RESCUE ME
RESILIENT CULTURAL LANDSCAPES

D1.5 DECISION MAKING FOR PATHWAYS BLUEPRINTS.

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Summary

The **RescueME project** is dedicated to safeguarding Europe's Coastal Cultural Landscapes (CCLs), dynamic areas with cultural significance shaped by the interplay of human and natural forces over time, against the threats of climate change, natural hazards, and other stressors. By emphasizing the value of historical understanding in shaping future resilience, RescueME seeks to co-create adaptive strategies that are both innovative and rooted in local contexts. This work is being tested and refined in five R-Labs across Europe: Crete (Greece), Neuwerk (Germany), Cinque Terre (Italy), Valencia (Spain), and Zadar (Croatia). These labs ensure that solutions are tailored to the unique environmental, cultural, and technological conditions of each site, prioritizing end-user input and practical applicability.

Central to its mission is the Resilient Heritage Landscape approach, that was developed in a first phase of the project and which bridges cultural heritage, ecological systems, and community needs through a socioecological lens. This documents reports another key component of the project developed in Task 1.4: the methodology to support decision-making for resilience CCLs. This methodology integrates prior project outputs, such as risk assessment models, resilience indicators, and the meta-repository of over 1,000 climate adaptation and disaster risk management (DRM) measures created in Task 2.1. The repository has been organized using the Intergovernmental Panel on Climate Change (IPCC) approach.

The methodology adopts an incremetal approach offering different levels of decision making with different levels of inforamtion requirements. In the most detailed level, it links these measures with the predictive impact modeling created in Task 1.3, allowing users to evaluate the potential outcomes of different resilience strategies. This tiered approach supports the creation of customizable "transformational pathway blueprints", which can be optimized for each R-Lab's unique cultural, ecological, and socio-economic context. These blueprints are designed to evolve through stakeholder collaboration and innovation, ensuring they remain responsive to changing conditions.

The methodology will be integrated into the Incremental Spatial Decision Support System (ISDSS), a tool that empowers users to simulate, refine, and implement resilience strategies dynamically (currently under development in T3.4 and T3.5). By combining data-driven modeling and community engagement, RescueME provides a scalable, adaptive approach to protecting Europe's CCLs. Ultimately, the project underscores the importance of integrating heritage, ecology, and community in building resilience.

List of acronyms

AHP	Analytic Hierarchy Process
BCR	Benefit-Cost Ratio
CBA	Cost Benefit Analysis
CCL	Coastal Cultural Landscape
CL	Cultural Landscape
DAPP	Dynamic Adaptive Policy Pathways
DRM	Disaster Risk Management
DSS	Decision Support System
ES	Ecosystem Services
HV	Heritage Values
IPCC	Intergovernmental Panel on Climate Change
ISDSS	Incremental Spatial Decision Making
KE	Key Elements
MEMI	Munich Energy-balance Model for Individuals
NBS	Nature-based solutions
NLP	Natural Language Processing
PET	Physiologically Equivalent Temperature
R-Lab	Resilience Labs
SETS	Socio-ecological-technical systems
WP	Work Package

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1 INTRODUCTION

1.1 Aims and Objectives

Cultural Landscapes are landscapes whose character is the result of the historic action and interaction of natural and human factors with significant cultural significance for the communities that live in them. RescueME project is developing a Resilient Heritage Landscape approach that relies on the belief that the past (and our understanding of it) must have a valuable role in shaping the future, linking culture with nature and community from a complex socioecological perspective. The objective is to develop, test, and demonstrate the effectiveness of an Actionable Framework based on this approach, complemented by data, models, methods, and tools to protect European cultural heritage and landscapes from climate change and other stressors.

RescueME is building on previous projects and defines solutions as practices, products, processes, actions, and initiatives for innovative, cooperative, and applicable resilience strategies connected with our culture and environment to address climate change, natural hazards, and societal and other crises. Everything is being co-created in 5 R-Labscapes (R-Labs): Psiloritis in Crete (Greece), the Island of Neuwerk in Hamburg (Germany), Portovenere, Cinque Terre & the Islands (Italy), the historical irrigation system at l'Horta de València (Spain) and the defensive system of Zadar (Croatia). This approach ensures that local conditions, available technologies, and the needs of end-users are considered in the development and implementation of resilience strategies.

This document describes the work undertaken as part of task 1.4, which aimed to develop a comprehensive **methodology for decision making to implement strategies that enhance resilience in Coastal Cultural Landscapes (CCLs) in order to build initial blueprints for a Transformational Pathways:** dynamic, iterative frameworks that could guide the evolution of adaptive strategies over time. These blueprints could serve as foundational roadmaps, combining scientific data, stakeholder input, and predictive modelling to identify, prioritize, and implement actions that address climate risks while preserving cultural and ecological values**.** The methodology has been built using previously generate results (mainly the Actionable Historic Landscapes Framework, the European and local level assessment and the meta-repository with resilience solutions) from the project, being a formal wrapping for the work package (WP) that has been creating the methodological foundations for resilience and risk assessment in the project. The level of local information needed for this decision-making has been classified in different levels of decision making, linking the required information with the accuracy of the results, implementing an incremental approach. As mentioned before, one of the project key outputs is the meta-repository, with more than 1000 characterised resilience and Disaster Risk Management (DRM) measures. This task had the objective of linking these measures with the predictive impact modelling developed in task

1.3 to support the decision making at the more detailed level. The meta-repository in its final version has different degrees of detail and generalisation. To ensure coherence and strategic alignment, these measures were organized using the classification structure proposed by the Intergovernmental Panel on Climate Change (IPCC). This approach not only standardizes the repository but also aligns with potential "adaptation narratives," facilitating strategic clustering and selection of measures tailored to specific contexts. The logic created in this task will allow the end-user to produce initial blueprints for a Transformational Pathway that can be optimised to the local context based on their context, innovation capacity/potential and their needs and expectations. In the context of the RescueME project, adaptation narratives are not rigid, prescriptive frameworks but inspiring themes that guide the creative selection and grouping of resilience measures. While they draw from the Intergovernmental Panel on Climate Change (IPCC)'s global adaptation classifications, their role in RescueME is to facilitate flexible, context-driven decision-making by offering a range of "lenses" through which stakeholders can approach complex challenges. These narratives enable users to cluster solutions based on specific priorities, such as responding to a single hazard, budget constraints (e.g., selecting cost-effective, low-tech solutions for resource-limited communities), reinforcing a key element or using Nature-based solutions (NBS) only. By providing these thematic adaptation narratives allow end-users to tailor resilience strategies to their unique socioecological and cultural contexts.

The implementation of this methodology in the Incremental Spatial Decision Support System (ISDSS) will facilitate the use of this methodology and will offer planning capabilities to the end-user.

1.2 Relation with other project activities

The main objective of the decision making methodology described in this deliverable is to integrate the informartion regarding CCLs at different levels with the information about the possible strategies and solutions from the meta-repository. Therefore, this task is inherently interconnected with other project components, as detailed below, to ensure a cohesive and comprehensive approach:

- Data about CLs will be provided mainly by the ATLAS of European coastal landscapes (**Task 1.2**) and the predictive impact assessment models (**Task 1.3**): the ATLAS offers a regional perspective for Coastal Cultural Landscapes (CCLs) at NUTS3 level and the predictive models provide a more detailed local assessment for our five R-Labs.
- Data about possible solutions is fed by the meta-repository built in **Task 2.1** with more than 1000 characterized solutions.
- The methodology for decision making has been based on the foundational work done in **Task 1.1** where the Actionable Landscape Framework was established. This

framework conceptualizes Cultural Landscapes as socio-ecological-technical systems (SETS), structured around five key capitals: natural, built, social, human, and financial and has guided the overall development of this methodology.

- The resultant methodology will be implemented in the Incremental Spatial Decision Support System (ISDSS) in **Task 3.4**
- The methodology, also, has been designed to be compatible with the Serious Game (Task 2.4 and Task 4.3)

Figure 1: Relation of the task with other project activities

1.3 Report Structure

The report is organized into seven main sections, each addressing a critical component of the RescueME project's Task 1.4, which focuses on developing a decision-making methodology for resilience in Coastal Cultural Landscapes (CCLs). Below is a breakdown of the structure:

- The **Introduction** sets the stage by outlining the RescueME project's mission to protect Europe's CCL. It introduces Task 1.4's goal: developing a decision-making methodology for CCLs that builds Transformational Pathways, flexible, context-driven blueprints for resilience.

- **Decision-Making in CCLs** explores the theoretical and practical foundations of resilience planning.
- **Clustering Solutions from the Meta-Repository** explains how the project's 1,000+ resilience and DRM measures has been organized.
- **Impact of the Measures** assesses how solutions affect key landscape elements and specific hazards culminating in a curated database of solution for decision-making.
- **Characterization and Data from R-Labs** integrates insights from the five R-Labs (Crete, Neuwerk, Cinque Terre, Valencia and Zadar).

  Decision-Making Methodology introduces the Incremental Decision-Making Approach, which includes three levels.
- **Conclusion & Future Research** summarizes the project's achievements identifies future steps.

2 DECISION MAKING IN COASTAL CULTURAL LANDSCAPES

The decisions required to enhance resilience in Coastal Cultural Landscapes (CCLs) are multifaceted, spanning the selection of resilience measures and the allocation of resources. These decisions must navigate a delicate balance between preserving cultural heritage, protecting ecological integrity, and addressing community needs, a challenge compounded by the interconnected nature of these systems (e.g. a solution that mitigates flood risks might inadvertently disrupt a historic irrigation system). Central to these decisions are four interrelated aspects:

- Hazard-Specific Risks: CCLs face a range of climate and environmental threats, from coastal flooding to heatwaves and sea-level rise. Decisions must prioritize interventions tailored to these risks.
- Cultural and Ecological Values: CCLs are defined by their intangible and tangible heritage, from historic architecture to traditional land-use practices, and their ecological functions. Resilience strategies must avoid compromising these values.
- Stakeholder Priorities: Decisions must reflect the diverse interests and capacities of stakeholders.
- Economic and Institutional Constraints: Financial and policy realities shape what is feasible. Budget limitations might restrict the scale of interventions, pushing decision-makers toward cost-effective, scalable solutions like community-led monitoring systems or adaptive reuse of existing structures. Institutional frameworks, such as heritage protection laws or EU funding eligibility criteria, can also influence choices, requiring alignment between technical solutions and regulatory compliance.

