multi-Risk sciEnce for resilienT commUnities undeR a changiNgclimate

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2. ABSTRACT

This report discusses and application of multi-criteria criteria for the prioritization of flood adaptation and mitigation measures, based on expected impacts of the measures and including the appreciation of win-win solutions.
The first part of the report briefly describes the rationale of the methodology. In the second part two application examples are described.

3. Table of contents

4.Section 1: methodological approach

4.1 Introduction

In recent decades, there has been a marked transition from traditional flood protection measures, which primarily focused on defense structures, to the broader concept of Integrated Flood Risk Management (IFRM). This approach addresses the different components of flood risk, seeking not only to reduce hazard but also to minimize exposure and vulnerability through multi-level, multi-sectoral strategies (Bubeck et al., 2016; Klijn et al., 2022). Importantly, IFRM calls for embedding flood risk governance with broader sustainability objectives, including environmental protection, sustainable economic growth, resource efficiency, equity, and community development. As such, IFRM contributes to the achievement of the Sustainable Development Goals (SDGs) set by the United Nations in 2015, particularly those related to climate action, resilience, and sustainable cities and communities (Molinari et al., 2023). Another key challenge for the successful implementation of IFRM strategies lies in increasing public acceptance and participation through active and inclusive stakeholder engagement.

In this context, ensuring that flood risk mitigation measures are not only technically effective but also socially equitable and environmentally sustainable becomes a core priority. The emphasis is therefore shifting towards evaluation approaches that incorporate multiple performance dimensions (technical, economic, environmental, and social), in line with contemporary policy goals at both national and international levels.

This reports is based on the work of Gallazzi (2025) where this need is approached by proposing a structured, multidimensional, and participatory decision-support methodology for evaluating and prioritizing structural flood risk mitigation measures. The evaluation framework is designed to reflect the complex and multifaceted nature of IFRM, moving beyond purely technical priorities and integrating broader environmental and social sustainability benefits into decision-making process. The proposed approach relies on Multi-Criteria Decision Analysis (MCDA), which has emerged as a promising tool for addressing these challenges (de Brito and Evers, 2016; EC – Directorate General for Environment, 2021).

4.2 Methodological approach

The terms Multiple Criteria Analysis (MCA), Multiple Criteria Decision Analysis (MCDA), Multiple Criteria Decision Making (MCDM), and Multiple Attribute Decision Analysis (MADA) are often used interchangeably in the literature to refer to structured methodological approaches that support complex decision-making processes involving multiple, often conflicting objectives, and diverse stakeholders with different needs and preferences.

4.2.1 Why MCDA?

The selection of MCDA as the methodological approach is motivated by its well-documented capacity to explicitly incorporate the multiple dimensions of sustainability into a single evaluation process. It is especially well suited to public investment contexts where decisions must account for diverse values, stakeholder preferences, and non-monetary outcomes (Figueira et al., 2005).

In the case of disaster risk management, MCDA offers a coherent way to compare interventions not only based on cost or effectiveness, but also on long-term sustainability, societal acceptance, and co-benefits, which are difficult to evaluate through conventional economic methods, such as Cost-Benefit Analysis (CBA). MCDA enables stakeholders to understand trade-offs and make informed decisions under uncertainty, an essential feature in managing climate-related risks (World Bank & EC, 2024).

The following sections present a critical comparison of CBA and MCDA, illustrating the rationale behind the adopted methodological choice.

4.2.2 Limitations of Cost-Benefit Analysis

Although Cost-Benefit Analysis (CBA) remains the most commonly applied method for evaluating public infrastructure projects and plans, it presents important limitations when applied to complex contexts like flood risk management.

CBA requires the monetization of all impacts, including intangible or non-market values such as ecosystem services, biodiversity, landscape aesthetics, human health, and equity concerns (World Bank & EC, 2024; Asafu-Adjaye, 2005). Methods used to assign economic value to these aspects, such as contingent valuation or hedonic pricing, often rely on subjective assumptions and introduce considerable uncertainty. Moreover, these techniques can potentially reinforce existing socio-economic inequalities. For example, valuations of life, health or environmental quality often correlate with income and willingness to pay, thereby disadvantaging lower-income populations (World Bank & EC, 2024; Asafu-Adjaye, 2005; Paruccini, 1994). As a result, key environmental and social externalities are frequently underestimated or completely omitted.

Moreover, CBA tends to aggregate all impacts into a single economic metric, typically the net present value, which can obscure how benefits and costs are distributed across social groups (i.e., intragenerational equity). This means that an intervention deemed economically beneficial overall may disproportionately favour certain groups while imposing significant costs on others. CBA also struggles to adequately capture intergenerational equity, typically discounting future benefits and costs, thus undervaluing interventions that provide long-term resilience and adaptation benefits, which are crucial in flood risk management (Asafu-Adjaye, 2005; Paruccini, 1994).

In summary, while CBA provides a seemingly objective framework, its economic logic often fails to capture the multidimensional and uncertain nature of flood-related decisions, limiting transparency, stakeholder involvement, and potentially leading to conflicts, delays, and reduced public acceptance (World Bank & EC, 2024).

4.2.3 Advantages of Multi-Criteria Decision Analysis

By contrast, MCDA allows for the simultaneous consideration of multiple evaluation criteria, without reducing all impacts to monetary values. This is particularly advantageous when assessing measures with significant environmental, social, or institutional components.

First, MCDA offers a structured decision-support tool, by guiding the definition of objectives, identification of alternatives, and selection of criteria in a systematic and traceable manner. Over time, hundreds of MCDA methods have been developed, differing in their theoretical background, the types of questions they address, and the types of outputs they produce (Hobbs & Meier, 1994). However, the general steps of any MCDA process include:

- Defining the decision context (such as the aims of the analysis, the decision makers involved and other key stakeholders)
- Identifying the alternatives
- Defining the objectives and evaluation criteria
- Eliciting the decision makers’ preferences (e.g., criteria weighting)
- Aggregating and synthesizing all these inputs to provide a comprehensive assessment of the options.

Another key strength of MCDA lies in its capacity to clarify trade-offs between competing evaluation criteria, allowing decision makers to understand and justify their choices. A MCDA-based evaluation procedure is therefore explicit and reproducible, enhancing transparency and enabling well-informed decision-making. This aspect is especially important in public governance contexts.

Furthermore, MCDA frameworks are inherently participatory, encouraging the involvement of all relevant actors throughout the decision process, from problem structuring to the weighting of criteria. Stakeholder engagement strengthens both the legitimacy and acceptance of decisions, while also promoting mutual learning, consensus-building, and conflict resolution (de Brito & Evers, 2016; Figueira et al., 2005). These participatory approaches are particularly relevant in disaster risk management, where diverse institutional responsibilities, public expectations, and territorial disparities often result in conflicting priorities. In the context of flood risk governance, active stakeholder involvement ensures that selected interventions reflect collective preferences and local needs, thereby improving implementation effectiveness and long-term sustainability (de Brito & Evers, 2016). Moreover, participatory processes play a crucial role in enhancing the social acceptability of flood mitigation strategies by increasing transparency, fostering trust, and ensuring that communities are actively involved in decisions that directly affect them (Bubeck et al., 2016).

MCDA methods are also suited to addressing uncertainty in both data and stakeholder preferences. The approach supports various techniques, such as sensitivity analysis, robustness analysis, and probabilistic modelling, which allow for the systematic exploration of uncertainty and its impact on final recommendations. The uncertainty analysis is crucial in flood risk management given the variability of climatic and socio-economic projections (de Brito & Evers, 2016; Figueira et al., 2005).

Its flexibility makes it especially useful for regional authorities that must evaluate a broad set of interventions under tight budget constraints, complex institutional arrangements, and evolving climatic conditions.

MCDA is specifically designed to address the following needs:

- It enables the incorporation of diverse performance dimensions (technical, economic, environmental, and social).
- It supports participatory development of the whole evaluation process.
- It offers a transparent and structured framework for comparing projects.
- It strengthens accountability and supports institutional coordination in resource allocation.

In conclusion, MCDA ensures that the evaluation and prioritization of flood mitigation measures are robust, inclusive, and aligned with the principles of sustainable development and good governance promoted at both national and European levels.

4.2.4 Evaluation flow-chart

The diagram below illustrates the full evaluation process identified in Gallazzi (2025) for the prioritization of flood mitigation intervention. It includes the sequence of technical evaluation steps, leading to the classification or rejection of each project, and the subsequent strategic evaluation by policymakers.

