relevant in the agricultural areas of Souroti, although Group 2 proposes an extension toward Kiourtsoglou. Meanwhile, interventions such as dune restoration, constructed wetlands for industrial wastewater, urban forests and trees, urban wetlands and ponds, and afforestation are generally not selected by either group, representing potential areas for future development.

3.4.1 Identification of co-benefits, barriers and trade-offs and their transformation into modelling variables

- **Benefits/ Co-benefits**

The NBS analysed show a recurring set of environmental and social co-benefits. Hydrologically, all contribute to reducing runoff and attenuating peak flows through linear green infrastructures (green routes, permeable pavements) and point-based solutions (rain gardens, green roofs, floodplain restoration). Additional cross-cutting benefits include mitigation of urban heat islands, enhanced biodiversity, improved landscape quality, and the creation of recreational spaces that support urban regeneration and well-being. Coastal NBS also provide natural protection against storm surges and add ecological and tourism value to shorelines.

- **Trade-offs**

Alongside these benefits, several trade-offs are common across many solutions. Maintenance demands tend to be higher than for traditional grey infrastructure: permeable pavements are prone to clogging, rain gardens accumulate sediments, and pocket parks require continuous green-space management. Other side effects include increased insects or standing water in vegetated systems, noise or user disturbances in recreational spaces, and, in coastal contexts, the need for ongoing interventions to maintain dunes and natural barriers. Urban NBS also often conflict with existing land uses, such as temporary loss of parking or changes in accessibility.

- **Barriers**

NBS face technical, regulatory, economic, and cultural obstacles. Regulatory barriers include complex permitting processes, restrictions on private property, outdated building regulations, and insufficient standards for water reuse. Economic barriers arise from high upfront costs (green roofs, dune nourishment, rainwater harvesting) and the difficulty of securing stable funding for maintenance. Social barriers include low public awareness or acceptance, resident resistance, concerns from economic stakeholders, and limited technical expertise within local authorities.

Finally, many NBS are hindered by fragmented governance structures, conflicts among urban functions, and limited operational capacity, all of which complicate the coordinated management of complex interventions.

3.4.2 Cause–Effect Relationships

- **Benefits/ Co-benefits**

The co-benefits most frequently associated with NBS relate to water management, ecological quality, and socio-economic advantages. Three variables stand out for their centrality:

- Stormwater absorption and storage (benefit)
Linked to a wide range of NBS—from green roofs to floodplain restoration—this co-benefit directly affects the capacity to mitigate flash floods, reduce sewer system overloads, and manage increasingly intense extreme events.
- Reduction of urban runoff (benefit)
A crucial variable in densely urbanized areas, strongly connected to permeable pavements, rain gardens, green routes, and urban agriculture. Lower surface runoff translates into fewer floods, reduced sewer overflows, and improved performance of existing infrastructure.
- Biodiversity and ecological connectivity
A cross-cutting co-benefit that emerges across all terrestrial and coastal habitat-based NBS (urban forests, riparian buffers, wetland restoration, dunes, and living shorelines). Higher biodiversity enhances system resilience and climate adaptation capacity.

Additional co-benefits—such as improved microclimate regulation, air quality, landscape quality, and recreational and economic opportunities—highlight the multi-value nature of NBS beyond hydrological performance.

- **Trade-offs**

The analysis indicates that the main trade-offs revolve around three cross-cutting themes:

- Economic costs and maintenance
NBS generally require higher upfront investment and continuous maintenance compared to grey solutions, which can reduce their political acceptability.
- Land-use conflicts
Many NBS—pocket parks, retention areas, riparian buffers—compete with parking spaces, development areas, or agricultural uses. Limited urban space makes this trade-off particularly relevant.
- Perceived lower reliability (climate-related risk)
Some stakeholders view NBS as less dependable than grey infrastructure during extreme events, especially under increasing climate uncertainty.

Other trade-offs emerge in specific contexts, such as erosion risks in coastal NBS or the redistribution of sediments along shorelines.

- **Barriers**

The analysis of barriers highlights three recurrent categories:

- Institutional and regulatory barriers
- Fragmented legislation, complex permitting procedures, and weak integration across sectors (water, urban planning, environment, coastal management) act as major obstacles. This is one of the main reasons why grey solutions are often preferred, as they generally require more straightforward approval processes.
- Economic barriers

The combination of high initial costs and the need for long-term maintenance budgets makes it difficult for municipalities to plan sustained investments. The lack of incentives and dedicated funding further limits NBS adoption.

- Technical and administrative capacity barriers

A widespread lack of technical expertise, standardised guidelines, and monitoring capacity hampers the design and long-term maintenance of NBS. Poor coordination among municipal departments exacerbates the issue.

Additional barriers include conflicts with residents or economic operators, land ownership constraints, and uncertainty about long-term NBS performance.

The CLD developed during the preliminary phase was subsequently enriched with the new variables that emerged from the participatory activities (highlighted in yellow in Figure 16). Many of the concepts that emerged were already present in the preliminary version of the CLD. New variables and related relationships have therefore been identified and included.