These aspects are not mutually exclusive but interdependent, requiring decisions that are context-sensitive and adaptive. The RescueME project builds on the Actionable Resilient Historic Landscape Framework (developp in Task 1.1), a foundational tool for decision-making in CCLs. This framework integrates a database of indicators tailored to European Coastal Cultural Landscapes (CCLs), designed to address their unique socioecological and cultural complexities. To adapt the CWA 17727:2022 standard—originally developed for urban historic areas, the project modified its methodology to reflect the interconnectedness of heritage and ecological systems in cultural landscapes. This adaptation recognizes that CCLs are not merely "heritage landscapes" (static, protected sites) but dynamic systems shaped by historical, natural, and human interactions. The framework aligns with the concept of Cultural Ecosystem Services, linking tangible and intangible heritage values to their contributions to quality of life. By mapping landscape attributes to natural, social, financial, human, and built capitals, it emphasizes resilience through adaptive capacity (responding to change), transformative capacity (restructuring systems), and coping capacity (managing immediate stressors). A GLOCAL strategy (global-local integration) ensures the framework remains flexible for both broad European typologies and site-specific challenges in the five R-Labs. Central to this approach is the integration of hazard, stressor, and climate scenario data, enabling risk assessments that inform decisions under uncertainty.

Following this framework development, the project advanced through a top-down and bottom-up baseline assessment aligned with the GLOCAL strategy. This process began with a European-level risk and community capitals assessment for NUTS3 coastal regions, followed by local-scale risk modeling tailored to the R-Labs. Simultaneously, a meta-repository of over 1,000 resilience solutions was compiled, organized using IPCC-aligned adaptation narratives (e.g., hazard-focused, budget-conscious or nature-based solutions).

This section synthesizes existing literature on solution evaluation, solution clustering, and decision-making frameworks, tailored to the complexity of CCLs. These elements are critical for systematically assessing, categorizing, and implementing interventions in socioecological systems where cultural and natural values are deeply intertwined.

2.1 Impact Assessment Of Solutions

The evaluation of solution impacts is central to decision making for resilience planning, particularly in dynamic environments like CCLs. Experts emphasize the need for multi-criteria frameworks that quantify both direct and indirect effects of interventions, including ecological, economic, social, and cultural dimensions [1]. RescueME defines solutions as practices, products, processes, actions, and initiatives for innovative, cooperative, and applicable resilience strategies connected with our culture and environment to address climate change, natural hazards, and societal and other crises. Key approaches could include cost-benefit analysis (CBA), which is widely used to compare financial and non-financial outcomes but often criticized for oversimplifying complex systems by reducing them to monetary terms, potentially overlooking non-economic factors such as impacts to cultural heritage, social benefits or ecological integrity[2]. Resilience indicators, such as adaptive capacity, redundancy, and system flexibility, are increasingly integrated to assess long-term sustainability, offering measurable metrics that reflect the ability of systems to absorb shocks and adapt over time[3]. Predictive modeling tools, like agent-based modeling or scenario analysis, further enhance planning by forecasting cascading impacts of solutions under varying climate and socio-economic conditions, enabling proactive adaptation strategies. However, literature highlights challenges in harmonizing qualitative (e.g., cultural heritage) and quantitative (e.g., economic) metrics, as well as the need for context-specific impact thresholds to avoid generic, one-size-fits-all solutions that may fail to address local complexities[4], [5] [6] These challenges underscore the importance of interdisciplinary collaboration and iterative feedback loops to refine frameworks and ensure they align with the unique needs of CCL systems. Given the data limitations regarding impacts of solutions in the resilence in CCLs, the assessment of solution impacts in RescueME has relied on synthesizing findings from past research and incorporating expert judgment.

2.2 Clustering of Solutions

Clustering of solutions is essential for managing complexity and identifying synergies among interventions in dynamic systems like CCLs. Existing studies propose taxonomy-based frameworks to group solutions by functional purpose, such as structural measures (e.g., seawalls), ecological interventions (e.g., mangrove restoration), or socio-institutional approaches (e.g., community-based governance), which align with the IPCC's emphasis on integrating diverse adaptation strategies[7]. Additionally, solutions are often categorized by scale and scope (local, regional, or national) to reflect governance structures and resource allocation needs, a framework highlighted in climate-resilient development literature[8]. The IPCC further advocates for clustering solutions under "adaptation narratives," such as protection, transformation, or retreat, to align interventions with strategic priorities and long-term resilience goals[9]. A narrative-based approach bridges scientific and local knowledge, empowering communities to co-create climate adaptation strategies rooted in their cultural identities and lived experiences[10]. As mentioned before, in the context of the RescueME project, adaptation narratives are adopted to helps users to tailor resilience strategies to their unique cultural, ecological, and socio-economic contexts.

Building on the IPCC's approach, the RescueME project adopts the concept of clustering solutions, since this approach not only organizes solutions into coherent categories but also aligns them with the broader goals of climate adaptation, enabling stakeholders to identify, prioritize, and implement strategies that are context specific. The clustering includes three main categories: structural and physical options, social adaptation measures, and institutional measures. By reflecting unique attributes, benefits, and challenges, each category also corresponds to specific competencies, such as technical expertise, social engagement, or institutional capacity, that directly support their practical application and implementation:

- **Structural and physical options** are defined by discrete, tangible outputs with clearly defined spatial, temporal, and functional boundaries. These include infrastructure upgrades such as sea walls and flood barriers, eco-engineering solutions like mangrove restoration and living shorelines, and built-environment modifications such as green roofs or permeable pavements. The advantages of these measures lie in their measurable impact, outcomes like reduced flood risk or improved water retention can be quantified using standardized metrics. They also offer immediate applicability, addressing urgent risks such as coastal erosion or extreme weather events, and are well-suited for integration into spatial decision support systems and simulation models. However, these solutions often overlook the cultural and social dimensions of resilience, potentially leading to technically sound but socially or culturally misaligned strategies.

- **Social adaptation measures** emphasize community-based adaptation and locally driven strategies that prioritize participation, empowerment, and knowledge co-creation. These approaches operate on a learning-by-doing, bottom-up paradigm, integrating social, technological, and institutional processes to foster adaptive capacity. Examples include traditional water management systems, community-led disaster response networks, and participatory mapping initiatives. The key strengths of this category include cultural relevance, as solutions align with local values, histories, and identities, that are critical in CCLs. They also build long-term resilience by strengthening social capital and adaptive capacity through trust, collaboration, and shared ownership. Additionally, they prioritize equity and inclusivity by centering marginalized groups, such as Indigenous communities or vulnerable populations, in decision-making. Challenges include the difficulty of quantifying intangible outcomes, such as enhanced community cohesion or increased awareness, and the resource intensity required for sustained engagement and capacity-building efforts.
- **Institutional measures** encompass policy, governance, and regulatory frameworks that shape the enabling environment for resilience. These include legal and regulatory reforms (e.g., land-use planning laws, building codes), institutional coordination (e.g., multi-stakeholder platforms, transboundary cooperation), and funding mechanisms (e.g., subsidies for climate-resilient infrastructure, insurance schemes). The advantages of institutional adaptation lie in its ability to address root causes of vulnerability by rethinking governance structures and power dynamics. It also offers scalability, as policies and frameworks can be applied across regions or sectors and provides legitimacy through accountability and long-term commitment. However, implementation can be slow due to bureaucratic processes and political resistance, and rigid institutional frameworks may struggle to adapt to rapidly evolving climate risks without iterative feedback.

2.3 Decision-Making Frameworks

Decision-making in resilience planning requires balancing scientific evidence, stakeholder values, and adaptive capacity. A critical component of this process, as confirmed with our R-labs, is optimizing the selection of a portfolio of solution under budget constraints, which ensures that limited resources are allocated to maximize resilience outcomes. Key frameworks for decision making could include:

- **Participatory Decision-Making**: Emphasizes stakeholder engagement to co-create strategies, ensuring inclusivity and legitimacy while integrating local knowledge into optimization criteria[11]. In RescueME this approach is adressed by the Serious

Game that is designed to be compatible with the approach proposed in this document.

- **Multi-Criteria Decision Analysis (MCDA):** A structured approach to weigh trade-offs among competing objectives (e.g., cost vs. cultural preservation) using weighted scoring systems. When combined with optimization algorithms, MCDA can prioritize solutions that align with budget limits while maximizing multi-dimensional benefits [12]. The ISDSS will offer a MCDA option to select the solutions from the meta-repository. This method has been used extensively for pathways design. [13]
- **Adaptive Management:** Iterative processes that refine decisions as new data or conditions emerge, particularly useful in uncertain environments. Optimization techniques, such as dynamic programming or robust optimization, enhance adaptive management by simulating how solution clusters perform under varying budget and climate scenarios[14]
- **Optimization Techniques**: Advanced methods like linear programming, genetic algorithms, and heuristic search are increasingly applied to select solution groups that maximize resilience metrics within financial thresholds [15], [16]

Literature underscores the importance of transparency and flexibility in decision-making tools, especially when addressing the unique vulnerabilities of CLs [17] . However, gaps persist in integrating local knowledge with technical models and in addressing power imbalances in stakeholder participation[18]. For instance, optimization models may prioritize technically optimal solutions but risk overlooking socio-cultural values unless stakeholder preferences are explicitly embedded in the criteria. Similarly, budget constraints can limit the scope of participatory processes, necessitating hybrid approaches that balance computational rigor with community input.