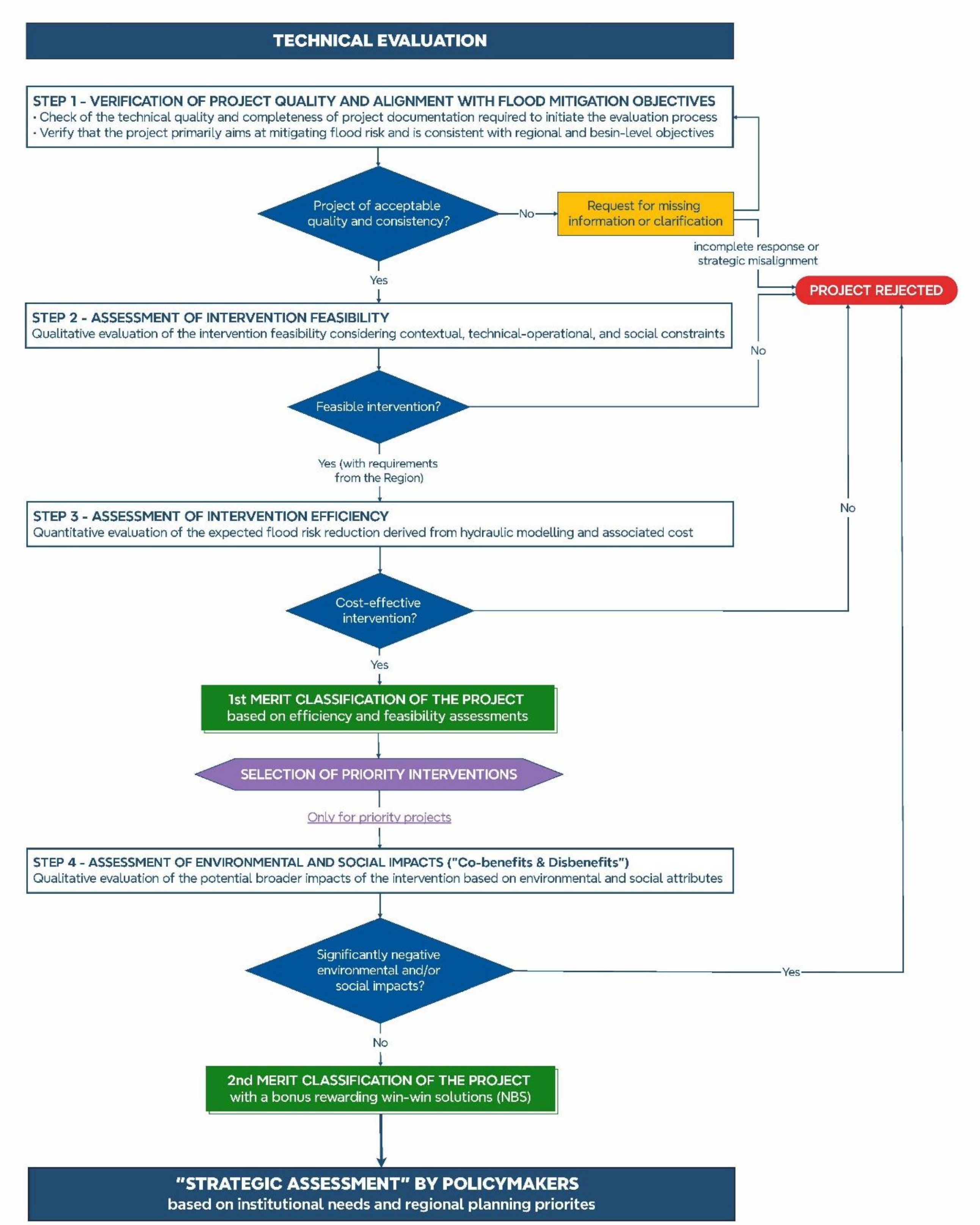

Figure 1. Flow chart of the evaluation procedure.

5. Section 2: Case studies

5.1 Case study 1: Flood detention basin on the Molgora Stream

5.1.1 Territorial and hydrological context

The flood risk management strategy for the Molgora catchment was established through a hydrological and hydraulic study commissioned by the Lombardy Region in 2016. This regional study confirmed and supplemented the set of mitigation measures proposed in the earlier 2004 study conducted by the Po River Basin District Authority, identifying four flood detention basins as priority interventions: three located along the Molgora Stream and one along its tributary, the Molgoretta, as shown in Figure 2. The project presented in this report specifically concerns the construction of the in-line flood detention basin on the Molgora, at the boundary between the municipalities of Bussero, Gorgonzola, and Pessano con Bornago, in the Province of Milan, Lombardy Region.

Topographically, the intervention site is characterized by a flat morphology with elevations ranging between 135 and 144 m a.s.l., sloping gently southward. This terrain results from the deposition of fluvio-glacial and alluvial sediments originating from the retreat of Pleistocene glacial tongues. The hydrographic network comprises the Molgora as the principal watercourse and a system of irrigation and drainage canals. The Molgora flows through highly urbanized areas where the natural floodplain has been progressively constrained. The project area lies within a critical segment of the watercourse, historically prone to flooding due to the limited hydraulic conveyance capacity of the downstream reaches, particularly near urban centers such as Gorgonzola and Melzo. The storage basin is designed to mitigate these risks by reducing peak flows associated with flood events of 100-year return period.

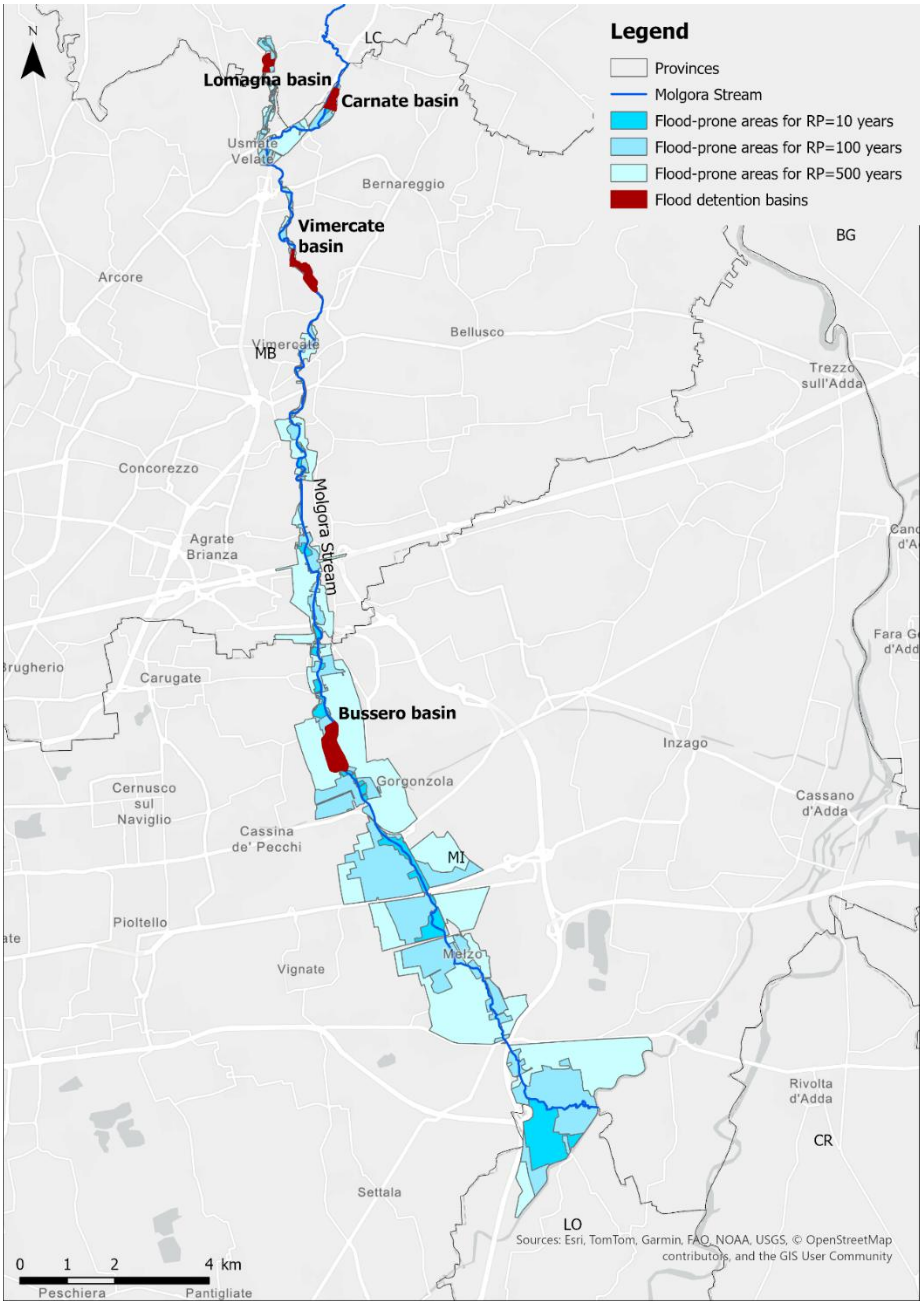

Figure 2. Location of the four priority flood detention basins in the Molgora catchment. The case study focuses on the Bussero basin, located between the municipalities of Bussero, Gorgonzola, and Pessano con Bornago. The figure also shows the current flood-prone areas (without detention basins) associated with flood events of 10-, 100-, and 500-year return periods (RP), representing high, medium, and low flood hazard, respectively (Source: GIS data provided by the Lombardy Region).

5.1.2 Project description

The feasibility-level project under consideration, completed in 2019, proposes a basin with a net storage volume of approximately 770,000 m^3 and a maximum flooded area of around 37 hectares. The basin will utilize existing riparian zones, which will be reshaped through excavation and embankment works to create five terraced compartments. These compartments, designed at different bottom elevations, will allow staged inundation and differentiated flood management strategies.

The project also includes the construction of new embankments and the reinforcement of existing levees downstream, in the municipalities of Melzo, Comazzo, and Truccazzano, to manage the regulated outflow from the basin. These complementary works are essential to address residual flood risk until the system of upstream basins is fully implemented.