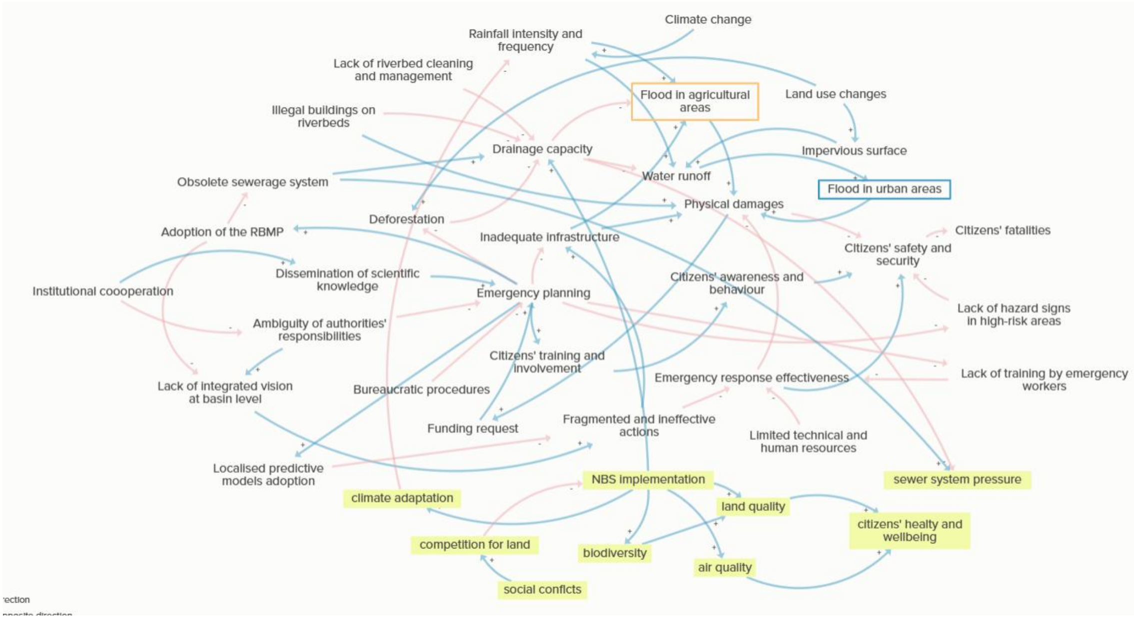

Figure 16 CLD in Thessaloniki

3.4.3 Ranking of key variables

From the joint discussion among the working groups, a set of key co-benefits, trade-offs, and barriers associated with the analysed Nature-Based Solutions emerged. The **co-benefits** identified include the ability of NBS to (i) absorb and store stormwater, (ii) reduce urban runoff, (iii) enhance biodiversity, (iv) decrease visual disturbance, and (v) generate socio-economic advantages such as recreational opportunities and new jobs.

Alongside these positive effects, participants also highlighted several **trade-offs**, such as (i) economic cost due to higher construction and maintenance costs, (ii) legislation fragmentation, (iii) land competition (iv) perceived lower reliability under extreme events, and (v) potential side effects like sediment redistribution. Similarly, a number of **barriers** were recognised, including (i) fragmented legislation, (ii) high economic costs, (iii) absence of technical specifications, (iv) limited administrative and technical capacity, and (v) the need for repeated interventions over time.

However, for the development of the scenarios, only the co-benefits were selected, as they represent the variables with the strongest systemic potential to drive change and shape future pathways.

3.4.4 Behaviour Over Time Scenario

The exercise compares the evolution of the five selected key variables (co-benefits) across the two scenarios considered: the Business-as-Usual (BAU) scenario, which continues current trends without a systemic adoption of Nature-Based Solutions, and the NBS scenario, which envisions the progressive and structural implementation of nature-based interventions through 2075.

In both scenarios, the evolution of the variables is represented in ten-year intervals, illustrating how they change over the long term as a result of climate change, urbanisation, and political choices.

For the first group of hydrological variables—capacity to absorb and store rainwater and reduction of stormwater runoff—the BAU scenario shows a progressive deterioration, with drainage systems becoming increasingly overloaded and a growing risk of urban flooding. In contrast, in the NBS scenario, the spread of green roofs, rain gardens, permeable infrastructures, and basin-scale retention measures leads to steady and long-lasting improvements, even under extreme climatic conditions.

The biodiversity variable follows a similar pattern: in the BAU scenario, ecosystems become increasingly fragmented and vulnerable, whereas in the NBS scenario, the creation of ecological corridors, habitat restoration, and the expansion of green infrastructure result in richer, more connected, and more resilient ecological systems.

Landscape quality and the reduction of visual disturbance also worsen under BAU due to the increasing presence of grey infrastructure and emergency works. Under the NBS scenario, however, the progressive shift towards green and blue solutions creates mature, recognisable, and socially accepted landscapes.

Finally, regarding socio-economic benefits, the BAU scenario is marked by rising flood-related damages, increasing emergency costs, and a decline in territorial attractiveness. Conversely, the NBS scenario generates new jobs, recreational opportunities, growth in sustainable tourism, and an overall improvement in quality of life.

Overall, the comparison shows a clear divergence: the BAU scenario leads to a progressive environmental, infrastructural, and economic decline, while the NBS scenario produces more resilient, higher-performing systems capable of generating long-term value.

3.4.5 Plenary session and lessons learnt

The comparison between the Business-as-Usual (BAU) scenario and the NBS implementation scenario with the resluts of activities provides several key lessons on the long-term implications of strategic choices in urban and territorial planning.

Incremental grey infrastructure is not sufficient under climate change pressures
The BAU scenario clearly shows that maintaining current trends without a systemic adoption of NBS leads to a gradual but continuous deterioration of hydrological performance. Drainage systems become increasingly overloaded, and flood risk intensifies over time. This highlights that conventional, reactive approaches based on grey infrastructure and emergency interventions are unable to cope with long-term climate change impacts and urbanisation dynamics.

Nature-Based Solutions deliver cumulative and long-lasting hydrological benefits
The NBS scenario demonstrates that solutions such as green roofs, rain gardens, permeable surfaces and basin-scale retention measures generate progressive improvements over time. Once implemented at scale, their benefits accumulate, leading to stable performance even under more extreme climatic conditions. This confirms that NBS are not short-term fixes, but strategic investments in long-term resilience.

Ecological connectivity is essential for biodiversity resilience
The divergent trajectories of biodiversity in the two scenarios underline the importance of spatial continuity. Fragmentation and ecosystem degradation in the BAU scenario contrast sharply with the NBS scenario, where ecological corridors, habitat restoration and green infrastructure networks enhance biodiversity richness and resilience. This shows that isolated green interventions are less effective than interconnected systems.

Landscape quality influences social acceptance and long-term sustainability
Under BAU, landscape quality deteriorates due to the proliferation of grey infrastructure and emergency works, leading to increased visual disturbance and lower public acceptance. In contrast, the NBS scenario illustrates how the gradual transformation towards green and blue infrastructures produces coherent, recognisable and socially valued landscapes. This reinforces the idea that aesthetic and cultural dimensions are not secondary, but central to the durability of planning solutions.

Prevention through NBS is economically more efficient than damage management

The socio-economic comparison highlights that BAU is associated with rising flood-related damages, growing emergency expenditures and declining territorial attractiveness. The NBS scenario, on the other hand, generates positive economic externalities, including job creation, recreational opportunities, growth in sustainable tourism and overall improvements in quality of life. This demonstrates that investing in NBS reduces long-term costs while creating new economic value.

Long-term vision and policy continuity are decisive factors

The ten-year interval analysis shows that meaningful improvements emerge gradually and require consistency over time. The success of the NBS scenario depends on sustained political commitment, long-term planning horizons and stable governance frameworks. Short-term or fragmented implementation would limit the transformative potential observed in the scenario.

Systemic adoption matters more than isolated interventions

Finally, the comparison makes clear that the effectiveness of NBS depends on their structural and widespread adoption. While isolated projects can deliver local benefits, only a systemic approach—integrated across scales, sectors and territories—can reverse the negative trends observed in the BAU scenario and generate resilient, high-performing systems.