Dynamic Adaptive Policy Pathways (DAPP) is a decision-support methodology designed to address complex, long-term planning challenges in systems characterized by deep uncertainty, interdependencies, and nonlinear dynamics like CCLs. It emphasizes the development of robust and adaptive strategies through iterative, scenario-based exploration of decision sequences, ensuring resilience to evolving conditions and emerging risks. DAPP is particularly suited for coupled physical-technical-human systems, such as water management, energy grids, or urban planning, where outcomes depend on interactions between natural processes, infrastructure, and human behavior. The approach is tailored for long-term planning horizons (e.g., 20–100 years) by accounting for uncertainties in climate change, socio-economic shifts, and technological evolution. Haasnoot et al. (2013) highlight that DAPP is "a structured approach to support decision-making under deep uncertainty by identifying robust and adaptive pathways in complex systems"[19]. The methodology generates a portfolio of plausible actions, combining near-term (low-cost, reversible measures like policy reforms or incremental infrastructure upgrades) and long-term options (high-investment strategies such as large-scale infrastructure or systemic policy shifts).

This portfolio is designed to remain effective under a range of plausible scenarios, such as climate projections or demographic trends.

In this project, this approach has been choosen to link the selection strategy with its monitoring, as at its core, DAPP employs an adaptation pathways framework to explore sequences of decisions over time. This involves identifying trigger points—thresholds for initiating actions based on observed changes—and mapping adaptive pathways as chains of decisions that remain viable under multiple future scenarios. For example, in flood risk management, DAPP might outline a pathway starting with early warning systems, followed by dike reinforcement, and eventually land-use changes if sea-level rise accelerates. Kwakkel et al. (2016) emphasize that pathways "capture the dynamic nature of adaptation by linking short-term actions to long-term strategies"[19]. Haasnoot et al. (2018) argue that a diverse portfolio of actions ensures resilience by allowing adjustments as new information emerges.[10]

A critical component of DAPP is the use of system-specific indicators (e.g., sea-level rise, population growth rates) to monitor changes and trigger adaptive actions. Threshold values are defined for these indicators to determine when a pathway needs to be adjusted. For instance, a 10 cm rise in sea level might prompt a review of flood defenses. Thresholds can provide unbiased basis for decision-making with uncertainty[19]. The methodological workflow of DAPP typically involves defining objectives and system boundaries, identifying uncertainties and scenarios, developing adaptive pathways, evaluating robustness and trade-offs, and implementing and monitoring actions (it is worth noting, that in the context of RescueME, the monitoring approach is adressed in task 1.5 and its related deliveralbe D1.6.)

3 CLUSTERING SOLUTIONS FROM META-REPOSITORY DATABASE

The RescueME resilience meta-repository was built in task 2.1, and it is described in detail in D2.1 [20]. The meta-repository is a catalogue that collects knowledge available from previous research projects (such as ARCH[1], SHELTER[2] and RURITAGE[3]) and local practices to offer an integrated searchable data base of solutions characterized by their effectivity in improving the resilience of CLs.

The meta-repository collects three typologies of solutions, which each address one or more dimensions of resilience:

- **Policy Recommendations (PR)** are solutions presented as a set of suggestions or guidance regarding future processes of changes (i.e., environmental, technical, social, institutional, behavioural).
- **Lesson Learnt (LL)** are solutions addressing one or more dimensions of resilience, proved, validated and potentially replicable regardless of the place of design and/or implementation.
- **Place-based Solutions (PBS)** are solutions addressing one or more dimensions of resilience presented in relation to its specific implementation location and its responsible body of management and administration. They are further categorised into five solution domains
- **Heritage based solutions** include practices, products, actions, and initiatives that have been proven as valid for tangible and intangible heritage valorisation in CLs.
- In the context of the RescueME project, **nature-based solutions** (NBS) encompass a variety of practices, products, actions, and initiatives aimed at protecting, conserving, restoring, and managing both natural and modified ecosystems.
- **Adaptive governance tools** include rules, norms, mechanisms, policies, interactions and actions that facilitate the desired state of social-ecological systems at a given time period. They promote polycentrism, collaboration, self-organization and innovation in reaction to different evolving situations.
- The **financing and business model strategies** domain includes practices, actions, and initiatives presented in relation to economic, financial and business models for incentivizing and leveraging regenerative capital investments.

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[1] Advancing Resilience of Historic Areas against Climate-related and other Hazards. https://www.heritageresearch-hub.eu/ (last accessed 22nd July 2025)
[2] Sustainable Historic Environments hoListic reconstruction through Technological Enhancement and community-based Resilience. https://shelter-project.com/ (last accessed 22nd July 2025)
[3] Heritage for Rural Regeneration. https://www.ruritage.eu/ (last accessed 22nd July 2025)

- The **Creative sectors and industries strategies** domain includes practices, actions, and initiatives, which integrate arts, culture and creativity in their design, development, and implementation.

To systematize the collection, each solution was linked with descriptive characteristics. These include the title, description, references, the solution typology and domain, and capitals and key elements (as explained in D1.1 "Actionable Resilient Historic Landscape Framework" [21]), as well as hazards the solution addresses. Other characteristics such as the location, the indicative costs, involved stakeholders, and the implementation time, were collected wherever applicable.

Further, a validation phase was foreseen to check the solutions collected. The main objectives of the validation were: i) to check the relevance of the solutions and strategies collected for cultural landscapes; ii) to find possible repetition and reflect on the potential grouping of similar solutions; iii) to insert data that were not yet available during the previous collection. A validation protocol has been created, and the validation process was carried out accordingly. After validation, the total number of solutions included in the meta-repository is 1000. The following figure further describes the main characteristics of the solutions included according to capitals and key elements defined by RescueME (Figure 2).

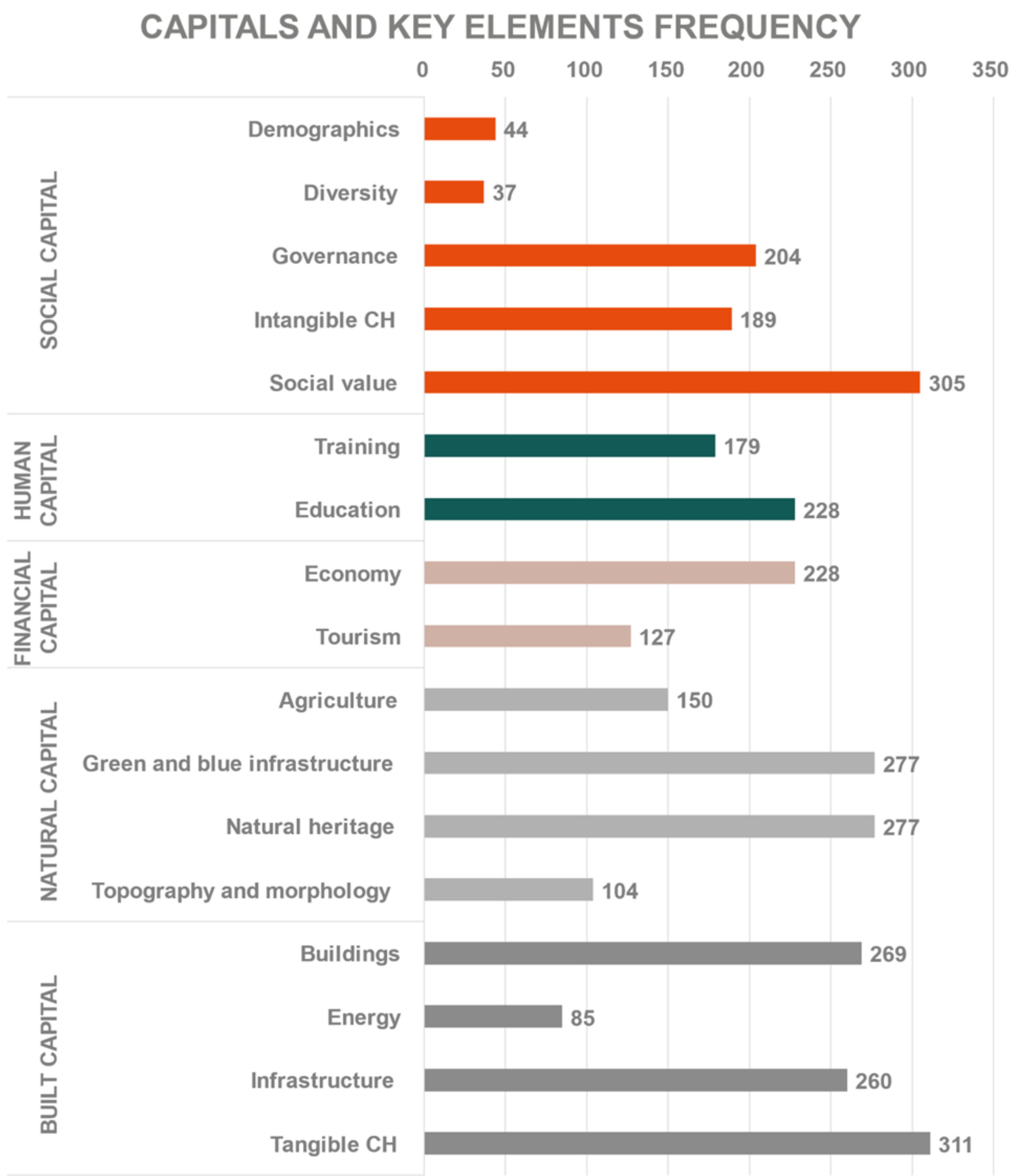

Figure 2: Solutions grouped by capitals and key elements as defined in RescueME.