The intervention is consistent with the design assumptions of the 2016 regional study, including a maximum discharge threshold of 50 m^3/s into the Muzza canal, which serves as the final receiving water body for the Molgora stream, and a reference flood event with a return period (RP) of 100 years.

The strategic relevance of this project is further evidenced by its positive evaluation by the Lombardy Region, which identified it as one of the priority flood mitigation projects eligible for funding. The construction of the Bussero detention basin has, in fact, already been financed in 2024 through national funds provided by the Ministry of the Environment and Energy Security (MASE), for a total amount of € 36,500,000.

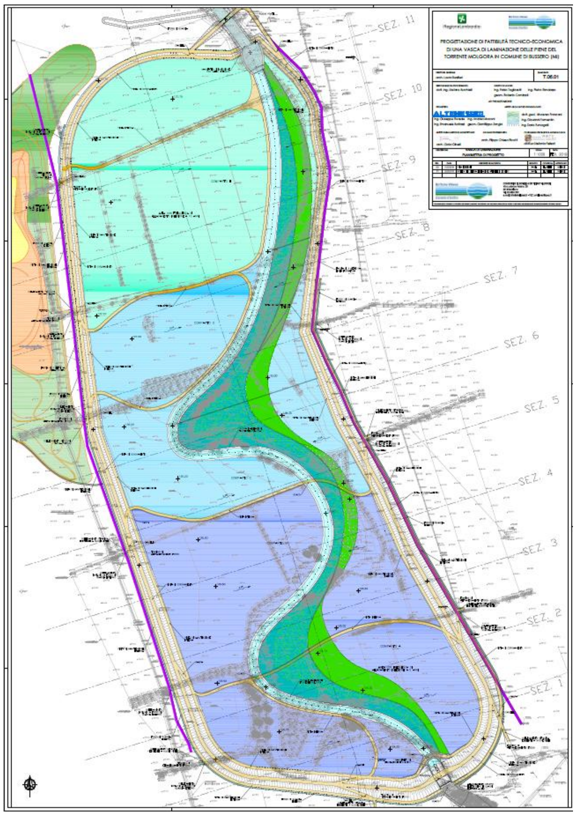

Figure 3. Technical layout of the planned Bussero flood detention basin (Autorità di Bacino Distrettuale del Fiume Po and Regione Lombardia, 2023).

5.1.3 Hydraulic modelling and results

A one-dimensional unsteady-state hydraulic model was developed and calibrated to represent current flow conditions along the Molgora stream. The model incorporated high-resolution topographic data and existing flood protection infrastructure, enabling the simulation of flood dynamics under both baseline and post-intervention scenarios. The model results demonstrate a significant reduction in peak discharge downstream of the basin site during flood events of 100-year return period. Specifically, the regulated outflow from the basin aligns with the permissible discharge limit of 50 m^3/s into the Muzza canal, ensuring compliance with the constraints of downstream conveyance capacity. Moreover, the partition of the basin into five compartments facilitates a gradual inundation sequence that optimizes the storage volume without inducing excessive backwater effects. The modelling outcomes also confirm the compatibility of the intervention with the regional and basin-level flood risk management strategy, supporting its prioritization within the broader planning framework.

5.1.4 Application of Procedure 1

Step 1 – Project quality and alignment with flood risk mitigation objectives

The first step of the evaluation procedure consists of a preliminary screening designed to verify the adequacy, completeness, and strategic consistency of the project documentation, in accordance with the technical quality requirements of the evaluation procedure (Figure 1). These include both mandatory documents required by current regulations and studies recommended by regional guidelines, as well additional data necessary to apply this new evaluation framework. This verification involves two main dimensions: (i) the completeness and technical soundness of the documentation provided, and (ii) the alignment of the project with the planning strategies and goals of flood risk mitigation established at the regional and river basin level.

For the Bussero detention basin project, the documentation submitted includes a full set of reports and graphical outputs, in line with regulatory requirements for feasibility-level projects, such as the general Technical Report, Hydrological and Hydraulic Studies, Environmental Feasibility Study, Utility Conflict Report, and Project Cost Summary. These documents allow for an in-depth understanding of the intervention from hydraulic, environmental, territorial, and landscape perspectives.

However, during the preliminary evaluation phase, the Lombardy Region deemed the project incomplete and requested specific integrations and modifications. In particular, the Lombardy Region asked to demonstrate the effectiveness of the intervention in reducing flood hazard and risk, with reference to the updated Flood Risk Management Plan (FRMP) maps, including comparative hydraulic simulations of pre- and post-intervention scenarios. Moreover, the Region asked to explore alternative solutions for managing surplus excavation material, such as on-site reuse through local regrading and terrain reshaping, to reduce the significant disposal costs. These requests were addressed by project proponents in the final documentation, thereby reinforcing the overall technical robustness and strategic value of the project proposal. The fulfilment of these requirements is clearly reflected in the hydraulic modelling and outcome analysis presented in the previous section.

In terms of strategic consistency, the primary objective of the intervention is clearly the mitigation of hydraulic risk, consistent with national and regional directives on soil and water protection. The project aligns with the flood mitigation objectives and strategies defined by the Po River Basin District Authority and is consistent with the following planning instruments:

- The Flood Risk Management Plan (FRMP), which classifies the Molgora catchment as an Area of Potential Significant Flood Risk (APSFR) of regional importance. The intervention represents an implementing measure of the FRMP, as it corresponds to one of the four priority flood detention basins identified in hydraulic studies conducted by the District Authority (2004) and the Lombardy Region (2016), as shown in Figure 2.
- The Water Management Plan, which promotes sustainable water management and the restoration of natural retention capacity in highly urbanized areas such as the Molgora basin.

Outcome of Step 1

The project is fully admissible to the next evaluation step. All required documentation, including hydraulic modelling and alternative material management strategies, was already integrated in the final 2019 feasibility project, ensuring full compliance with strategic and technical quality criteria.

Step 2 – Feasibility of the intervention

Step 2 involves a qualitative multicriteria evaluation of the actual feasibility of the project, based on five attributes included in the procedure. The objective of this step is to determine whether the project can be realistically implemented within its current territorial and regulatory context, and thus whether it should proceed to the subsequent stages of evaluation. The assessment of feasibility attributes is carried out though multiple sources of information: (i) the contents of the available project documentation (e.g., Environmental Feasibility Study, Utility Conflict Report, and Technical Report), (ii) the specific characteristics of the territorial and regulatory context, and (iii) expert judgment based on the intrinsic features of the proposed type of intervention, in this case a flood detention basin. The following section presents the attribute-by-attribute application of the methodology to the Bussero case study.

Attribute 1: Compatibility with existing constraints and interferences

The proposed detention basin is located in an unbuilt rural area, currently used as arable land, and is not affected by significant territorial constraints such as nature reserves, landscape protection areas, or archaeological zones. According to the Environmental Feasibility Study, no environmental, naturalistic, or cultural heritage restrictions have been identified that would interfere with project implementation. The site is also free from contaminated areas or incompatible land uses. Regarding underground and surface infrastructures, the Utility Conflict Report confirms the presence of a major gas transmission line along the western boundary and a sewer collector on the eastern side. The design of the basin was adapted to maintain the required safety distances and avoid physical interference. Minor utilities and infrastructures (e.g., power lines and local access roads) are either outside the project footprint or will be managed during construction through standard engineering solutions. A typical potential constraint for detention basin projects is the management of large excavation volumes. In this case, the issue was proactively addressed: most the 1,125,600 m^3 of excavated material will be reused on site for basin shaping and landscape compensatory interventions. This solution, developed in response to earlier feedback from the Lombardy Region, enhances the overall compatibility of the project with implementation constraints.

Evaluation: The project demonstrates full compatibility with existing territorial constraints, with no critical interference issues.

Classification: “Yes”.

Attribute 2: Consistency with local and regional planning instruments

The intervention is also consistent with the current planning instruments at different administrative levels. As reported in the Environmental Feasibility Study and Technical Report, the project aligns with: the Regional Territorial Plan (Piano Territoriale Regionale, PTR), including the Regional Landscape Plan (Piano Paesaggistico Regionale, PPR) and Regional Ecological Network (Rete Ecologica Regionale, RER); the Provincial Territorial Coordination Plan (Piano Territoriale di Coordinamento Provinciale, PTCP) of the Province of Milan; and the Municipal Land Use Plans (Piani di Governo del Territorio, PGT) of the involved municipalities (Bussero, Gorgonzola, Pessano con Bornago). Notably, the detention basin is explicitly identified in the Regional Territorial Plan (PTR) as a priority infrastructure for achieving regional soil protection objectives. As such, the project not only complies with local and provincial land use designations but is also directly aligned with the regional strategic framework whose provisions take precedence over subordinate plans. The PTR also classifies the project area as part of the secondary ecological network (RER) and within a landscape protection zone along the Molgora stream, which implies the need to activate both Habitats Directive Appropriate Assessment and Landscape Authorization procedures during the project's approval process.

Evaluation: The project is in full alignment with local and regional planning instruments. The need to activate an Appropriate Assessment and a Landscape Authorization is consistent with standard regulatory procedures and is already anticipated in the feasibility design. These assessments will be carried out during the subsequent design phase and do not affect the project's overall compatibility with the existing planning framework.

Classification: “Yes”.