3.5 Birkirnkara-Msida and Burmarrad (Malta)

The workshop was held in Qormi on 20 November 2025 and involved 26 participants. The participants were divided into four groups, which worked considering the two catchments: urban and rural-natural and respectively in the areas of Birkirkara-Msida and Burmarrad.

Figure 17 Training and Co-creation Workshop in Malta

From the aggregated results of the four working tables, a shared vision clearly emerges: urban solutions and those envisaged for rural areas are not alternatives, but complementary approaches. More specifically, In urban settings, attention has mainly focused on interventions capable of improving quality of life, water management, and the urban microclimate. Participants identified green roofs, green walls, and vertical gardens as priority measures, recognizing them as key tools to mitigate the urban heat island effect and to increase the presence of nature within the built environment.

A central role was also assigned to rain gardens and bioswales, together with permeable pavements, which were considered effective solutions for sustainable stormwater management and for reducing flood risk.

The ecological dimension of the city was further strengthened through urban forests, tree planting, pocket parks, and natural playgrounds, acknowledged not only as environmental elements but also as social and well-being spaces. In some tables, urban wetlands and small ponds were also identified as multifunctional tools capable of combining water management, biodiversity enhancement, and public use.

Finally, several groups emphasized the importance of rainwater harvesting systems and urban and regenerative agriculture, sometimes conceived as transitional solutions between urban and rural contexts, capable of enhancing local resilience and environmental awareness.

For natural and rural settings, discussions focused more strongly on territorial-scale interventions, with a particular emphasis on ecosystem restoration and hydrogeological risk reduction. All working tables recognized the strategic value of river floodplain restoration and inland wetland restoration, considered essential for flood attenuation and biodiversity enhancement.

Along coastal areas, solutions such as natural coastal barriers and living shorelines clearly emerged, viewed as sustainable alternatives to traditional hard infrastructure.

In agricultural and hilly landscapes, participants identified soil conservation practices as a priority, including terracing, sustainable slope management, and land management techniques, supported by Natural Water Retention Measures (NWRM).

3.5.1 Identification of co-benefits, barriers and trade-offs and their transformation into modelling variables

- **Benefits/ Co-benefits**

The discussions show broad agreement on the multifunctional nature of Nature-Based Solutions. The most frequently identified co-benefits include:

Environmental and climate benefits: reduction of flood and runoff risk, improvement of water quality, increased infiltration and groundwater recharge, mitigation of the urban heat island effect, improved air quality, and enhanced biodiversity.

Social and health benefits: improved physical and mental health, increased access to high-quality green spaces, enhanced well-being and urban liveability, strengthened social cohesion, and expanded recreational opportunities.

Economic benefits: job creation (particularly related to green space management and maintenance), reduced costs associated with damage from extreme events, lower long-term healthcare costs, and support for local and rural economies.

Governance-related benefits: increased environmental awareness, opportunities for community engagement, and strengthening of local skills and capacities.

- **Barriers**

Alongside the benefits, the groups identified several critical challenges and obstacles to implementation:

Institutional and governance barriers: fragmented responsibilities, limited integration across policies and sectors, lengthy and complex decision-making processes, and difficulties in coordination between public and private actors.

Economic and financial barriers: lack of dedicated funding, difficulties in accessing financial resources, and uncertainty regarding long-term maintenance costs.

Spatial and physical barriers: limited availability of space (especially in urban areas), conflicts with existing land uses, and development pressure.

Social and cultural barriers: lack of awareness or acceptance among the population, resistance to change, and perceptions of insecurity or loss of control over spaces.

Technical barriers: lack of specific expertise and the need for more detailed local data and knowledge.

- **Trade-offs**

Finally, several trade-offs were highlighted, requiring careful management:

Land use versus ecosystem benefits: allocating land to nature-based solutions may conflict with other uses such as construction, intensive agriculture, or infrastructure.

Upfront costs versus long-term benefits: high initial investments compared to benefits that mainly materialise in the medium to long term.

Maintenance and management requirements: NBS require continuous management; inadequate maintenance can reduce effectiveness or generate unintended negative effects.

Accessibility and safety concerns: the expansion of natural areas may raise concerns related to safety and access, particularly in urban contexts.

Social equity issues: the risk that benefits may be concentrated in specific areas or among certain groups, leading to territorial or social inequalities.

3.5.2 Cause–Effect Relationships

From the aggregation of the results of the four groups, the main relationships that emerged are:

Nature-based solutions as a driver of environmental quality and social well-being

Across all working groups, a strong and consistent relationship emerged between the expansion of green and blue infrastructure and improvements in environmental quality. Increasing the presence of nature in both urban and rural contexts leads to better air quality, reduced noise, and mitigation of heat stress. These environmental improvements directly translate into social benefits, including better physical and mental health, increased opportunities for outdoor activities, and greater overall liveability.

Participants emphasized that healthier ecosystems create more attractive and inclusive places, which in turn stimulate local economies through recreation, tourism, and related services. In this sense, environmental benefits act as a foundation upon which social and economic benefits are built.

Water management solutions reducing risk and long-term costs

Another key relationship identified concerns water management. The implementation of nature-based measures that enhance water infiltration, storage, and retention—such as wetlands, permeable surfaces, and natural water retention measures—was consistently linked to a reduction in flood risk, erosion, and damage caused by extreme weather events.

By addressing water challenges at their source, these solutions reduce reliance on costly grey infrastructure and lower long-term expenditure on repairs and emergency responses. Participants highlighted that investing in ecological water management is not only an environmental choice but also an economically sound strategy that increases safety and resilience for both urban and rural communities.

Land use as a central trade-off between competing priorities

Land use emerged as a critical point of tension. While allocating space to nature-based solutions generates significant ecosystem benefits, it can also conflict with other land uses such as housing development, intensive agriculture, or infrastructure expansion. This trade-off was particularly evident in dense urban and peri-urban areas, where space is limited and competing demands are high.

Participants stressed that these conflicts do not negate the value of nature-based solutions, but rather highlight the need for careful spatial planning and multifunctional design. When land is planned holistically, the same space can deliver ecological, social, and economic functions, helping to balance competing priorities rather than forcing a zero-sum choice.

Governance and planning as enabling or limiting factors

Governance and planning frameworks were repeatedly identified as decisive factors in determining whether nature-based solutions succeed or fail. Where responsibilities are clearly defined, policies are aligned, and funding mechanisms are accessible, solutions are more likely to be implemented effectively and maintained over time.

Conversely, fragmented governance, lengthy approval processes, and weak coordination between institutions can undermine even well-designed interventions. Participants noted that poor governance can lead to underused or overcrowded green spaces, insufficient maintenance, and declining public trust. Strong, integrated governance was therefore seen as essential to unlocking the full potential of nature-based solutions.