As a result, the final meta-repository functions as a semi-structured, text-based repository containing over 1,000 resilience solutions, organized through a hierarchical classification system. While the repository includes free-text metadata (e.g., descriptive summaries) across multiple categories, its irregular schema and unstructured format pose significant technical challenges for integration into the ISDSS. Although the repository is a very valuable project output, offering rich descriptive content for users, its current structure limits its utility for automated optimization processes.

Therefore, to improve the usability of this repository and facilitate the calculation of the impact of resilience solutions, the project adopted a clustering framework based on the IPCC's classification as explained in section 2.2. By clustering solutions into these three categories, the project leverages IPCC adaptation narratives to frame climate action in ways that are context-sensitive, culturally meaningful, and participatory. The narrative framework enables stakeholders to co-create pathways that translate abstract climate scenarios into actionable, story-based strategies. For example, a narrative might focus on safeguarding traditional irrigation systems through modern water conservation technologies and participatory governance models, blending traditional irrigation practices with innovative, community-driven solutions. This approach integrates the structural (e.g., solar-powered drip irrigation, soil moisture sensors), social (e.g., intergenerational knowledge transfer, community-led water rationing), and institutional (e.g., water-sharing agreements, climate-responsive policy reforms) dimensions of adaptation and it bridges scientific data (e.g., risk models) with local knowledge (e.g., traditional practices), ensuring that resilience strategies are not only technically robust but also culturally embedded and socially accepted. By organizing solutions into these three categories, the project aligns with the DAPP framework, which emphasizes iterative, scenario-based planning to build resilience under deep uncertainty. The clustering of measures in structural, social, and institutional categories provides a structured foundation for identifying adaptive pathways that evolve with changing conditions, enabling stakeholders to co-develop dynamic strategies that balance immediate needs with long-term transformation.

Adaptation Needs and Options Chapter 14

Table 14-1 | Categories and examples of adaptation options.

Category		Examples of options*
Structural/ physical	Engineered and built environment	Sea walls and coastal protection structures (5.5.2 and 24.4.3.5; Figure 5-5); flood levees and culverts (26.3.3); water storage and pump storage (Section 23.3.4); sewage works (3.5.2.3); improved drainage (24.4.5.5); beach nourishment (5.4.2.1); flood and cyclone shelters (11.7); building codes (Section 8.1.5); storm and waste water management (8.2.4.1); transport and road infrastructure adaptation (8.3.3.6); floating houses (8.3.3.4); adjusting power plants and electricity grids (10.2.2; Table 10-2)
	Technological	New crop and animal varieties (7.5.1.1.1, 7.5.1.1.3, 7.5.1.3; Box 9-3; Table 9-7); genetic techniques (27.3.4.2); traditional technologies and methods (7.5.2, 27.3.4.2, 28.2.6.1, and 29.6.2.1); efficient irrigation (10.3.6 and 22.4.5.7; Box 20-4); water saving technologies (24.4.1.5 and 26.3.3) including rainwater harvesting (8.3.3.4); conservation agriculture (9.4.3.1 and 22.4.5.7); food storage and preservation facilities (22.4.5.7); hazard mapping and monitoring technology (15.3.2.3 and 28.4.1); early warning systems (7.5.1.1, 8.1.4.2, 8.3.3.3, 11.7.3, 15.4.3.2, 18.6.4, 22.2.2.1, 22.3.5.3, and 22.4.5.2); building insulation (8.3.3.3); mechanical and passive cooling (8.3.3.3); renewable energy technologies (29.7.2); second-generation biofuels (27.3.6.2)
	Ecosystem-based[a]	Cross Chapter Box CC-EA, Ecological restoration (5.5.2, 5.5.7, 9.4.3.3, and 27.3.2.2; Box 15-1) including wetland and floodplain conservation and restoration; increasing biological diversity (26.4.3); afforestation and reforestation (Box 22-2); conservation and replanting mangrove forest (15.3.4 and 29.7.2); bushfire reduction and prescribed fire (Section 24.4.2.5; Box 26-2); green infrastructure (e.g., shade trees, green roofs) (8.2.4.5, 8.3.3, 11.7.4, and 23.7.4); controlling overfishing (28.2.5.1 and 30.6.1); fisheries co-management (9.4.3.4 and 27.3.3.1); assisted migration or managed translocation (4.4.2.4, 24.4.2.5, 24.4.3.5, and 25.6.2.3); ecological corridors (4.4.2.4); ex situ conservation and seed banks (4.4.2.5); community-based natural resource management (CBNRM) (22.4.5.6); adaptive land use management (Section 23.6.2)
	Services	Social safety nets and social protection (Box 13-2; 8.3, 17.5.1, and 22.4.5.2); food banks and distribution of food surplus (29.6.2.1); municipal services including water and sanitation (3.5.2.3 and 8.3.3.4); vaccination programs (11.7.1), essential public health services (11.7.2) including reproductive health services (11.9.2) and enhanced emergency medical services (8.3.3.8); international trade (9.3, 9.4, and 23.9.2)
Social	Educational	Awareness raising and integrating into education (11.7, 15.2, and 22.4.5.5); gender equity in education (Box 9-2); extension services (9.4.4); sharing local and traditional knowledge (12.3.4 and 28.4.1) including integrating into adaptation planning (29.6.2.1); participatory action research and social learning (22.4.5.3); community surveys (Section 8.4.2.2); knowledge-sharing and learning platforms (8.3.2.2, 8.4.2.4, 15.2.4.2, and 22.4.5.4); international conferences and research networks (8.4.2.5); communication through media (22.4.5.5)
	Informational	Hazard and vulnerability mapping (11.7.2, 8.4.1.5); early warning and response systems (15.4.2.3 and 22.4.5.2) including health early warning systems (11.7.3, 23.5.1, 24.4.6.5, and 26.6.3); systematic monitoring and remote sensing (15.4.2.1 and 28.6); climate services (2.3.3) including improved forecasts (27.3.4.2); downscaling climate scenarios (8.4.1.5); longitudinal data sets (26.6.2); integrating indigenous climate observations (22.4.5.4, 25.8.2.1, and 28.2.6.1); community-based adaptation plans (5.5.1.4 and 24.4.6.5) including community-driven slum upgrading (8.3.2.2) and participatory scenario development (22.4.4.5)
	Behavioral	Accommodation (5.5.2); household preparation and evacuation planning (23.7.3); retreat (5.5.2) and migration (29.6.2.4), which has its own implications for human health (11.7.4) and human security (12.4.2); soil and water conservation (23.6.2 and 27.3.4.2); livelihood diversification (7.5.1.1, 7.5.2, and 22.4.5.2); changing livestock and aquaculture practices (7.5.1.1); crop-switching (22.3.4.1); changing cropping practices, patterns, and planting dates (7.5.1.1.1, 23.4.1, 26.5.4, and 27.3.4.2; Table 24-2); silvicultural options (25.7.1.2); reliance on social networks (Section 29.6.2.2)
Institutional	Economic	Financial incentives including taxes and subsidies (Box 8-4; 8.4.3 and 17.5.6); insurance (8.4.2.3, 13.3.2.2, 15.2.4.6, 17.5.1, 26.7.4.3, and 29.6.2.2; Box 25-7) including index-based weather insurance schemes (9.4.2 and 22.4.5.2); catastrophe bonds (8.4.2.3 and 10.7.5.1); revolving funds (8.4.3.1); payments for ecosystem services (9.4.3.3 and 27.6.2; Table 27-7); water tariffs (8.3.3.4.1 and 17.5.3); savings groups (8.4.2.3 and 11.7.4; Box 9-4); microfinance (Box 8-3; 22.4.5.2); disaster contingency funds (22.4.5.2 and 26.7.4.3); cash transfers (Box 13-2)
	Laws and regulations	Land zoning laws (22.4.4.2 and 23.7.4); building standards (8.3.2.2, 10.7.5, and 22.4.5.7); easements (27.3.3.2); water regulations and agreements (26.3.4 and 27.3.1.2); laws to support disaster risk reduction (8.3.2.2); laws to encourage insurance purchasing (10.7.6.2); defining property rights and land tenure security (22.4.6 and 24.4.6.5); protected areas (4.4.2.2); marine protected areas (Box CC-CR Chapter 6; 23.6.5 and 27.3.3.2); fishing quotas (23.9.2); patent pools and technology transfer (15.4.3 and 17.5.5)
	Government policies and programs	National and regional adaptation plans (15.2 and 22.4.4.2; Box 23-3) including mainstreaming climate change; sub-national and local adaptation plans (15.2.1.3 and 22.4.4.4; Box 23-3); urban upgrading programs (8.3.2.2); municipal water management programs (8.3.3.4; Box 25-2); disaster planning and preparedness (11.7); city-level plans (8.3.3.3 and 27.3.5.2; Boxes 26-3 and 27-1), district-level plans (26.3.3), sector plans (26.5.4), which may include integrated water resource management (3.6.1 and 23.7.2), landscape and watershed management (4.4.2.3), integrated coastal zone management (2.4.3, 5.5.4.1, and 23.7.1), adaptive management (2.2.1.3 and 5.5.1.4; Box 5-2), ecosystem-based management (6.4.2.1), sustainable forest management (2.3.4), fisheries management (7.5.1.1.3 and 30.6.2.1), and community-based adaptation (5.5.4.1, 8.4, 15.2.2, 21.3.2, 22.4.4.5, 24.5.2, 29.6.2.2, and 29.6.2.3; Tables 5-4 and 8-4; FAQ 15.1)

Notes: These adaptation options should be considered overlapping rather than discrete, and are often pursued simultaneously as part of adaptation plans. Examples given can be relevant to more than one category.

[a]A number of these would fall under the term "green infrastructure" in some European Commission documents (European Commission, 2009).
*WGII AR5 sections containing representative sample of adaptation options.