Attribute 3: Maintenance guarantees

While the feasibility-level project does not include a detailed operation and maintenance plan, the long-term maintenance of a flood detention basin typically involves predictable and technically straightforward activities such as sediment removal, vegetation control, and inspection of inlets, outlets, and spillways. These tasks are manageable, provided that the site remains accessible and is not subject to prolonged waterlogging. In this case, the basin is in an open rural area with good access via existing roads and sufficient space for maintenance vehicles and equipment. The intervention is not located in a heavily urbanized or environmentally critical area, and its hydraulic design relies on passive control, with no need for pumping systems or complex infrastructure. Given the type of intervention and site characteristics, maintenance operations are expected to be limited in complexity and frequency, and they can be planned and budgeted in advance.

Evaluation: The project presents adequate conditions for long-term maintenance, with no technical or logistical constraints.

Classification: “0”.

Attribute 4: Robustness of the intervention

The robustness of a flood mitigation measure in the short term refers to its resistance to external stressors that may compromise its structural integrity or operational functionality shortly after implementation. This assessment considers the nature of the intervention, including its level of exposure, susceptibility to mechanical failures, and reliance on active systems or complex components. In this case, the intervention consists of a dry detention basin with passive hydraulic control, located in a rural area with minimal exposure to anthropogenic disturbance or accidental interference. The design does not involve pressurized systems, movable gates, or critical mechanical parts, which significantly reduces the likelihood of failure due to malfunction or maintenance delays. Moreover, earthworks and embankments are engineered using standard methods, with gradual slopes and reinforced materials, making the structure inherently stable and resilient to regular hydrological stresses and erosion processes during initial operational phases.

Evaluation: The intervention is structurally simple, passive, and not exposed to significant short-term stressors.

Classification: “0”.

Attribute 5: Presence of conflicting elements

The project involves the construction of a large detention basin in a predominantly agricultural area, requiring the permanent expropriation of approximately 430,000 m² of private land. This could potentially represent a source of conflict, particularly due to the perceived imbalance between local burdens and downstream benefits.

Nonetheless, various elements contribute to reducing the likelihood of strong opposition. First, the project has been planned within a well-established regional strategy and follows a long-standing prioritization process that reinforces its public legitimacy. Second, compensation measures are explicitly foreseen, both from an economic and environmental point of view. The economic compensation is detailed in the expropriation plan and financial framework, with a dedicated budget of over 4 million euros allocated for land acquisition, temporary occupation, and related procedures. On the environmental side, the project includes extensive compensatory interventions to requalify the surrounding landscape and ecological corridors. These are detailed in the Environmental Feasibility Study and aim to offset potential disruptions through targeted planting, habitat restoration, and visual mitigation measures. Overall, no public opposition or legal disputes have been reported, and the design incorporates multiple elements to facilitate local acceptance and minimize social or territorial conflicts.

Evaluation: The project entails land expropriation, but it includes clear compensatory measures, and no evidence of conflict has emerged.

Classification: “0”.

Outcome of Step 2

The project is considered fully feasible based on all five evaluation attributes, with no critical constraints or issues, as summarized in Table 1. Thus, the project proceeds to Step 3 without conditions. This outcome reflects the completeness and quality of the feasibility-level design.

Table 1. Qualitative classification of the feasibility of the Bussero detention basin project, based on the five attributes defined in Step 2 of Procedure 1.

#	Attribute	Indicator type	Qualitative classification
1	Compatibility with existing constraints and interferences	Project- and context-specific	**Yes** (no constraints)
2	Consistency with local and regional planning instruments	Project- and context-specific	**Yes** (fully consistent)
3	Maintenance guarantees	Measure- and context-specific	**0** (no issues identified)
4	Robustness of the intervention	Measure-specific	**0** (no issues identified)
5	Presence of conflicting elements	Project-specific	**0** (no issues identified)

Step 3 – Efficiency of the intervention

The third step of Procedure 1 aims to assess the overall efficiency of the proposed flood mitigation project by estimating its expected benefits in relation to associated cost. The analysis is based on the quantitative evaluation of flood damage reduction for different asset categories and the classification of the benefit-to-cost ratio (i.e., efficiency value) using predefined thresholds.

In this case study, the assessment is carried out using the hydraulic modelling results, which compare flood-prone areas before and after the implementation of the Bussero detention basin. The simulations assume a design return period of 100 years, consistent with the regional standard for primary flood protection infrastructure in minor river basins such as the Molgora. Due to the lack of flood intensity maps (e.g., water depth or velocity), the analysis focuses on changes in flood hazard extent and exposure (potential damage) for each asset category. Table 2 summarizes the results in terms of hazard extent and exposure reduction across the ten asset categories considered by the procedure, estimated using the MOVIDA/NATFIM project's tools. Despite a moderate reduction of approximately 40% in the total flood-prone area, as also illustrated in Figure 4, the project results in substantial reductions in exposure for nearly all asset types.

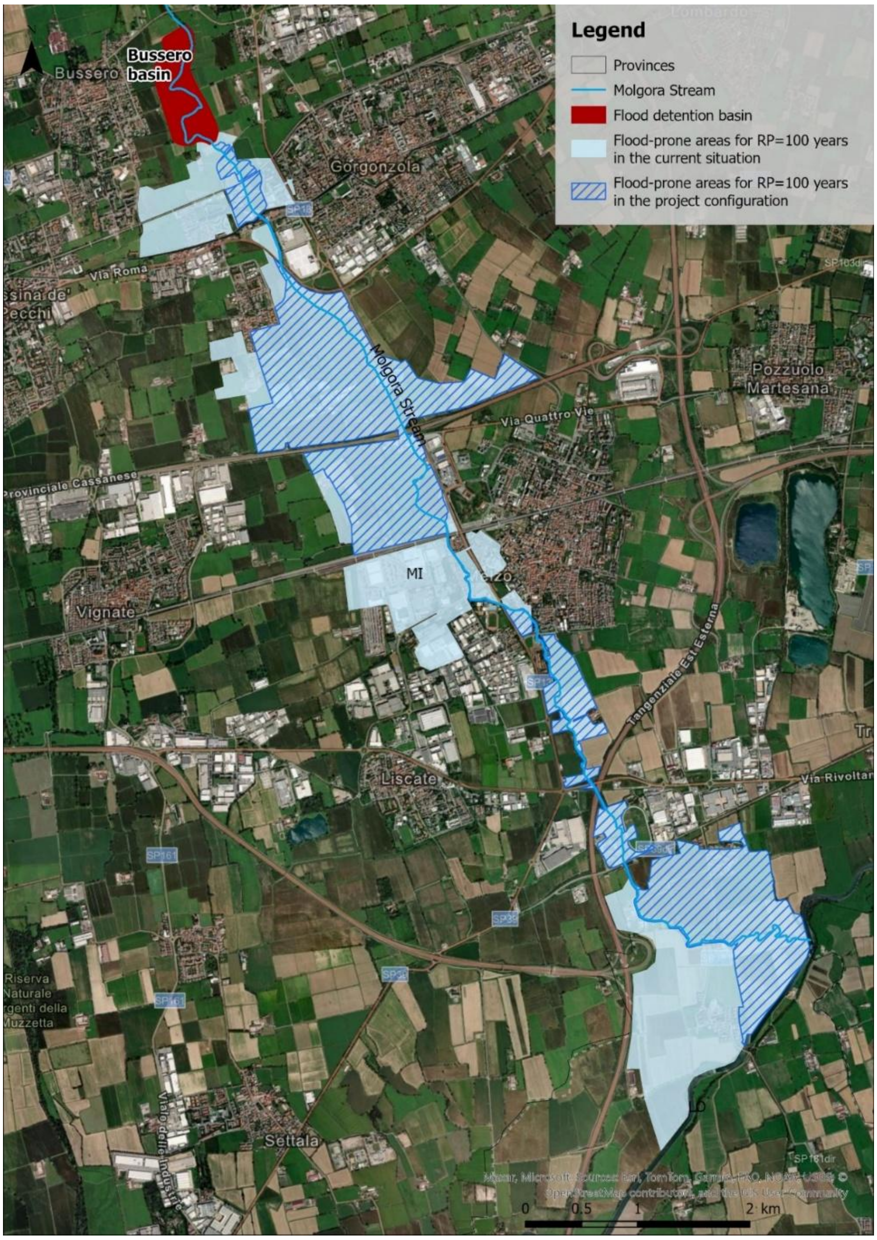

Figure 4. Flood-prone areas along the Molgora stream under current conditions (solid blue) and after the implementation of the Bussero detention basin (hatched blue), for a return period (RP) of 100 years. The figure illustrates the expected reduction in flood hazard extent resulting from the intervention (Source: GIS data provided by the Lombardy Region).

Table 2. Reduction in flood hazard and exposure by asset category for the Bussero basin project (turn= 100 years), estimated using the GIS tools developed within the MOVIDA/NATFIM tool. Reduction values are reported in absolute terms, with percentage changes shown in parentheses.