Short-term investments versus long-term benefits

A final recurring relationship relates to time horizons. Nature-based solutions often require upfront investment, political commitment, and institutional effort, while many of their benefits—such as improved health outcomes, ecosystem restoration, and reduced climate risks—materialise gradually over the medium to long term.

This temporal mismatch can create hesitation among decision-makers focused on short-term results. However, participants argued that recognising and communicating the long-term value of these solutions is crucial. When viewed over time, nature-based solutions consistently deliver higher and more durable returns than conventional approaches, making them a strategic investment for sustainable development.

The CLD is shown in Figure 19.

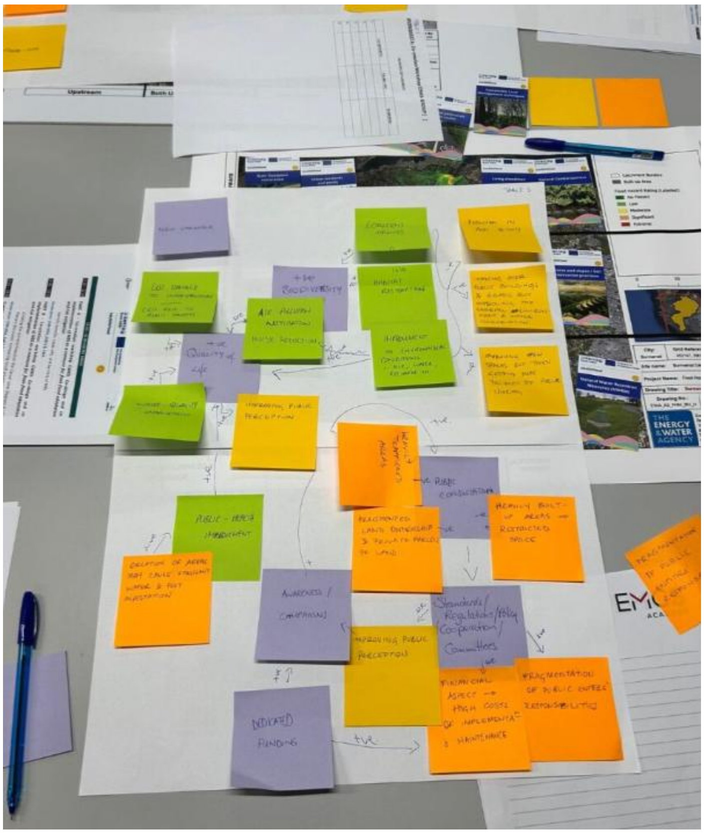

Figure 18 CLD building during Training and Co-creation Workshop in Malta

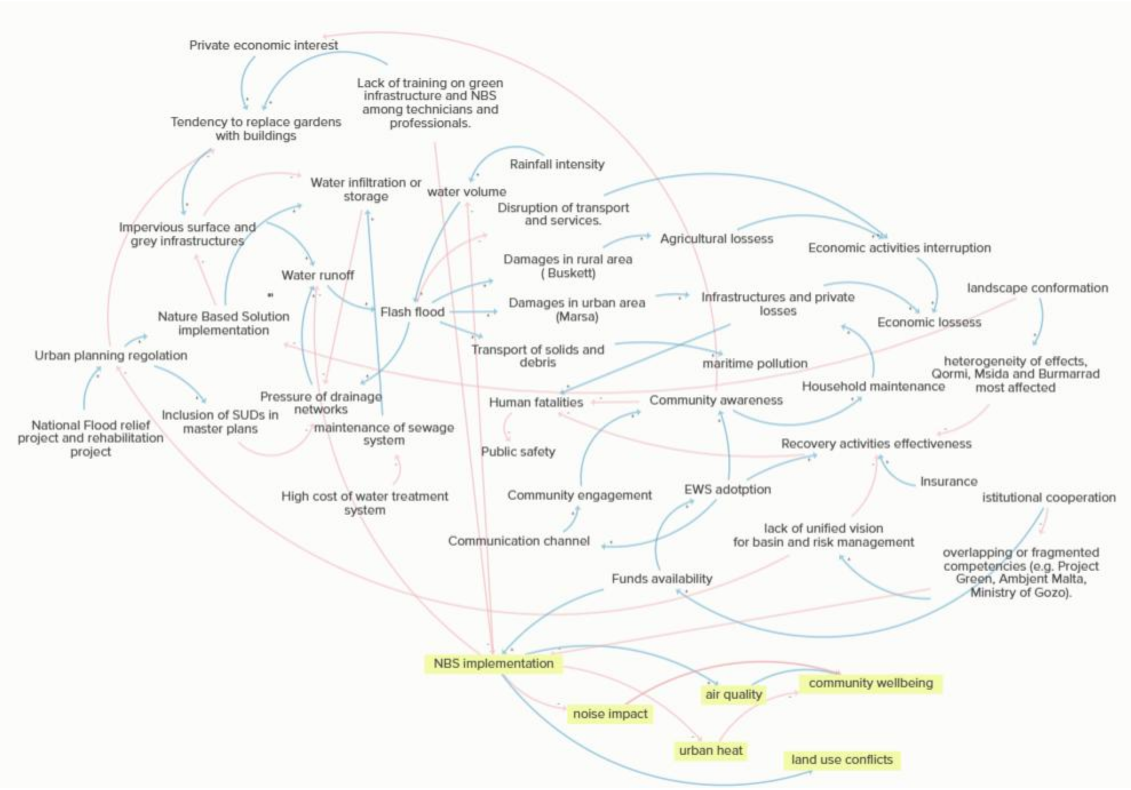

Figure 19 CLD in Malta

3.5.3 Ranking of key variables

All tables identified benefits related to water management and risk reduction as top priorities. In particular, water retention and the reduction of flooding and damage were highlighted as central, especially in relation to extreme events. Alongside these aspects, the groups strongly emphasized public health benefits, improvements in quality of life, and the enhancement of ecosystem services.

Some tables placed greater emphasis on ecological and climate-related benefits, such as greening, biodiversity, and climate resilience, while others highlighted socio-cultural benefits, including human well-being, recreational spaces, and a stronger connection between communities and the environment. One group also pointed to the role of European funding opportunities as an indirect enabling factor for the implementation of nature-based solutions.

With regard to trade-offs, the groups mainly identified conflicts related to land use. Allocating space to nature-based solutions may result in a reduction of land available for urban development or certain agricultural activities, particularly in dense or highly productive contexts.