Figure 3: Categories and examples of adaption options (source[30])

4 IMPACT OF THE MEASURES

To evaluate the impact of resilience measures for CCLs, a dual-method approach was adopted, combining both qualitative and quantitative assessments. This hybrid methodology ensured a comprehensive understanding of the performance and relevance of each measure. For the qualitative assessment a key input was the work developed in the ARCH project as it is explained below.

4.1 Reviewing of ARCH Performance of Solutions and Pathways Building

The ARCH (Advancing Resilience of Historic Areas against Climate-related and Other Hazards) project conducted a comprehensive desk-study to evaluate the environmental effectiveness, economic efficiency, and institutional acceptability of resilience measures targeting historic urban and heritage areas, that has been a key input for the methodology.[4] The study focused on three primary hazards—floods, extreme heat, and earthquakes—while economic assessments also considered a multi-hazard perspective, especially for agricultural heritage. A total of 322 references were consulted, yielding 536 case studies that provided a substantial evidence base. These studies produced:

- 166 flood-related effectiveness entries, assessing:
  - *Flooded area reduction* (%),
  - *Runoff reduction* (% or cm), and
  - *Infiltration rate* (mm/l).
- 446 entries related to heat, focusing on:
  - *Air temperature reduction* (°C),
  - *Indoor air temperature reduction* (°C), and
  - *Physiologically equivalent temperature (PET)* (°C).
- 1,000 economic performance entries, primarily through the *Benefit-Cost Ratio (BCR)* as a unified metric applicable across all hazard types.

4.1.1 Flood effectiveness metrics

Flood resilience performance was assessed using spatial and hydrological metrics. ***Flooded area reduction*** gauges how much area is spared from flooding after implementing mitigation, usually evaluated via GIS or remote sensing. ***Runoff reduction*** measures the volume of water not flowing overland due to increased infiltration or retention, while ***infiltration rate*** reflects

[4] Advancing Resilience of Historic Areas against Climate-related and other Hazards. https://www.heritageresearch-hub.eu/ (last accessed 22nd July 2025)

soil's ability to absorb water, crucial for reducing surface runoff. Together, these indicators quantify how effective structural and nature-based solutions are at mitigating flood risk.

4.1.2 Heat effectiveness metrics

For heat hazards, three metrics were used:

- ***Air Temperature Reduction*** **and** ***Indoor Air Temperature Reduction*** measure cooling effects brought about by interventions like increased vegetation or reflective surfaces. These are recorded using thermometers, data loggers, weather stations, or thermal imaging, and validated via simulations.
- ***Physiologically Equivalent Temperature (PET)*** assesses human thermal comfort by translating complex environmental conditions into a single, comprehensible °C value. It uses the Munich Energy-balance Model for Individuals (MEMI) to account for human heat balance, including metabolic heat production, heat transfer via skin and clothing, and sweat evaporation. PET is particularly valuable for evaluating outdoor comfort in urban public spaces.

4.1.3 Economic Efficiency (Multi-Hazard)

The economic efficiency component relies on the ***Benefit-Cost Ratio (BCR)***, offering a standardized way to compare the return on investment across diverse resilience measures. This approach accommodates structural, social, and institutional interventions, even when direct hazard-reduction metrics are hard to apply (e.g., in drought conditions). However, while the BCR metric is comprehensive, the report notes limitations in applying it to agricultural heritage due to information gaps and difficulties harmonizing drought-related data such as soil moisture and water consumption.

4.1.4 Institutional Acceptability

A preliminary investigation into **institutional acceptability** was also carried out, involving **11 stakeholders**. This qualitative assessment explored how well different measures were received by policymakers, practitioners, and heritage managers. However, detailed findings—such as stakeholder segmentation or acceptability rankings—are not included in the summary, indicating a need for more structured engagement and transparency in this area.

The results of the desk study from ARCH revealed a substantial information gap concerning the performance of resilience measures. Approximately 54%—equating to 117 measures—could not be linked to any of the defined economic or environmental performance metrics. Resilience measures addressing flood risks were the most comprehensively assessed, with 55 measures evaluated for economic performance and 11 for environmental effectiveness. Measures targeting heat risks followed, with 14 having both economic and environmental performance data. Notably, the selected environmental effectiveness metrics primarily apply to structural interventions, which explains the lower number of measures characterized in this category. Overall, the findings highlight a significant lack of evidence-based performance data across many resilience strategies. As such, enhancing efforts in performance assessment, systematic monitoring, and knowledge generation is critical to support informed decision-making and improve resilience planning.

As ARCH proved, modeling the effectiveness of solutions or finding relevant performance information in the literature to support decision-making is a complex and time-consuming task. It often requires sifting through vast amounts of data, identifying reliable sources, and reconciling differing methodologies or formats. Additionally, harmonizing information from diverse domains or stakeholders presents another significant challenge, as it demands standarized methos and integration efforts that can be both technically and logistically demanding. Thus, the RescueME project aimed to leverage existing information and knowledge to enhace efficiency and avoid duplication of efforts, while ensuring the information was grounded in established evidence. After reviewing the meta-repository of solutions and organizing them into a coherent classification framework, a significant overlap was identified with the ARCH Resilience Measure Inventory. Consequently, RescueME adopted the same metrics related to heat, flood, and economic efficiency to characterize the solutions. As a result, similar knowledge gaps were identified within the RescueME project.

4.2 Economic Characterization of The Sub-Groups of Measures

Economic characterization was essential to provide an indicative understanding of the cost implications associated with the different sub-groups of measures collected in the meta-repository. The qualitative evaluation of the cost ranges for the groups of measures was carried out in a two-phase process.

Preliminary assessment

The first phase involved a broad exploratory effort to compile existing cost data through a meta-repository of previously collected information, standardization of cost currency, and web-based searches. This allowed for the aggregation of average cost values where available. However, the resulting dataset revealed a wide variability in reported costs due to differing contexts, scales of implementation, and underlying assumptions. As such, while this phase provided a general overview of the possible cost ranges, it proved insufficient for deriving precise or comparable estimates across the diverse groups of measures.

Targeted research and qualitative cost estimation

To address the limitations identified in the preliminary phase, a second phase was conducted focusing on the targeted estimation of the costs of sub-groups of measures (see Section 2.2 for details on how sub-groups were identified). This involved systematic web-based research supported by information from previous projects, scientific publications, reports, public tender data, and other search tools. The aim was to obtain reference costs for typical activities, equipment, and implementation contexts associated with each measure sub-group. To ensure greater consistency and comparability, a set of standardized reference cases was defined:

- **Policies, programmes, and similar interventions:** Based on a middle-sized city (100,000–500,000 inhabitants).
- **Cultural heritage-related measures:** Costs are calculated per single asset (e.g., one museum, cultural institution, or individual historical artifact).
- **Public and private economic instruments:** The cost of incentives was included, particularly where private investment was expected. Estimations accounted for the size and administrative capacity of small to medium municipalities, as well as socio-demographic factors such as remoteness or population decline.
- **Training programmes:** Estimated as a one-year initiative involving approximately 100 participants.
- **Early warning systems, nature-based solutions, and similar interventions:** Included both initial investment costs and recurring annual maintenance costs.

For **structural/physical measures**, a more detailed set of proxies was applied based on different spatial scales to ensure consistency and comparability.

Table 1: Set of proxies for structural/physical measures.

Scale	Description	Example of measure sub-group	Reference Unit (Proxy)
Small scale	Localized interventions	Green roofs; Green walls	1,000 m²
Medium to large scale	Structural interventions that can extend from neighborhoods to river basins	Water containment system against floods (dikes, flood barriers, etc.).	1 hectare
Linear	Structural interventions where cost references are commonly expressed in length	Street tree planting	1 km

Staff costs were considered only where internal effort was assumed to be significant. Budget figures for local-level adaptation projects often lack transparency regarding the share allocated to staff and administrative costs. To address this gap, we adopted the following pragmatic assumptions: around of 30% of total cost was assumed in the case of measures involving substantial administrative work (e.g., drafting new regulations), in line with the average overhead (OVH) rates commonly used in EU-funded projects. For measures primarily dependent on internal municipal personnel (e.g., information generation and dissemination), higher shares (up to 60%) were assumed, reflecting the prominent role of internal staffing and coordination in such interventions. . No staff costs were included for measures implemented by private actors or external contractors (e.g., agricultural practices, construction works).

Overall, a two-phase approach allowed for the approximation of economic dimensions where precise numbers were unavailable, offering a common basis to inform comparison and further refinement. Specifically, 5 cost ranges were assigned to the sub-groups of measures (Figure 4):

- < €20,000 – 25 sub-groups of measures
- €20,000–€100,000 - 34 sub-groups of measures
- €100,000–€500,000 – 34 sub-groups of measures
- €500,000–€1,000,000 – 8 sub-groups of measures
- €1,000,000 – 10 sub-groups of measures

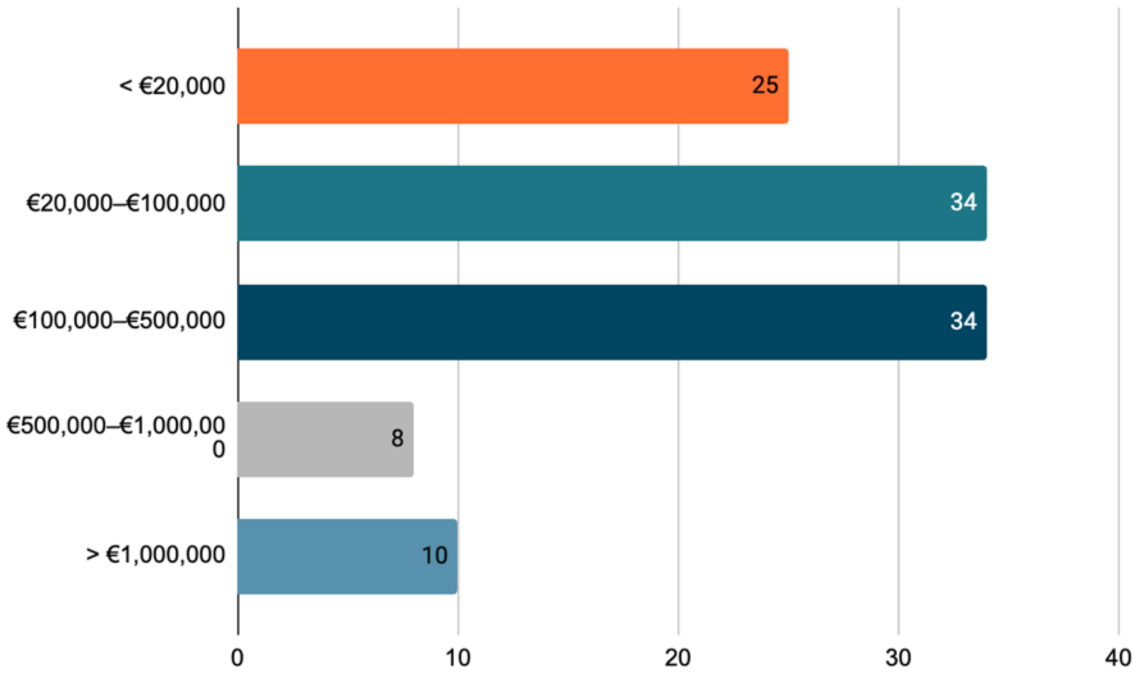

Figure 4: Distribution of the sub-groups of measures under each cost range.