	Ante operam	Post operam	Reduction
FLOOD-PRONE AREA [km²]	8.1	4.7	3.4 (42%)
EXPOSED ASSETS			
Population [inhabitants]	5048	1372	3676 (73%)
Strategic buildings [units]	1	0	1 (100%)
Na-tech sites [units]	19	11	8 (42%)
Road infrastructure [km]	60.7	24.6	36.1 (59%)
Railway infrastructure [km]	10	3.5	6.5 (65%)
Commercial and industrial activities [M€]	662.5	269	393.5 (59%)
Residential building [M€]	540.5	145.2	395.3 (73%)
Crops [M€]	3.2	2	1.2 (38%)
Livestock [livestock heads]	2788	486	2302 (83%)
Cultural heritage [units]	19	3	16 (84%)

For each asset category, the procedure estimates the efficiency of the intervention by calculating the benefit-to-cost ratio (B/C), where the benefit is the reduction in direct flood damages and the cost is the total project cost (in this case, 36.5 Meur). To enable comparison across the ten dimensionally heterogeneous asset categories, efficiency values are classified into three qualitative levels based on proper thresholds: Class 1 (high efficiency), Class 2 (medium efficiency), and Class 3 (low efficiency). None of the three reward conditions defined in the procedure were applied in this case. Specifically, the intervention does not fall within the scope of measures designed to reduce the risk of loss of life (e.g., protection against flash floods or debris flows), and no strategic buildings such as hospitals or Seveso-classified industrial sites are located within the affected area. Table 3 presents the results of the evaluation.

Table 3. Efficiency values and corresponding qualitative classification by asset category.

Asset category	Efficiency value	Efficiency class
Population [inhabitants/M€]	101	Class 2
Strategic buildings [units/M€]	0.03	Class 2
Na-tech sites [units/M€]	0.2	Class 1
Residential buildings [M€/M€]	11	Class 3
Road infrastructure [km/M€]	1	Class 2
Railway infrastructure [m/M€]	177	Class 1
Commercial and industrial activities [M€/M€]	11	Class 3
Cultural heritage [units/M€]	0.4	Class 1
Livestock [livestock heads/M€]	63	Class 2
Crops [k€/M€]	33	Class 1

Output of Step 3

The final part of the assessment consists in aggregating the efficiency classes of the ten asset categories to assign an overall project efficiency class, following the assignment rule established for Step 3 of the procedure. This aggregation is performed twice using two different weighting sets: one derived from the revised Simos method ("Simos"), and one from the alternative Simos-based method introduced in this research, which assumes a fixed 20% reduction rate between successive attributes ("SimosVar"). This dual calculation serves as a sensitivity analysis to verify the stability of the results. The assignment rule is based on the cumulative weights of the ten attributes falling into each efficiency class (W_1, W_2, W_3), compared against predefined thresholds (50% and 75%). As shown in Table 4, the Bussero basin project is classified as Class 2 (moderate efficiency) overall under both weighting schemes, since W_1≤50% and (W_1+W_2)≥75%. The consistency of the results across both weighting methods further confirms the robustness of the classification.

Table 4. Step 3 results for the Bussero project: final efficiency classification under two weighting configurations ("Simos" for the revised Simos method, and SimosVar with a 20% decrement). W_1, W_2, and W_3 indicate the cumulative weights of attributes falling into Class 1, Class 2, and Class 3, respectively.

Asset category	**Efficiency class**	**Simos weights [%]**	**SimosVar weights [%]**
Population [inhabitants/M€]	Class 2	16	20
Strategic buildings [units/M€]	Class 2	14	16
Na-tech sites [units/M€]	Class 1	13	13
Residential buildings [M€/M€]	Class 3	13	13
Road infrastructure [km/M€]	Class 2	11	10
Railway infrastructure [m/M€]	Class 1	11	10
Commerce & Industry [M€/M€]	Class 3	9	8
Cultural heritage [units/M€]	Class 1	8	6
Livestock [livestock heads/M€]	Class 2	5	3
Crops [k€/M€]	Class 1	1	2
	W_1 [%]	**33**	**31**
	W_2 [%]	**46**	**49**
	W_3 [%]	**22**	**21**
	Overall efficiency class	**Class 2**	**Class 2**

As the Bussero basin project has been classified as Class 2 under both weighting schemes, it meets the criteria to advance to Step 4 of the procedure, focused on evaluating potential environmental and social impacts.

Step 4 – Environmental and social impacts

Step 4 involves a qualitative evaluation of the expected environmental and social impacts associated with the implementation and operational phases of the proposed intervention, based on the 14 attributes (specifically, 11 environmental and 3 social). Each attribute is assessed using project-specific qualitative indicators derived exclusively from the available technical documentation.

For the present case study, the evaluation draws on three key documents prepared at the feasibility design stage: the Technical Report, the Environmental Feasibility Study, and the Material Management Report. The following paragraphs present an attribute-by-attribute assessment of the potential co-benefits and disbenefits of the Bussero project.

Attribute 1: Morphological state of the watercourse

The intervention directly affects one of the few remaining natural sections of the Molgora stream, characterized by a meandering course, irregular morphology, and dense riparian vegetation. While the existing riverbed within the basin footprint will be completely reconstructed, the project explicitly aims to preserve and enhance the stream's morphological complexity. The design includes the creation of new meanders, floodplain areas, and nature-based bank protections (e.g., willow cuttings, brushwood fascines, and stone groynes), promoting the balance between erosion and sedimentation processes. Importantly, the project considers the evolution of the riverbed over time in response to different flood events, as a reinforcing element of the fluvial environment dynamics. These features demonstrate a strong commitment of the project to fluvial morphological restoration, rather than mere hydraulic optimization.

Classification: "+".

Attribute 2: Ecological status of the watercourse

In line with the morphological objectives, the project also envisions a substantial improvement in the ecological quality of the aquatic and riparian ecosystem. Within the basin, two large functional areas are defined: an agricultural zone (west) and a natural zone (east), the latter designed to flood more frequently. The natural zone will host wetland habitats with variable water depths, creating hydrological and ecological heterogeneity ideal for supporting diverse aquatic and terrestrial species. Planting schemes with native, flood-resilient species and wooded patches with filtering functions are also foreseen to support nutrient uptake and improve water quality. These interventions align with the concept of ecological status defined by the Water Framework Directive, as they support biological elements (e.g., fish, macroinvertebrates, vegetation) and the physic-chemical conditions necessary for a healthy aquatic ecosystem.

Classification: "+".

Attribute 3: Chemical status of the watercourse

The intervention is not expected to alter the chemical status of the Molgora stream. Since the detention basin is designed to operate only during flood events (with a RP of 100 years), for limited durations, its influence on water quality under normal flow conditions is negligible. The project does not include direct water treatment measures or pollution control systems, nor does it involve the continuous release of pollutants or any specific action that would compromise the chemical integrity of surface waters.

Classification: "0".

Attribute 4: Chemical status of groundwater

There is no indication that the implementation of the detention basin would pose any contamination risk to groundwater bodies. The project does not include activities involving the use, storage, or disposal of hazardous substances, and no pollutant pathways are expected to be activated during either the construction or operational phase. Additionally, the intervention site is not located within a designated groundwater protection area.

Classification: "0".

Attribute 5: Quantity of surface water

The detention basin is designed to temporarily store excess runoff during high-flow events and gradually release it downstream once peak conditions have subsided. This mechanism effectively mitigates flood risks without permanently altering the river's flow regime or the overall hydrological balance. Importantly, the project does not interfere with baseflows or ecological flows during normal conditions, and therefore, no significant variation in surface water availability is expected.

Classification: "0".

Attribute 6: Groundwater quantity (aquifer recharge)

The intervention is not expected to affect groundwater quantity or recharge dynamics. The detention basin is intended solely for temporary floodwater storage and does not incorporate features to promote infiltration, such as permeable bottoms or artificial recharge systems. According to the project documentation, the basin's base is impermeable, and water is released gradually through controlled outlets rather than seeping into the subsoil. Consequently, the hydrological regime of the underlying aquifer is unlikely to be affected.

Classification: "0".

Attribute 7: Biodiversity and ecology (terrestrial ecosystem)

The intervention is situated in an agricultural and peri-urban landscape with currently limited ecological value. However, the project includes substantial environmental compensation measures aimed at improving biodiversity and restoring natural habitats. In particular, the eastern portion of the detention basin is designated for ecological restoration and will include riparian woodlands, wet meadows, ponds, and areas with shallow and deep water levels to support a mosaic of habitats. Reforestation with native species is also planned, along with natural engineering works to stabilize banks and promote ecological niches. These measures are expected to enhance both terrestrial and aquatic biodiversity over time, support ecological continuity, and contribute positively to landscape quality.

Classification: "+".

Attribute 8: Excavated materials

The Bussero project involves the excavation of approximately 1.13 million cubic meters of soil. However, most of this material will be reused directly on-site for the morphological shaping of the basin and the implementation of environmental compensation measures. In particular, excavated soil will be employed for the construction of the basin's perimeter embankments, downstream sectors, and a hill at the west of the basin that serves as a key landscape compensation work. This solution significantly reduces the need for transport and landfill disposal, thereby minimizing associated environmental impacts, including emissions and heavy vehicle traffic. The proposed reuse plan aligns with regional guidelines for sustainable material management and directly addresses the preliminary feedback from the Lombardy Region regarding the need to reduce externalities associated with excavation.

Classification: "+".

Attribute 9: Soil quality

The intervention area is currently used for agriculture and does not present any known contamination. The Environmental Feasibility Study confirms that excavation works will not interfere with contaminated soils or sensitive land uses. Although the construction phase may involve potential risks of accidental spills (e.g., fuel leakage), standard safety and mitigation measures are foreseen in the project's preliminary safety plan to prevent soil degradation. These safeguards are considered adequate to manage temporary risks.