Tensions were also noted between environmental benefits and local economic dynamics, for example in upstream–downstream relationships within agricultural catchments, or in the potential increase of issues such as pests and vectors if management is inadequate. Some groups further observed that increased use of green spaces may lead to higher pressure and management needs.

The barriers identified were highly consistent across the tables. The most frequently cited was the limited availability of space, especially in urban areas. This was followed by challenges related to maintenance and monitoring, often perceived as long-term costs and responsibilities that are not clearly defined.

Another major obstacle concerns governance, including fragmented responsibilities among institutions, lack of political coordination, and in some cases the absence of clear policies or a shared strategic vision. Finally, several groups highlighted low levels of public awareness and acceptance, noting that the benefits of nature-based solutions are not always immediately visible, despite being substantial in the medium to long term.

3.5.4 Behaviour Over Time Scenario

Under the BAU scenario, the groups share a common understanding of a progressive decline in territorial performance. Water retention is expected to decrease in the medium term, while flood risk increases, particularly in the long term, driven by growing soil sealing and the impacts of climate change.

From a socio-economic perspective, several tables point to a reduction in socio-cultural benefits and human health outcomes, along with a weakening capacity for damage mitigation. Agricultural dynamics between upstream and downstream areas are expected to remain unchanged or deteriorate, with no significant structural improvements.

In the absence of targeted policies, the scenario is also characterised by stagnant or declining investment, with environmental improvements being only marginal or perceived rather than real. Overall, the BAU scenario is described as one of inertia, where existing problems persist and intensify over time.

In contrast, under the NBS implementation scenario, all tables identify a positive and progressive trend over time. Water retention increases, leading to a reduction in flooding and damage, particularly in the medium to long term.

The groups highlight that the introduction of NBS initially requires greater effort in terms of maintenance and monitoring, especially in the first years, followed by a stabilisation and gradual reduction of costs over time. At the same time, damage mitigation improves significantly, as do socio-cultural benefits and human health outcomes, which are described as increasing substantially.

From an economic and institutional perspective, NBS implementation is associated with greater access to funding (especially European funds) and improved relationships between upstream and downstream territories, particularly in agricultural contexts. Even where benefits are not immediately visible, the tables agree that NBS trigger virtuous processes that generate tangible results over time.

3.5.5 Plenary session and lessons learnt

Based on the analysis of the workshop results the main lessons learnt are:

Urban and rural solutions should be addressed as part of a single territorial system, rather than as separate domains. The documents show that upstream and downstream interactions, as well as urban–rural linkages, strongly influence the effectiveness of interventions.

Water management emerged as a central lever for resilience. Measures that increase water retention and infiltration, as identified in the worksheets, generate significant medium- to long-term benefits in terms of flood reduction and damage mitigation.

The benefits of Nature-Based Solutions are not always immediate, a point repeatedly noted in the scenario analyses. This highlights the need for long-term planning horizons and effective communication strategies to overcome limited short-term perception of urgency.

Limited space availability is one of the main constraints, particularly in urban contexts, as identified by several tables. This underlines the importance of multifunctional and integrated spatial design.

Maintenance and monitoring are critical success factors, as clearly indicated in the barriers and scenario worksheets. Without adequate long-term management, the effectiveness of Nature-Based Solutions may be significantly reduced.

Fragmented governance structures limit the potential impact of interventions. The worksheets point to the need for stronger coordination across institutions, sectors, and administrative levels to fully realise co-benefits.

Public awareness and stakeholder engagement play a decisive role, since social acceptance directly affects the durability and performance of Nature-Based Solutions, especially where benefits are gradual rather than immediate.

Initial investments are offset by long-term benefits, including reduced damage costs, lower pressure on grey infrastructure, and improved health outcomes, as shown in the comparison between BAU and NBS scenarios.

Access to dedicated funding, particularly European funding instruments, acts as a key enabling factor, but the documents also stress that financial resources must be accompanied by adequate technical and administrative capacity to ensure successful implementation.

3.6 Gurri Catchment (Vic-Gurb, Spain)

The workshop was held in Vic on November 7th and involved 20 stakeholders.

During the third workshop, a selected set of NBS was considered and applied as part of the participatory assessment and scenario development process. The measures selected and included in the participatory process originated from D1.4 and from a technical study that assessed different NBS measures applicable to the municipalities of Vic and Gurb to reduce river flooding, in collaboration with the municipal councils, which identified potential areas for implementing these measures. The measures discussed and used during the workshop include rain gardens and bioswales, permeable pavements, urban wetlands and ponds, urban forests and trees, pocket parks and natural playgrounds, urban and regenerative agriculture, rainwater harvesting systems, natural inland wetlands restoration, terraces and slope soil conservation practices, green corridors, natural water retention measures (NWRM), sustainable land management techniques, and afforestation and reforestation.

3.6.1 Identification of co-benefits, barriers and trade-offs and their transformation into modelling variables

The workshop discussions revealed a **strong level of consensus among stakeholders** regarding the potential benefits of Nature-Based Solutions. Participants consistently recognised NBS not only as effective tools for flood risk reduction, but also as interventions capable of delivering multiple environmental and social benefits. Five co-benefits, in particular, emerged as the most highly valued.

- **Benefits/ Co-benefits**

First and foremost, stakeholders highlighted the reduction of flood impacts through increased **water infiltration** as the most significant benefit. Hydrological measures such as permeable pavements and rain gardens were widely acknowledged for their ability to expand permeable surfaces, leading to an immediate reduction in surface runoff. This, in turn, results in lower flood magnitudes and a reduced risk to existing urban infrastructure.

A second key outcome relates to **enhanced biodiversity and the restoration of ecological functions**. Interventions such as wetland restoration and the development of urban forests were recognised for their direct contribution to increasing biodiversity. Beyond their intrinsic ecological value, these measures were seen as essential for strengthening ecosystem resilience and improving functions such as water quality regulation.

Stakeholders also strongly valued the **mitigation of the urban heat island effect** and improvements in thermal comfort. The expansion of tree cover and vegetation was associated with lower ambient temperatures through shading and evapotranspiration. This benefit was closely linked to public health outcomes, particularly in reducing heat stress during increasingly frequent and intense heatwaves.

Another important co-benefit identified was the **creation of recreational spaces** and associated health benefits. The introduction of pocket parks and accessible green areas was seen as a way to provide new opportunities for leisure and physical activity, while also fostering environmental awareness, social interaction, and greater public acceptance of NBS. These spaces were perceived as contributing significantly to overall community well-being.

Finally, participants emphasised the compatibility of NBS with existing urban functions. Demonstrating that solutions such as permeable pavements can coexist with uses like parking helped **reinforce perceptions of feasibility and practicality**. This multifunctionality was considered a decisive factor in increasing acceptance and facilitating implementation in dense and consolidated urban settings.