In addition to cost estimations for the sub-groups of measures, the economic characterization of the measures was carried t using several economic indicators, including:

- Relative importance of the measures to directly or indirectly protect the local economy from the impact of extreme (or chronic) climate events.
- Relative importance of measures to diversify local income sources against climate risks.
- Relative importance of the measures to promote sustainable and resilient business practices.
- Relative importance of measures in mitigating economic losses from climate events.

See the section below for the methodological approach used to define and qualitatively evaluate the impact on key elements using these indicators.

4.3 Impact in the Key Elements

A core component of the methodology involved structured qualitative evaluation conducted by expert judgment within the expertise of the consortium. In this process a set of qualitative indicators (41 indicators) tailored to each per key element under consideration (see Table 2). The indicators served as a standardized framework to systematically assess the relevance, appropriateness and potential impact of the resilience measure. Since measures were selected based on their adaptation goals to address climate vulnerabilities and their long-term resilience outcomes, this approach is particularly valuable in contexts where a common framework of assessment is sought for social, institutional and structural measures. Furthermore, it offers flexibility and captures context nuanced insights that quantitative data might overlook, making it especially useful in early-stage evaluations, policy development, or environments where data is limited or difficult to quantify. It also allows us to better capture the potential of measures to adapt, protect and save cultural heritage from climate risks.

Table 2. Qualitative indicator's representativeness per key element

Key element	Number of indicators
Demographics	1
Diversity	3
Governance	3
Intangible heritage	2
Social value	1
Training	2

Education	1
Economy	10
Tourism	1
Agriculture	4
Green and blue infrastructure	2
Natural heritage	2
Topography	1
Buildings	3
Energy	2
Infrastructure	2
Tangible CH	1

The analysis results indicated that resilience measures with broad applicability can enhance the resilience of multiple key elements. Among these, programs and policies, information generation, capacity building, innovative governance models, adaptation strategies, economic incentives, training, and monitoring stand out as particularly transversal across various key elements.

4.4 Impact in Hazards

Quantitative assessment, that is, data-driven analysis to address the performance of measures to address climate impacts (floods, thermal discomfort) is usually linked to a subset of all resilience measures available - mainly structural ones. For these measures, a quantitative assessment was performed using data sourced from existing databases, particularly the ARCH performance database, which compiles case studies and metrics related to environmental effectiveness and economic efficiency. Key indicators such as Flooded Area Reduction, Runoff Reduction, Air Temperature Reduction, and BCR were used to evaluate the effectiveness of measures where data was available. The analysis leveraged both measured and modelled data from previous implementations to identify patterns of impact across different hazard types (e.g., floods, heatwaves).

4.5 Solutions Group Database

The clustering process outlined in Section 4 ("Clustering Solutions from Meta-repository Database") resulted in the creation of a structured tabular database comprising 113 sub-groups of solutions derived from the IPCC classification. Each sub-group is characterized by a set of quantitative metrics designed to facilitate comparative analysis and informed decision-making. These metrics include implementation cost ranges (e.g., low, medium, high translating to an impact score of 0–1–3–5) for key elements, indicators, and hazards, and implementation scales spanning from cadastral lots to national levels.

The cost ranges provide a preliminary understanding of the financial feasibility of each solution, while the impact scores quantify their effectiveness in addressing specific resilience goals. The implementation scale further contextualizes each solution’s applicability, ensuring that strategies are matched to the appropriate spatial and administrative context. This approach enables multi-objective optimization, allowing users to navigate trade-offs between cost, impact, and scale.

5 CHARACTERIZATION AND DATA FROM R-LABS

The aim of this activity was to relate the solutions and solution subgroups collected in the meta-repository with the information gathered on each R-Lab, stemming from the baseline resilience assessments and impact chains of task 4.2, and the local risk assessments of task 1.3. an initial step was to identify the solution subgroups of the meta-repository that may be relevant for the R-Lab in question. The selected subgroups should respect the following criteria:

- They should address the local hazards identified through the local impact chains in task 4.2
- They should address the specific capitals relating to the infrastructure, heritage and population affected
- They should be applicable on the administrative implementation scale in question
- They should directly relate to the indicators used for the risk assessment as conducted in task 1.3

To achieve this, a methodology following three steps was developed:

- First, the relevance of each subgroup was assessed directly with the assignment of a ranking between "Low", "Medium" or "High". This selection was conducted by experts familiar with the territory based on the criteria above and the feasibility of applying the solutions to the local conditions with restraints such as, for example, limited potential for large scale structural changes due to heritage protection status.
- The second step utilised the solutions group database and the assigned solution subgroup impact scores on key elements, indicators, hazards and the implementation scale. With the help of these characterizations, the database was used to filter solution subgroups applicable for each R-Lab following these criteria: A solution subgroup was considered relevant if it highly relates to at least one of the key area capitals, at least one of the hazards, the scale in question and at least one of the indicators that are relevant for the respective R-Lab.
- To allow this, the R-Labs themselves needed to be classified according to the key area capitals, the hazard, the scale and the indicators that apply to the local conditions. This characterization was carried out based on the results of task 4.2 and task 1.3 and can be seen in Annex.
- The final step was then to combine the previous ones by considering only solution subgroups that were deemed relevant through both step 1 and 2. This is aimed at increasing the robustness of the selected solution subgroups and tailoring the selection more closely to the local conditions in question.

6 DECISION MAKING METHODOLOGY

6.1 Framework For Transformative Pathways

After carrying out an analysis of the state of the art the framework was developed, to guide the research. It was decided to follow the framework established by (Tamberg et al., 2020). Given the difficulty of making the term 'resilience' fully operational, the authors propose an approach inspired by Carpenter et al. (2001) 'Resilience of What to What?' [23] and Meerow & Newell (2019) 'Urban resilience for whom, what, when, where, and why?' [24]that introduces a checklist of questions for modellers to systematically address. This framework aims to clarify precise communication, ensure compatible modeling, and narrow down the specific form of resilience under study — such as the system, stressor, stakeholders, or timeframe — thereby aligning research and policy priorities with the complexity of coastal cultural landscapes. The adapted questions from the checklist are the following:

1. Resilience of what: What is the system?
2. Resilience regarding what: What is the "sustainant"?
3. Resilience against what: What is the adverse influence?
4. Resilience how: What are the response options?
5. Resilience when and who

In the following figure the guiding framework can be seen (see Figure 5):

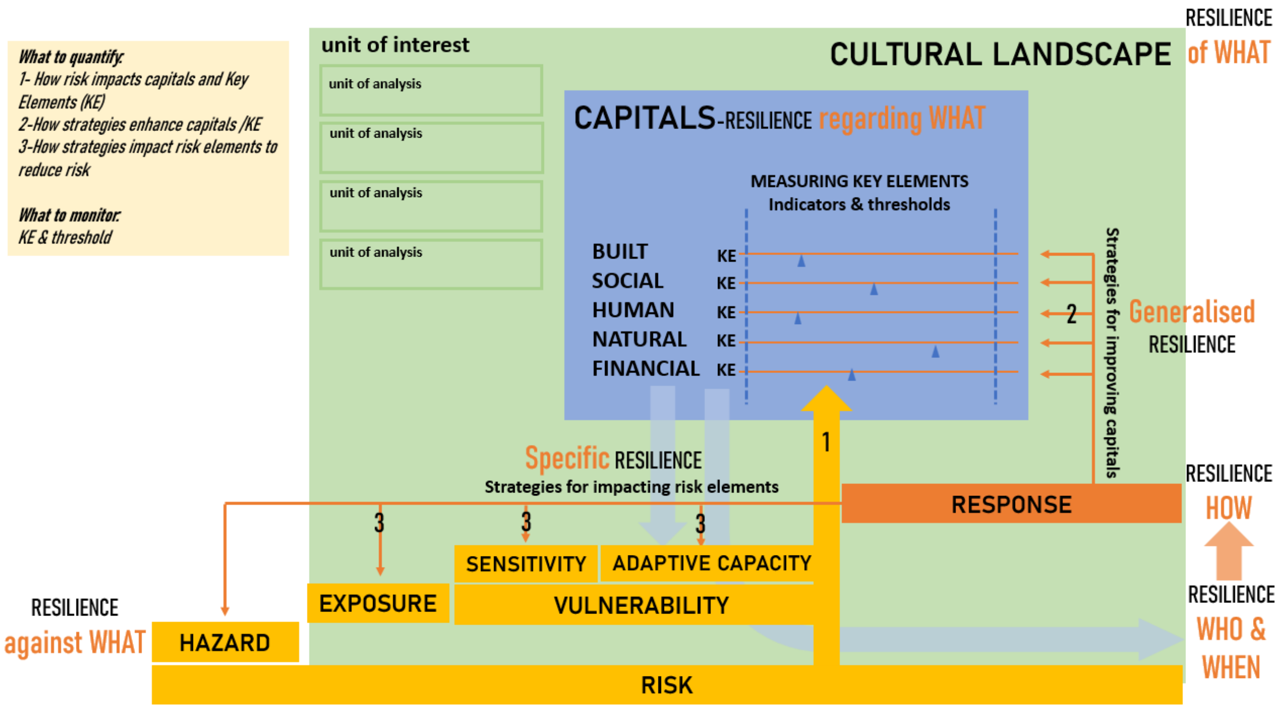

Figure 5: Guiding framework for T1.3

In our specific context, “Resilience of what: What is the system?” refers to the scale of our CCL. “Resilience regarding what: What is the “sustainant”?” address the community capitals, or more specifically the Key Elements (KE) the community wants to preserve and maintain. The “Resilience against what: What is the adverse influence?” clearly addresses the Hazard component. “Resilience how: What are the response options? The solutions and strategies that can be used to improve resilience. Finally, “Resilience when and who” refers to the planning of these strategies.