Classification: "0".

Attribute 10: Air quality

Potential impacts on air quality are mainly linked to the construction phase, due to vehicle and machinery emissions and dust generation. However, the reuse of most excavated material within the project area significantly limits the need for long-distance transportation, reducing related emissions. Additionally, the project foresees standard mitigation measures such as dust suppression, controlled vehicle access, and careful site logistics, which are expected to keep emissions within acceptable limits. Overall, the impact on air quality is considered minor and temporary.

Classification: “0”.

Attribute 11: Noise pollution

Noise-related impacts are also limited to the construction-phase activities such as excavation, vehicle movement, and site preparation. The basin is located in a predominantly rural area with low population density, and there are no sensitive receptors, such as schools, hospitals, or residential complexes, in the immediate vicinity. Construction works are planned to occur during standard daytime hours. No significant long-term sources of noise are foreseen during the operational phase, as the flood detention basin functions passively and does not require mechanical pumping or active infrastructure.

Classification: “0”.

Attribute 12: Well-being and quality of life

The Bussero detention basin is expected to generate positive impacts on local well-being and quality of life, primarily by reducing flood risk in a vulnerable area. In addition to this core benefit, the project includes the creation of ecological compensation areas and a series of landscaping interventions that will improve the visual and environmental quality of the peri-urban landscape. Although recreational use is not among the primary objectives, the presence of naturalized areas, such as wetlands, wooded patches, and open green spaces, can enhance opportunities for informal outdoor activities, passive recreation, and nature appreciation. These elements contribute to a more liveable and resilient local environment.

Classification: “+”.

Attribute 13: Social cohesion

The intervention does not include dedicated initiatives aimed at enhancing social cohesion, such as community engagement programs, inclusive design features, or public events. However, it does not introduce barriers to accessibility or exclude specific user groups. The project preserves existing land use structures and does not alter local dynamics in a way that might affect residents’ sense of identity or belonging. As such, it is not expected to generate either positive or negative impacts on social cohesion.

Classification: “0”.

Attribute 14: Socio-economic impacts

The project is expected to generate positive socio-economic effects, both directly and indirectly. In the short term, construction activities will create temporary employment opportunities. More significantly, in the medium and long term, the creation of a landscaped hill adjacent to the basin is designed to host multifunctional spaces, including terraced agricultural plots, cycling and walking paths, and facilities such as a bike-camping area. Located at the intersection of two major regional cycling routes (the Villoresi Canal and the Martesana Canal), the site has the potential to become a strategic hub for soft mobility and tourism, offering services to cyclists and enhancing local attractiveness. These developments may stimulate new local economies related to recreational and eco-tourism activities, while maintaining agricultural productivity.

Classification: “+”.

Output of Step 4

As summarized in Table 5, the impact assessment conducted in Step 4 did not identify any negative effects associated with the construction or operation of the Bussero detention basin. On the contrary, the project shows multiple positive contributions, particularly in terms of environmental enhancement, such as improvements in the morphological and ecological status of the Molgora stream and support for local biodiversity, as well as social benefits. These include increased well-being and quality of life for residents, and potential long-term socio-economic opportunities related to soft mobility and landscape valorisation.

Table 5. Qualitative classification of the potential environmental and social impacts of the Bussero detention basin project, based on the 14 attributes defined in Step 4 of Procedure 1.

#	Attribute	Indicator type	Qualitative classification
1	Morphological state of the watercourse	Project-specific	**+**
2	Ecological status of the watercourse	Project-specific	**+**
3	Chemical status of the watercourse	Project-specific	**0**
4	Chemical status of groundwater	Project-specific	**0**
5	Quantity of surface water	Project-specific	**0**
6	Groundwater quantity (aquifer recharge)	Project-specific	**0**
7	Biodiversity and ecology (terrestrial ecosystem)	Project-specific	**+**
8	Excavated materials	Project-specific	**+**
9	Soil quality	Project-specific	**0**
10	Air quality	Project-specific	**0**
11	Noise pollution	Project-specific	**0**
12	Well-being and quality of life	Project-specific	**+**
13	Social cohesion	Project-specific	**0**
14	Socio-economic impacts	Project-specific	**+**

To complete Step 4, a synthetic aggregation of the attribute-level results is required to determine whether to assign a bonus or penalty to the project. This was carried out using four different weighting configurations to ensure consistency and allow a sensitivity check: two aggregation approaches (Approach 1 and Approach 2), each applied using two different weighting methods (the revised Simos method and SimosVar with a 20% decrement). Table 6 summarizes the results obtained by applying all four weighting schemes to the project’s attribute classification. In every case, the sum of the weights for positively rated attributes (W_+) exceeds the 60% threshold, while the weight for negatively rated attributes (W_-) is zero. As a result, the project consistently qualifies for a bonus, regardless of the weighting scheme used. This outcome reinforces the internal coherence of the evaluation framework: the positively rated attributes, particularly those related to biodiversity, morphological and ecological quality, and social well-being, are exactly those that received the highest weights across all four weighting scenarios. This convergence demonstrates a clear alignment between the actual co-benefits generated by this intervention and the preferences expressed by regional stakeholders during the participatory process. It also confirms the suitability of the Bussero case as a reference application for testing the robustness and transparency of the overall evaluation methodology.

Table 6. Step 4 results for the Bussero project: classification of each attribute and aggregated outcomes under four different weighting configurations, based on two aggregation approaches (A1 and A2) and two weighting methods (Simos and SimosVar with a 20% decrement). W_+ and W_- indicate the cumulative weights of attributes classified as positive (+) and negative (-), respectively.

Attribute	**Class**	**Simos (A1) weights [%]**	**Simos (A2) weights [%]**	**SimosVar (A1) weights [%]**	**SimosVar (A2) weights [%]**
Morphological state of the watercourse	**+**	12.8	13.3	18.3	20.4
Ecological status of the watercourse	**+**	12.4	12.2	16.3	16.4
Chemical status of the watercourse	**0**	6.1	5.5	3.8	3.4
Chemical status of groundwater	**0**	7.0	6.6	4.8	4.2
Quantity of surface water	**0**	8.0	7.7	7.1	5.4
Groundwater quantity	**0**	3.8	3.2	2.2	2.2
Biodiversity and ecology	**+**	12.4	12.2	16.3	16.4
Excavated materials	**+**	8.5	10.0	6.7	8.4
Soil quality	**0**	3.3	3.2	2.0	2.2
Air quality	**0**	1.8	2.0	1.4	1.8
Noise pollution	**0**	0.9	1.0	1.1	1.4
Well-being & quality of life	**+**	9.4	10.0	9.1	8.4
Social cohesion	**0**	7.0	8.8	5.5	6.7
Socio-economic impacts	**+**	6.6	4.3	5.4	2.7
	W+ [%]	**62.1**	**62.0**	**72.1**	**72.7**
	W- [%]	**0**	**0**	**0**	**0**
	Outcome	**Bonus**	**Bonus**	**Bonus**	**Bonus**

Evaluation outcome and final classification

Based on the results of the four-step evaluation process, the flood detention basin project in the municipality of Bussero is classified as follows:

Feasible (Step 2)

Medium efficiency (Step 3)

With a bonus assigned for relevant environmental and social co-benefits (Step 4)

According to the merit classification framework developed in this research, the project is therefore assigned to Class 3, corresponding to Priority level 3.

It is important to note that, despite its intermediate technical priority, the Bussero project was selected by the Lombardy Region for funding under the 2024 MASE programme. This confirms the role of the technical evaluation as a tool for supporting, rather than substituting, strategic decision-making. However, the final selection of projects is also influenced by broader institutional considerations and regional planning priorities.

In this case, the strategic relevance of the intervention stems from its inclusion in a coordinated flood risk mitigation plan for the entire Molgora catchment. The Bussero basin is one of four priority flood detention basins identified in the 2004 study by the Po River Basin District Authority and subsequently confirmed by the 2016 hydraulic modelling commissioned by the Lombardy Region. The decision to implement the Bussero basin reflects its function as a key element in a systemic, basin-wide approach to flood risk management, aligned with regional planning objectives.

5.2 Case study 2: Levee maintenance on the Mincio River

5.2.1 Territorial and hydrological context

The second case study concerns a structural maintenance intervention along a section of the Mincio River, in the Province of Mantua, Lombardy Region. The Mincio is a major watercourse within the Po River basin, extending for approximately 75 km from Lake Garda to its confluence with the Po River. The intervention area is located downstream of the city of Mantua, in a predominantly rural and agricultural setting, and includes various riverbank and levee segments across the municipalities of Bagnolo San Vito, Borgo Virgilio, Mantua, and Roncoferraro.

According to the project's technical report, the need of the intervention along this reach of the Mincio river is due to recurring levee instability caused by bank erosion, toe scouring, and increasingly frequent flood events. These processes are exacerbated by the current levee geometry, particularly the excessive slope of the embankments, which contributes to instability and gravitational failure. Critical structural deficiencies are observed in several sections of the levees, compromising their ability to provide adequate flood protection. In this context, ensuring the structural integrity and functionality of the levee system is essential to safeguard adjacent areas that include urban settlements, agricultural land, and key infrastructures.