- **Trade-offs**

One of the most immediate trade-offs concerns the l**oss of parking spaces and/or traffic lanes.** The introduction of measures such as permeable pavements or rain gardens in urban areas often requires reallocating space currently dedicated to vehicles. If not properly communicated and integrated into broader mobility strategies, this can negatively affect short-term public acceptance.

A second major trade-off relates to the loss of **agricultural land and the need for expropriation.** Nature-based interventions such as wetland restoration in rural areas may involve converting privately owned productive land. This process can trigger complex expropriation or compensation mechanisms, increasing both project costs and administrative burdens.

The discussions also identified a **potential risk of gentrification**. Improvements in thermal comfort and the creation of high-quality green and recreational spaces can enhance neighbourhood attractiveness, potentially driving up property values. While this is often seen as a positive outcome, it may also lead to the **displacement of lower-income residents,** a concern raised in particular by research stakeholders.

Another important trade-off is linked to **urban development pressure**. Allocating land for NBS can conflict with existing development expectations, especially in areas long designated for urban expansion. This creates tension between conservation objectives and established planning frameworks, representing a critical challenge at the territorial planning level.

Finally, the need for sustained **public engagement and maintenance** emerged as a key issue. The long-term performance of NBS, such as urban gardens or community-managed green spaces, depends heavily on active citizen involvement. Ensuring this level of engagement requires continuous organizational support and coordination to maintain the social sustainability of the benefits delivered.

- **Barriers**

A primary barrier relates to **insufficient technical capacity and ongoing maintenance** challenges. Limited expertise, particularly in areas such as appropriate vegetation selection, often translates into practical difficulties during operation and upkeep. This gap directly threatens the long-term performance of NBS and increases the risk of underperforming investments.

Another major obstacle concerns **conflicts with private property ownership**. In areas where interventions such as sustainable forest management are needed, the predominance of private land ownership—combined with the lack of binding regulatory instruments—creates friction with landowners. This significantly constrains the implementation of NBS at the landscape scale.

High upfront **costs and limited access to funding** were also identified as key barriers. The perceived complexity of NBS design, including vegetation management and earthworks, often leads to higher initial cost estimates compared to conventional grey solutions. When coupled with difficulties in securing grants or dedicated funding, this perception reduces acceptance among developers and undermines financial viability.

Governance-related issues represent another important challenge. Fragmented institutional responsibilities and coordination requirements—for example, when infrastructure assets are owned by different public authorities—tend to increase project timelines and management complexity. Moreover, insufficient consideration of social perceptions during the design phase can further weaken public acceptance and complicate long-term maintenance.

Finally, participants highlighted **limited acceptance among developers and established construction companies.** Resistance to unfamiliar or seemingly more expensive solutions can hinder active engagement. At the same time, this barrier was also recognised as a strategic opportunity: with appropriate capacity-building and collaboration, traditional actors could play a key role in scaling up NBS implementation.

Overall, effectively addressing these shared challenges requires a clear understanding of the motivations, constraints, and incentives of the different stakeholder groups involved, as well as tailored strategies to engage them throughout the planning and implementation process.

3.6.2 Cause–Effect Relationships

From an aggregated analysis of the results emerging from this phase, it is evident that co-benefits are driven by robust physical and ecological relationships, while trade-offs and barriers arise mainly from social, spatial, and institutional dynamics. The key to the success of Nature-Based Solutions therefore lies in the ability to strengthen the positive connections between interventions and benefits, while proactively managing conflicts and overcoming barriers through integrated governance, capacity building, and targeted communication.

More specifically, with regard to benefits and co-benefits, the main relationships identified are:

from a hydrological perspective, the increase in permeable surface area represents the most critical structural benefit. The implementation of solutions such as rain gardens and permeable pavements enhances infiltration and reduces surface runoff. This primary benefit triggers a cascading effect that leads to reduced flood impacts and, consequently, to a lower risk for urban infrastructure.

From an ecological standpoint, the implementation of urban forests and wetland restoration results in increased biodiversity and the recovery of ecosystem functions. These benefits enhance ecosystem resilience and support key regulatory services, including improved water quality.

In climatic and health-related terms, expanded vegetation cover contributes to the reduction of the urban heat island effect, improving thermal comfort and delivering direct public health benefits, particularly through reduced heat stress.

Finally, social and functional benefits include the creation of recreational and educational spaces (such as pocket parks and urban green areas), which strengthen community engagement and public acceptance of NBS, as well as the demonstrated compatibility of NBS with existing urban uses (e.g. parking), which increases feasibility and replicability in consolidated urban contexts.

Looking at the trade-offs, the analysis shows that Trade-offs represent the negative side effects or conflicts associated with NBS implementation, particularly in relation to space allocation, social impacts, and economic costs.

The most immediate trade-off is the loss of parking spaces or traffic lanes, resulting from the installation of permeable pavements or rain gardens in urban areas. This negative effect is perceived in the short term and can reduce public acceptance before environmental benefits become visible.

In rural and peri-urban contexts, the loss of agricultural land associated with interventions such as wetland restoration leads to the need for expropriation or compensation, increasing costs, timelines, and administrative complexity.

A more complex socio-economic trade-off is the risk of gentrification. Improvements in thermal comfort and high-quality green spaces increase neighbourhood attractiveness, potentially reducing housing affordability and displacing vulnerable populations.

Another relevant trade-off concerns the transfer of responsibility to the community. Some NBS, such as socially used gardens and green spaces, require sustained public activation and maintenance, making social benefits dependent on continuous citizen engagement.

In relation to the barriers, the analysis indicates the lack of technical capacity, particularly regarding vegetation selection and management. This gap directly affects maintenance quality and can compromise the long-term effectiveness and durability of NBS.

Widespread private land ownership represents a major territorial barrier, especially for large-scale interventions such as wetland restoration and sustainable land management. In the absence of binding regulatory frameworks, conflicts with landowners significantly reduce implementation rates.

Economic and financial barriers include both the perception of higher upfront costs—linked to the design complexity of NBS—and real difficulties in accessing funding. These factors undermine acceptance among developers and decision-makers.

Finally, governance-related barriers—such as fragmented responsibilities, inter-administrative coordination requirements, and insufficient stakeholder engagement—lead to delays, increased project complexity, and reduced social acceptance. NBS whose benefits materialise mainly in the long term may also suffer from limited political urgency, increasing the risk of postponed implementation.

The CLD developed during the preliminary phase was subsequently enriched with the new variables that emerged from the participatory activities (highlighted in yellow in Figure 20). Many of the concepts that emerged were already present in the preliminary version of the CLD. New variables and related relationships have therefore been identified and included.