6.2 Incremental Decision Making

The different levels of decision making of the incremental approach to improving resilience in CCLs can be seen in Figure 6. The three levels (DM0, DM1, and DMII) represent a progressive, incremental decision-making framework where each level builds on the previous one, moving from regional assessment to localized action and long-term monitoring. Below is a concise description of each level:

Level DM0: Regional Solution Selection: The objective of this level is the identification of region-specific strategies from the meta-repository. It uses the information contained in the ATLAS and serves as entry point for the ISDSS to understand broad-scale vulnerabilities and community capitals.

Level DMI: Coastal Cultural Landscape Assessment: At this level the CCLs are characterized with more information provided by the end user to shift from regional to local-level analysis of cultural, ecological, and socioeconomic systems.

Level DMII: Strategy Implementation and Monitoring: this level translates the local level assessment developed in task 1.3 (see [25]) into spatially explicit decision making and actionable strategies and track outcomes.

This framework ensures a bottom-up, adaptive approach that balances a solid scientific methodology with cultural and community needs. The methodology emphasizes incremental, adaptive decision-making tailored to the unique cultural, ecological, and socioeconomic contexts of coastal regions where the information requirement is balanced with the accuracy and level of detail of the results.

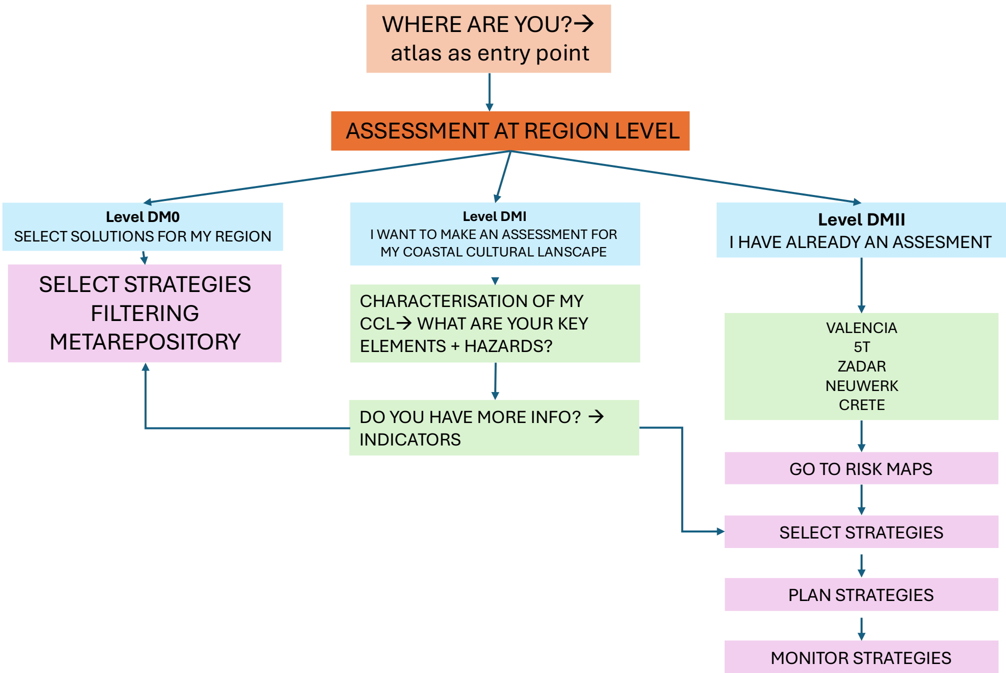

Figure 6: Decision tree for the different levels of decision making

Pathway design generally follows a phased and iterative process, beginning with the exploration of potential options, followed by their screening, refinement, and eventual selection. This process involves multiple layers of analysis, ranging from qualitative insights drawn from narratives and literature to more detailed, model-based evaluations, all conducted with active stakeholder participation [13]

The proposed methodology and the posterior implementation in the IDSS, facilitates this process by providing a structured framework that integrates both qualitative and quantitative analyses. It enables iterative refinement of pathways through interactive visualizations, scenario modeling, offering real-time feedback to the end-user. This ensures that decision-making remains transparent, adaptive, and grounded in both empirical evidence and local knowledge.

The following sections explain the decision making in each level starting for the most detailed one.

6.2.1 Level DMii: Strategy Implementation And Monitoring

BASELINE CALCULATION

The baseline calculation for this level is based on the work carried out in task 1.3. The task delivered a climate risk assessment for the five RescueME Labscapes, using predictive models to evaluate impacts on ecosystem services and cultural heritage. Key risks included coastal flooding, extreme rainfall, droughts, landslides, and temperature changes, analyzed through weighted indicators to generate spatial risk maps. Findings highlighted significant threats: Neuwerk faces storm risks inland, L'Horta de Valencia's agriculture is vulnerable to torrential rain, Portovenere and Cinque Terre face landslide increases, Psiloritis risks rise with temperature shifts, and Zadar's buildings show medium-to-high vulnerability to flooding. To flooding. The study underscored the need to prioritize vulnerability reduction (e.g., conservation) and integrate local knowledge, emphasizing that landscape-specific characteristics are critical for adaptive strategies.

The analysis followed the conceptual framework outlined in the IPCC's Fifth and Sixth Assessment Reports (AR5 and AR6), which define climate-related risk as a social construct, a concept shaped by the dynamic interactions between natural hazards, exposure, and vulnerability within societal and contextual frameworks, as illustrated in the accompanying figure.

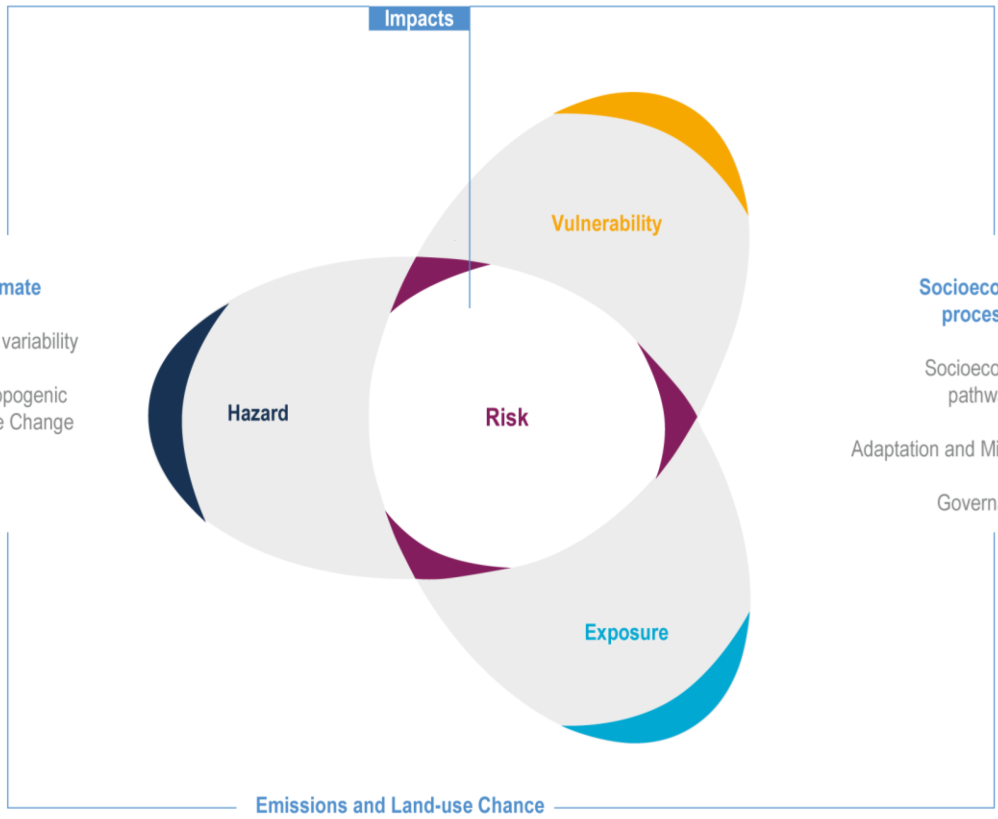

Figure 7. Risk and its components. Source: IPCC (2021)

The risk assessment framework was based on the IPCC AR6 definitions of hazard (climate-related threats), exposure (presence of vulnerable assets), and vulnerability (susceptibility and adaptive capacity). It emphasized a multiscale approach for CCLs, integrating heritage values (tangible and intangible) and ecosystem services (ES) to assess resilience. Key elements include:

- **Heritage Values (HV)**: Cultural assets (e.g., historic structures like Neuwerk Tower or Zadar's walls) reduce vulnerability by providing shelter, tourism revenue, and symbolic resilience. A holistic approach considers natural and intangible heritage (e.g., landscapes, traditions).
- **Ecosystem Services (ES):** Categorized into provisioning (food, water), regulating (climate, water regulation), cultural (recreation, spiritual value), and supporting (soil, nutrient cycles), these services directly modulate disaster risk. The study focuses on regulating services (e.g., flood mitigation by wetlands) and their interaction with hazards like coastal flooding or landslides.
- **Vulnerability Framework:** Combines sensitivity (positive polarity) and adaptive capacity (negative polarity) with exposure and hazard (positive polarity). Heritage and ES indicators are weighed to reflect their role in reducing risk, while additional factors (governance, socio-demographics, innovation) are also analyzed.