5.2.2 Project description

The intervention entails extraordinary maintenance, and structural restoration works on riverbanks and levee crests along the Mincio River. The project was developed by the Interregional Agency for the Po River (Agenzia Interregionale per il fiume Po, AIPO), the technical authority responsible for planning, designing, and implementing hydraulic risk mitigation interventions across the Po River basin in collaboration with regional authorities. AIPO's institutional mandate includes both ordinary and extraordinary maintenance of the primary river network and hydraulic infrastructure of supra-regional interest.

In accordance with national regulations established by Legislative Decree 36/2023, the design process for both new works and maintenance interventions begins with the preparation of a document intended to identify and compare possible technical alternatives (DOCFAP, Documento di Fattibilità delle Alternative Progettuali). For maintenance works, the subsequent design phases (feasibility and executive design levels) may be simplified or merged, although the DOCFAP remains a required preliminary step. In the case of the Mincio River project, the DOCFAP consists of a single technical report outlining the rationale for intervention and identifying the riverbank and levee segments to be structurally restored. This report outlines a set of integrated actions, including slope reshaping, re-compaction of eroded segments, crest reconstruction, vegetation removal, and targeted reinforcement works based on hydraulic and geotechnical principles. These interventions aim to restore the original performance and structural integrity of the levee system, ensuring adequate protection against flood events with a return period of up to 200 years, without modifying the current hydraulic regime. Accordingly, no new hydraulic modelling was carried out as part of the design process.

The relevance of this intervention is demonstrated by its inclusion among the priority projects selected by the Lombardy Region for national funding under the 2025 MASE programme, with a proposed allocation of € 3,500,000. A preliminary allocation of € 400,000 was already granted by the Region in 2024 for emergency maintenance works along the right bank of the Mincio river, in areas where repeated slope failures and embankment damage have compromised road stability (D.g.r. n. 2838 del 22 Luglio 2024). However, the widespread and continuous deterioration observed across multiple levee segments highlights the need for a more extensive and coordinated structural maintenance intervention, as outlined in the current project proposal.

5.2.3 Definition of area of influence

As part of current selection and funding procedures, particularly for all projects submitted to the national ReNDiS platform supported by MASE, proponents are required to delineate the area of influence for each proposed intervention. This area represents the territory most directly exposed to flood risk in the absence of the intervention and where the expected benefits are concentrated. When available, hydraulic modelling is used to define this spatial extent. In the case of the Mincio River project, however, no new modelling was conducted, due to the limited scope of the design phase and the short timeframe for preparing the DOCFAP.

In this context, the area of influence was delineated by AIPO as the potentially flood-prone zone in the event of levee failure or overtopping, using an expert-based approach grounded in field experience and morphological assessment of the river corridor, without the support of simulation tools. A shown in Figure 16 (orthophoto 1), the planned intervention focuses on the most critical segment of the levee (segment C–D), which currently exhibits structural damage and requires urgent maintenance. Nevertheless, the area of influence was extended to a broader levee section (segment A–B), due to the homogeneous structural condition observed along the entire stretch. As AIPO clarified, similar failures have occurred in the past within this zone, and additional collapses are expected in the coming years, especially given the estimated implementation timeline.

The boundaries of the area of influence were identified using prominent natural and infrastructural features in the vicinity of the damaged segment: to the north, the right-bank levee of the Mincio River; to the south, the left-bank levee of the Po River; to the east, the SP33 provincial road embankment; and to the west, the A22 motorway embankment and a local consortium canal. These elements, while not designed as flood protection structures (except for the river levees), were expected to temporarily contain inundation in the short term, particularly if supported by emergency measures such as mobile barriers. As emphasized by AIPO, this expert-based analysis provided a more realistic and intervention-specific reference scenario than simply referring to the broad inundation area associated with a 500-year return period flood, as outlined in the Po River Basin plan (PAI, Figure 5, orthophoto 2).

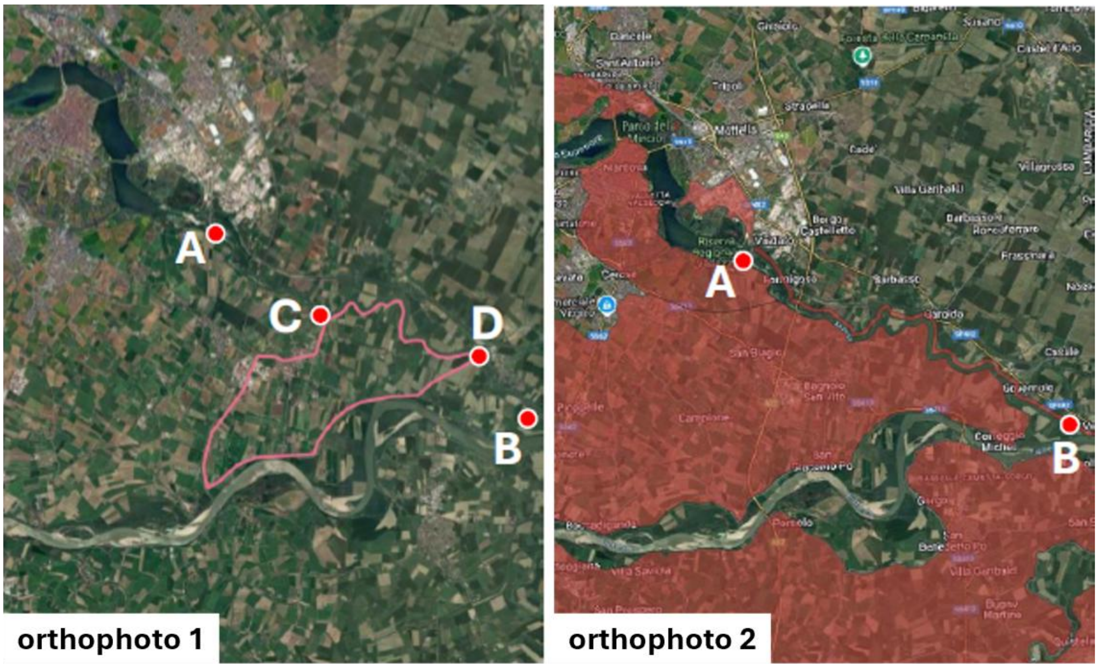

Figure 5. Orthophoto 1: initial delineation of the area of influence (red outline), corresponding to the most critical levee segment (C–D), later extended to a broader river reach (A–B) due to structural homogeneity and recurring failures. Orthophoto 2: flood-prone area for catastrophic flood events with a 500-year return period (PAI hazard map, red overlay).

5.2.4 Application of procedure 2

Step 1 – Project quality and alignment with flood risk mitigation objectives

The first step mirrors the methodology applied in Procedure 1 and serves as a preliminary screening to verify the adequacy and completeness of the available technical documentation and to assess the alignment of the proposed intervention with the flood risk mitigation objectives defined by regional and basin-level planning instruments.

In the case of the Mincio River project, the intervention is still at a preliminary stage and has not yet reached the formal design phase. The only available documentation is the already quoted DOCFAP, prepared by the competent river authority (AIPO). As defined by Legislative Decree 36/2023, the DOCFAP is a preliminary document that outlines the rationale for intervention, identifies the main technical alternatives, and provides a first-order estimate of costs and implementation timelines. In this case, it consists of a single technical report describing the current condition of the levee system, highlighting recurring failure mechanisms, and identifying the segments requiring structural restoration (see previous section). Although the level of detail is limited compared to subsequent design stages, the documentation complies with regulatory requirements and provides sufficient information to support a preliminary technical evaluation. It also outlines a clear strategy for restoring the hydraulic functionality of existing levees and reducing local flood risk.

From a strategic standpoint, the project is consistent with both regional and basin-level planning priorities. According to the summary report prepared by the Lombardy Region (Regione Lombardia - Direzione Generale Territorio e sistemi verdi, 2025), the intervention targets levees that form the hydraulic protection system against 200-year return period flood events, as defined in the Po River Basin Authority's hazard mapping (PAI). Furthermore, the project contributes to the implementation of a specific measure included in the FRMP of the Po River Basin District, which promotes the regular maintenance and restoration of existing levee systems.

Based on this verification, the project is classified as admitted and proceeds to Step 2 of the evaluation procedure.

Step 2 – Feasibility of the intervention

Step 2 evaluates the feasibility of the proposed maintenance intervention through a qualitative assessment of three key attributes. These include: (i) compatibility with existing territorial constraints and interferences; (ii) consistency with local and regional planning instruments; and (iii) the presence of potential social or administrative conflicts. Two attributes used in Procedure 1 (maintenance guarantees and robustness of the intervention) are excluded here, as they are not applicable to maintenance projects, which typically do not involve the construction of new hydraulic works.

The following section presents the attribute-by-attribute application of the methodology to the Mincio River case, based on the analysis of the only available technical document (DOCFAP) and the corresponding summary report issued by the Lombardy Region (Regione Lombardia - Direzione Generale Territorio e sistemi verdi, 2025).

Attribute 1: Compatibility with existing constraints and interferences

The intervention is located in a predominantly rural and agricultural setting. Although it lies within the broader territory of the Mincio Regional Park, it does not intersect with core naturalistic or landscape conservation zones that would restrict implementation. The planned maintenance and restoration works are compatible with the surrounding environmental and landscape features, do not affect areas of historical or archaeological value, and are limited to localized levee segments showing signs of erosion and instability. No significant infrastructural interferences or utility conflicts are identified, and any minor interactions with service roads or irrigation systems are considered manageable during the executive design phase. The intervention footprint does not include contaminated sites or critical environmental constraints.