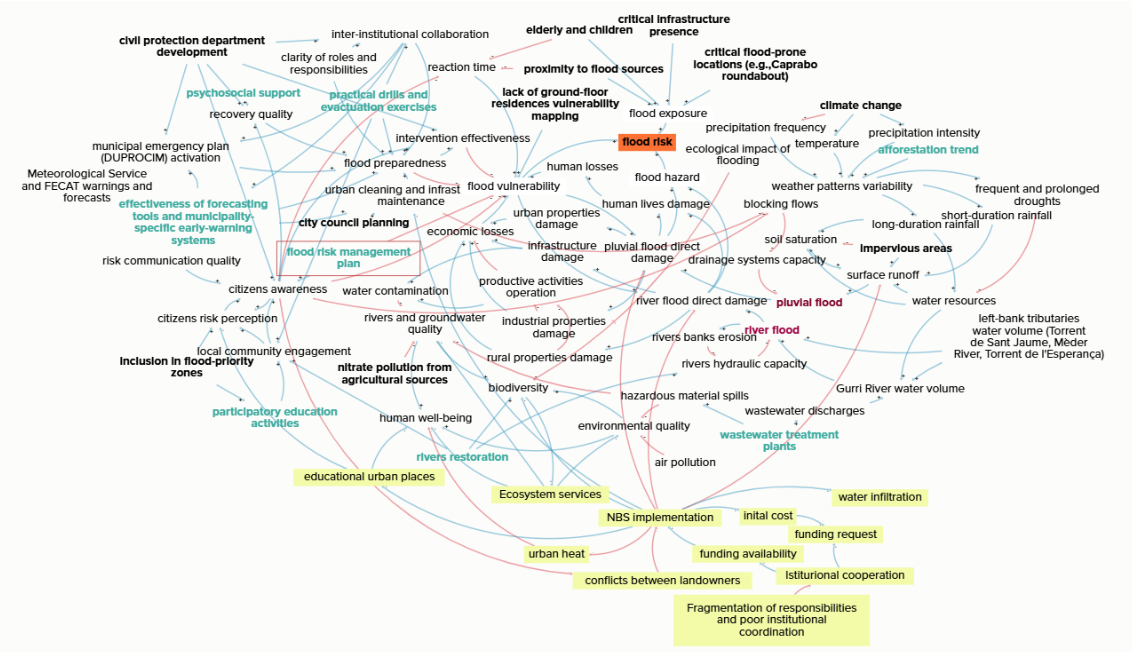

Figure 20 CLD in Vic-Gurb

3.6.3 Ranking of key variables

For each co-benefit, trade-off and barrier, we have evaluated:

Benefits / Co-benefits

1. **Reduced flood impact and increased infiltration**, achieved through hydrological NBS that enhance permeable surfaces and reduce surface runoff, directly lowering flood risk and protecting urban infrastructure.
2. **Increased biodiversity and recovery of ecological functions**, driven by interventions such as wetland restoration and urban forests, which improve ecosystem resilience and regulatory services.
3. **Reduction of the urban heat island effect and improved thermal comfort**, resulting from increased vegetation cover, shading, and evapotranspiration, with positive implications for public health.

4. **Increased recreational space and associated health benefits**, linked to the creation of pocket parks and accessible green areas that support physical activity, social interaction, and well-being.
5. **Compatibility with existing urban uses**, such as parking, demonstrating the multifunctionality of NBS and increasing their feasibility in dense urban environments.

Trade-offs

1. **Loss of parking spaces and/or traffic lanes**, due to the reallocation of urban space for hydrological NBS, potentially affecting short-term public acceptance.
2. **Loss of agricultural land and the need for expropriation**, associated with large-scale ecological restoration measures, increasing administrative complexity and costs.
3. **Risk of gentrification**, arising from improved environmental quality and attractiveness of greened areas, with potential impacts on housing affordability.
4. **Urban development pressure**, where land designated for NBS conflicts with existing or planned urban development expectations.
5. **Need for public activation and maintenance**, as some NBS rely on continuous community engagement to sustain their social and environmental benefits.

Barriers

1. **Limited technical capacity and difficulties in vegetation maintenance**, which can undermine the long-term effectiveness and durability of NBS.
2. **Conflicts with private landowners**, particularly in areas dominated by private ownership and lacking binding regulatory frameworks.
3. **High perceived costs and limited access to funding**, reducing acceptance among developers and decision-makers.
4. **Governance and coordination challenges**, including fragmented institutional responsibilities and insufficient consideration of social perceptions.
5. **Limited acceptance by developers and established construction companies**, linked to resistance to unfamiliar solutions and market inertia.

3.6.4 Behaviour Over Time Scenario

The analysis of future trajectories highlights a clear contrast between the Business-as-Usual scenario and the Nature-Based Solutions implementation scenario, revealing markedly different outcomes for flood risk management, thermal comfort, and overall system resilience.

Under a **Business-as-Usual approach**, flood risk is expected to progressively increase over the short, medium, and long term. Continued soil sealing and the absence of structural changes in land-use and water management practices lead to a gradual degradation of the system's capacity to absorb and regulate runoff. At the same time, thermal comfort is projected to decline steadily, with rising heat stress placing growing pressure on public health. These trends are reinforced by persistent barriers, such as limited technical capacity and unresolved property-related conflicts, which prevent meaningful improvements and lock the system into a path of increasing vulnerability.

By contrast, **the implementation of Nature-Based Solutions** offers a fundamentally different trajectory. Shortly after installation, NBS deliver tangible benefits in terms of flood mitigation, which stabilize at a high level of effectiveness over the medium and long term as the systems mature. As vegetation develops and ecological processes become fully established, thermal comfort improves continuously, eventually reaching its full potential in the long term. Although technical, governance, and property-related barriers are initially significant, they are not static. With targeted training, accumulated experience, and institutional learning, technical constraints gradually decrease. Similarly, property conflicts tend to diminish once regulatory frameworks, compensation mechanisms, and stakeholder agreements are put in place.

The divergence between these two scenarios is therefore substantial and becomes more pronounced over time. While the Business-as-Usual pathway leads to progressive system degradation, the Nature-Based Solutions scenario demonstrates a clear capacity to reverse negative trends and build long-term resilience. This contrast underscores the urgency of early action: delaying intervention not only increases future risks but also postpones the realization of the multiple environmental, social, and climate-related benefits that Nature-Based Solutions can provide.

3.6.5 Plenary session and lessons learnt

The stakeholder plenary discussion carried out within the Vic–Gurb pilot highlights a set of cross-cutting lessons that are critical for the successful planning, implementation, and long-term management of Nature-Based Solutions.

Public administrations are pivotal but constrained actors

Local and supramunicipal authorities play a central role in translating NBS strategies into practice, yet they face significant operational constraints. Limited access to funding, complex inter-administrative coordination, and insufficient technical familiarity with NBS—particularly regarding vegetation management and maintenance—represent recurring challenges. At the same time, public administrations are the primary actors responsible for managing social trade-offs, including negotiations with private landowners and addressing public concerns related to space reallocation. This confirms that strengthening institutional capacity is a prerequisite for effective implementation.

Technical expertise and long-term system performance are closely linked

The research sector's contributions underline that the success of NBS depends heavily on sound technical design, especially in vegetation selection and ecosystem integration. A systemic and long-term perspective is essential to fully capture both benefits and risks, including those that may not be immediately visible, such as social impacts linked to gentrification. This reinforces the lesson that NBS cannot be treated as purely aesthetic or short-term solutions, but require scientifically informed planning and monitoring.

Economic feasibility and land ownership strongly influence acceptance

Private sector stakeholders consistently frame NBS adoption in terms of cost, operational efficiency, and long-term maintenance requirements. The perception of higher upfront costs compared to conventional solutions, combined with uncertainties related to land ownership—particularly in agroforestry and industrial contexts—emerges as a decisive barrier. This highlights the need to align NBS proposals with clear economic arguments and predictable governance arrangements in order to secure private-sector engagement.

Social acceptance and community benefits are key enablers

Civil society and NGOs emphasize the social, educational, and environmental value of NBS, particularly in relation to public spaces, schools, and community safety. However, concerns raised by emergency services regarding functionality and risk reduction effectiveness demonstrate that social acceptance depends not only on perceived benefits, but also on trust in performance and safety. This illustrates the importance of co-design processes that balance environmental ambition with practical usability.

Governance and coordination are as important as technical solutions

Across all stakeholder groups, governance-related challenges repeatedly emerged as a limiting factor. Fragmented responsibilities, infrastructure ownership by multiple authorities, and weak regulatory frameworks for private land significantly complicate implementation. This confirms that NBS projects require dedicated coordination mechanisms and early engagement of all relevant actors, including landowners and higher-level authorities.

Strategic project management can turn barriers into opportunities

The analysis shows that many barriers—technical capacity gaps, social trade-offs, and private-sector resistance—can be mitigated through targeted actions. Investing in training, developing structured communication strategies, establishing formal coordination platforms, and framing funding applications around quantifiable co-benefits are not ancillary activities, but core components of successful NBS implementation.

Convergence on NBS value provides a strong foundation for action

Despite differing priorities and constraints, there is broad agreement across stakeholder groups on the relevance and necessity of investing in NBS, particularly for flood risk reduction, thermal comfort, and biodiversity enhancement. This shared understanding provides a solid basis for collaborative governance and long-term commitment, provided that identified tensions are addressed proactively.

Conclusions

This deliverable has documented the outcomes of the testing phase of mitigation-oriented NBS across the nine pilot sites of the LocAll4Flood project, within the framework of an integrated, multi-stakeholder governance model. Through the application of Participatory System Dynamics Modelling (PSDM) and a structured co-creation process, the project has demonstrated how NbS can be effectively co-designed, evaluated, and embedded within local flood risk management strategies in diverse Mediterranean contexts.

A first key conclusion is that NBS must be understood as systemic interventions rather than isolated technical measures. Across all pilot sites, the participatory modelling process revealed that the effectiveness of NBS depends on complex interactions between hydrological processes, social behaviours, institutional capacities, and long-term management conditions. The use of causal loop diagrams and qualitative scenarios enabled stakeholders to explicitly identify feedback loops, delays, and potential policy resistance, fostering a shared understanding of system dynamics that would not emerge through conventional planning approaches.

The results consistently show that NBS deliver multiple and cumulative co-benefits beyond flood risk mitigation. These include increased water retention and infiltration capacity, improved water quality, urban and coastal cooling, enhanced biodiversity, and improved quality of life. Importantly, these benefits tend to grow over time as ecosystems mature and social acceptance increases, reinforcing the long-term value of NbS as multifunctional infrastructures for climate adaptation and resilience.

At the same time, the testing outcomes highlight that trade-offs and barriers are intrinsic to NbS implementation and must be explicitly addressed. Spatial constraints, land-use conflicts, maintenance requirements, institutional fragmentation, and limited financial and technical capacity emerged as recurring challenges across pilots. However, the participatory process proved essential in transforming these barriers into leverage points, enabling stakeholders to identify governance solutions, phased implementation strategies, and hybrid approaches combining NbS with existing grey infrastructure.

Another major conclusion concerns the central role of governance and stakeholder engagement. The workshops confirmed that technical feasibility alone is insufficient to ensure the success of NBS. Social acceptance, environmental awareness, and institutional coordination are decisive variables that strongly influence long-term performance. Co-design processes enhanced ownership, reduced resistance, and supported the emergence of shared responsibility for implementation and maintenance, particularly at the municipal and community levels.

The comparison between Business-as-Usual (BAU) and NbS implementation scenarios clearly demonstrates that incremental or reactive approaches are inadequate under increasing climate change pressures. In all pilot sites, BAU scenarios lead to a progressive deterioration of hydrological performance, higher flood risk, and growing socio-economic losses. Conversely, NbS scenarios show more stable and resilient system trajectories, capable of absorbing shocks, reducing damages, and generating sustained environmental and social value.

From a methodological perspective, the deliverable confirms the added value of PSDM as a decision-support and learning tool. PSDM facilitated the integration of scientific knowledge with local expertise, supported collective learning, and enabled stakeholders to explore long-term consequences of alternative strategies. This approach proved flexible enough to be applied across heterogeneous contexts while maintaining a coherent analytical framework.

Finally, the testing outcomes demonstrate that the LocAll4Flood integrated multi-stakeholder governance model is both robust and transferable. While specific NbS portfolios must be tailored to local environmental, social, and institutional conditions, the underlying principles—multi-scale integration, ecosystem-based design, policy alignment, and participatory governance—can be adapted to other Mediterranean and European contexts facing increasing flash flood risk.

In conclusion, the deliverable provides strong evidence that NBS, when co-designed through inclusive and systemic approaches, represents a viable and effective pathway for enhancing flood resilience, supporting climate adaptation, and promoting sustainable territorial development. The lessons learned from the pilot sites offer a solid foundation for scaling up NBS implementation and embedding them more firmly within flood risk management policies and practices at local, regional, and European levels.

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