Evaluation: The project is compatible with existing territorial and infrastructural constraints and does not involve substantial land transformation or critical interferences.

Classification: "Yes".

Attribute 2: Consistency with local and regional planning instruments

The intervention consists of extraordinary maintenance works aimed at restoring the hydraulic efficiency and structural stability of existing levees, without altering the configuration or function of the river corridor or adjacent areas. Since no permanent land modifications are expected, the project is not subject to prior landscape authorisation. Although a formal verification of consistency with local and regional planning instruments has not yet been carried out, the nature and limited spatial impact of the intervention suggest that it is unlikely to interfere with local zoning or land use regulations. Specific verifications will be conducted during the feasibility and executive design phases, including landscape compatibility assessments where required, but no substantial conflicts are anticipated.

Evaluation: Despite the absence of an explicit compatibility assessment, the limited and restorative nature of the intervention supports a positive evaluation under this attribute.

Classification: "Yes".

Attribute 3: Presence of conflicting elements

The intervention does not require land expropriations, as the levees fall within the hydraulic domain managed by AIPO. No evidence of social or institutional opposition has emerged. The project addresses safety concerns related to the potential failure of critical flood defences and is supported by both technical assessments and local authorities. As a maintenance initiative, it does not alter surrounding territory or produce redistributive effects that might generate conflict.

Evaluation: No relevant conflicts are identified. The project enjoys institutional support and addresses recognized hydraulic safety needs.

Classification: “0”.

Outcome of Step 2

Based on the assessment of the three attributes, the project is considered fully feasible and eligible to proceed to Step 3 without additional requirements, as summarized in Table 7.

Table 7. Qualitative classification of the feasibility of the Mincio river project, based on the three attributes defined in Step 2 of Procedure 2.

#	Attribute	Indicator type	Qualitative classification
1	Compatibility with existing constraints and interferences	Project- and context-specific	**Yes** (no constraints)
2	Consistency with local and regional planning instruments	Project- and context-specific	**Yes** (fully consistent)
3	Presence of conflicting elements	Project-specific	**0** (no issues identified)

Step 3 – Urgency and cost of the intervention

Step 3 of Procedure 2 provides a prioritisation criterion for maintenance interventions based on the urgency associated with the degradation of existing hydraulic works and the expected implementation cost. Urgency is assed based on two main attributes: the severity of current damage and its rate of progression over time. However, as this framework is still under development, specific indicators and metrics for these attributes have yet to be formalised. In this context, a qualitative application based on available documentation is proposed.

According to the DOCFAP, the need for intervention is justified by recurrent signs of levee degradation, including slope instability and toe erosion, which compromise the hydraulic functionality of the system. These issues, although not yet affecting the entire reach, are visible at several points and have become increasingly frequent. The degradation is attributed to morphological conditions (e.g., excessive levee slope), adverse weather events, and prolonged lack of maintenance. While no quantitative structural assessment is available, the recurrence and progressive nature of damage support the classification of the intervention as urgent. The intervention is defined as extraordinary maintenance, aimed at restoring the structural integrity and flood retention capacity of levees designed for events with a 200-year return period. Though no new hydraulic works are introduced, the proposed actions is essential to preserve the existing protection system and prevent future failures.

To complement the urgency assessment, the Lombardy Region has estimated the exposure of assets and population in the event of levee failure or overtopping, using the GIS tools developed within the

MOVIDA/NATFIM tool. These results, summarized in Table 8, refer to the area of influence delineated by AIPO. The intervention is not associated with any of the three bonus priority conditions defined in the procedure: no risk to human life (e.g., due to flash floods or debris flows), no essential healthcare facilities, and no Seveso-classified industrial sites are present in the area.

Table 8. Estimated exposure of population and assets within the area of influence of the proposed intervention. The values represent the potential damage in the event of levee failure or overtopping, based on spatial analysis conducted using the GIS tools developed within the MOVIDA/NATFIM tool.

Exposed assets	Estimate	Notes
Population [inhabitants]	2,438	No risk to human life expected
Strategic buildings [units]	2	No hospitals or other essential healthcare facilities
Na-tech sites [units]	8	No Seveso-classified establishments
Road infrastructure [km]	63	
Railway infrastructure [km]	0	
Commerce & Industry [M€]	169	
Residential building [M€]	497	
Crops [M€]	4	
Livestock [livestock heads]	7192	
Cultural heritage [units]	1	

Regarding implementation cost (€ 3,500,000), the estimate appears proportionate to the scale of intervention and consistent with comparable projects, especially considering the extent of protected assets and territory.

Given the current methodological stage, pending the final definition of indicators and cost/urgency classes, no merit class can yet be assigned. The project would ultimately be positioned within the prioritisation matrix for maintenance works as illustrated in Procedure 2.

Step 4 – Environmental and social impacts

The final step of Procedure 2 involves a simplified evaluation of the potential environmental and social impacts associated with maintenance interventions. Unlike Procedure 1, this step does not rely on a detailed attribute-based assessment, but rather considers two macro-attributes, environmental and social impacts, evaluated qualitatively as positive (+), neutral (0), or negative (−).

In the case of the Mincio River project, the planned intervention is limited to structural maintenance and restoration of existing levees, without the introduction of new hydraulic infrastructure or substantial land transformation. Consequently, no significant environmental or social impacts are anticipated. As specified in the summary report prepared by the Lombardy Region (Regione Lombardia - Direzione Generale Territorio e sistemi verdi, 2025), the intervention does not qualify as an integrated or "win-win" project and does not generate co-benefits beyond its primary flood protection function. As a result, no adjustment to merit class is applied to the project.

5.2.5 Evaluation outcome and final consideration

While no specific merit class could be assigned under Step 3 due to the ongoing development of the evaluation metrics, the strategic importance of the Mincio River intervention is clearly recognised by regional authorities. The project was prioritised and included in the 2025 MASE programme following a formal request by AIPO, the competent river authority, and a field inspection by regional technicians. The decision to fund the intervention was based on visible evidence of levee degradation, the risk of further damage in the short term, and the potential consequences of levee failure in terms of exposed population and assets, assessed using GIS-based modelling tools. Although the technical documentation is still at a preliminary stage (DOCFAP), the project meets regulatory requirements and aligns with regional and basin-level flood mitigation objectives. It is therefore considered eligible for funding and planning support.

6. References

Asafu-Adjaye, J.: ENVIRONMENTAL ECONOMICS FOR NON-ECONOMISTS: Techniques and Policies for Sustainable Development, 2nd ed., World Scientific Publishing Co. Pte. Ltd., https://doi.org/10.1142/5727, 2005.

Bubeck, P., Aerts, J. C. J. H., de Moel, H., and Kreibich, H.: Preface: Flood-risk analysis and integrated management, Natural Hazards and Earth System Sciences, 16, 1005–1010, https://doi.org/10.5194/nhess-16-1005-2016, 2016.

Bubeck, P., Kreibich, H., Penning-Rowsell, E. C., Botzen, W. J. W., de Moel, H., and Klijn, F.: Explaining differences in flood management approaches in Europe and in the USA – a comparative analysis, J Flood Risk Manag, 10, 436–445, https://doi.org/10.1111/jfr3.12151, 2017.

de Brito, M. M. and Evers, M.: Multi-criteria decision-making for flood risk management: a survey of the current state of the art, Natural Hazards and Earth System Sciences, 16, 1019–1033, https://doi.org/10.5194/nhess-16-1019-2016, 2016.

European Commission (EC) – Directorate General for Environment: Current practice in flood risk management in the European Union, Brussels, https://doi.org/10.2779/235272, 2021.

European Commission (EC) – Directorate General for Research and Innovation: Evaluating the Impact of Nature-based Solutions: A Handbook for Practitioners, Brussels, 2021.

Figueira, J. and Roy, B.: Determining the weights of criteria in the ELECTRE type methods with a revised Simos' procedure, Eur J Oper Res, 139, 317–326, https://doi.org/10.1016/S0377-2217(01)00370-8, 2002.

Figueira, J., Greco, S., and Ehrgott, M.: Multiple Criteria Decision Analysis: State of the Art Surveys, Springer New York, New York, NY, https://doi.org/10.1007/b100605, 2005.

Gallazzi, A. (2025): A multi-criteria decision framework for flood risk mitigation planning in the lombardy region, PhD thesis, Politecnico di Milano.

Hobbs, B. F. and Meier, P. M.: Multicriteria methods for resource planning: an experimental comparison, IEEE Transactions on Power Systems, 9, 1811–1817, https://doi.org/10.1109/59.331435, 1994.

Klijn, F., Lang, M., and Bakonyi, P.: Integrated flood risk management: Novel approaches for an uncertain future, Water Secur, 17, 100125, https://doi.org/10.1016/j.wasec.2022.100125, 2022.

Molinari, D., Dewals, B., Haun, S., El Kadi Abderrezzak, K., and Vitthal Kale, R.: Integrated flood risk management as a tool to achieve UN Sustainable Development Goals, Hydrolink 1, 2023.

Paruccini, M.: Applying multiple criteria aid for decision to environmental management (ENVIRONMENTAL MANAGEMENT Vol. 3), edited by: Paruccini, M., Kluwer Academic Publishers

World Bank and European Commission: From Data to Decisions: Tools for Making Smart Investments in Prevention and Preparedness in Europe, Washington, DC, 2024.