This approach highlighted the interdependence of cultural heritage, ecosystem services, and social-ecological systems in building climate resilience. The overall methodology of this assessment was the following:

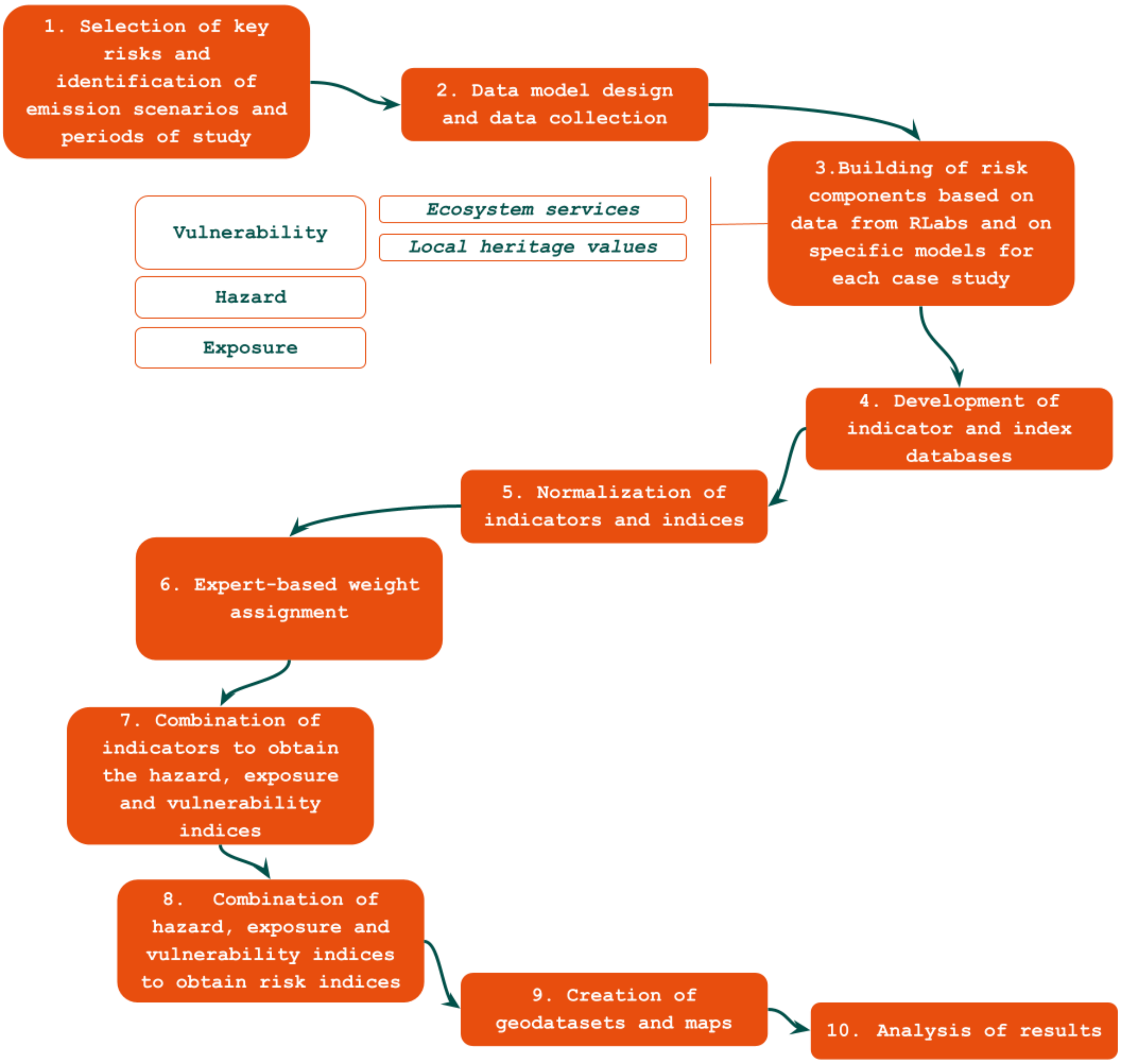

Figure 8: Methodological steps carried out for the analysis of risk in each case study. (Source: D1.4)

The risk selection process for each RescueME R-Lab combined existing knowledge (e.g., impact chains from task 4.2) with local expertise to prioritize hazards, exposed elements, and vulnerabilities. Key steps included:

- Stakeholder Engagement: A prioritization exercise refined the scope, focusing on primary impacts and ensuring alignment with project goals.
- Model Development: Bilateral meetings with R-Labs addressed uncertainties, defining spatial resolution, assessment detail, and hazards (e.g., coastal flooding, landslides, droughts).

Risks were chosen based on future intensification of existing impacts and local knowledge from R-Lab technical staff. Key risks and scenarios by R-Lab (see Table 1):

- Neuwerk (Germany): Coastal flooding impacts on buildings and agriculture (2013–2100, RCP 8.5).
- Psiloritis (Greece): Precipitation and temperature changes affecting culture (1980–2099, RCP 4.5/8.5).
- Portovenere, Cinque Terre (Italy): Landslides on terraced landscapes (1980–2100, RCP 4.5/8.5).
- Zadar (Croatia): Coastal flooding on heritage buildings (2012–2100, RCP 8.5).
- L'Horta de Valencia (Spain): Torrential rainfall and droughts on agricultural heritage (1971–2100, RCP 4.5/8.5).

The indicators selected for risk analysis were chosen based on the ones identified in D1.1[21] and D1.3[26] and selected by their relevance, reliability, and appropriateness to the spatial scale of each R-Lab. They are closely tied to the assessed risks, covering socio-ecological-technical systems and integrating natural, built, social, human, and financial capitals.

Table 3. Components assessed in each R-Lab (Source: D1.4[25])

R-Lab	Vulnerability			Exposure	Hazard	Risk
	Ecosystem services assessment	Local heritage value assessment	Other indicators			
Island of Neuwerk in Hamburg	x	x	x	x	x	x
Psiloritis Geopark	x	x	x	x	x	x
Portovenere, Cinque Terre and the Islands	x	x	x	x	x	x
Defensive system of Zadar		x		x	x	
L'Horta, València	x	x	x	x	x	x

To integrate local knowledge into the risk analysis, technical staff from each R-Lab assigned weights to exposure and vulnerability indicators. Experts collectively emphasized that vulnerability should carry greater weight, as it integrates ecosystem services and cultural heritage, elements most responsive to human intervention and adaptive strategies. This approach ensured that local insights directly influenced the prioritization of risk components, aligning with the study's focus on actionable resilience-building. The calculations of the relative exposure (E) and vulnerability (V) indices were carried out using processes analogous to those proposed in other methodologies in which the different risk components are integrated[27]. For more detail of the methodology D1.4 can be consulted [25].

As a result of this analysis the following baseline for each R-lab have been obtained for each unit of analysis.

- HV index: Heritage Value index
- ES index: Ecosystem Services index
- Risk index

Additionally, risk maps have been produced representing all the indicators spatially.

PRIORIZATION OF UNIT OF ANALYSIS

To prioritize the different units of analysis inside each CCLs, a table is shown with the indexes (Risk, ES and HV) and the risk components. Additionally, the prioritized KE will be shown. An MCDA tool will be integrated into the ISDSS to allow users to:

- Adjust Criteria Weights: Customize the importance of Risk, ES, KE and HV based on project goals.
- Rank Units Dynamically: Generate a prioritization ranking as weights change.

The Analytic Hierarchy Process (AHP)[28] is a hierarchical decomposition method where criteria and alternatives are compared pairwise to derive weights and rankings and have been previously used for decision making in cultural environments[29]. The steps involved include defining criteria such as Risk Index, ES Index, and HV Index, performing pairwise comparisons of criteria and alternatives using a 1–9 scale, and calculating weights to prioritize units. AHP has several advantages: It handles both qualitative and quantitative data, allows users to adjust criteria weights dynamically (for example, prioritizing Heritage Value over Ecosystem Services), and provides sensitivity analysis to test the robustness of rankings.

In the ISDSS, the user can pairwise compare Risk, ES, KE and HV indexes and as a result a dynamic rank of prioritized unit of analysis will be offered. With these ranks the user will select the unit of analysis to start with.

STRATEGY SELECTION

Building on the prioritized units of analysis and AHP-derived weights, the strategy selection phase integrates the impact of solution groups on baseline indicators (e.g., Risk Index, Ecosystem Services, Heritage Value) using the indicators that were used for these indexes[25]. As seen before a discrete impact score (0–1–3–5) for each indicator and group of solution has been assigned by expert judgement, reflecting its effectiveness in reducing risk or enhancing co-benefits. The optimization model then selects solution groups that maximize risk reduction while satisfying constraints on budget, scale, and narrative alignment.

Once the unit of analysis is selected, the scale makes a first filter of the possible groups of the solution that could be implemented in this unit of analysis. Using optimization techniques (multi-objective linear program), those groups of solutions will be calculated that most reduce the risk calculated in the baseline. The user then will choose the type of strategy they would like to apply. Here "adaptation narratives" will play a critical role in shaping how communities choose their adaptation pathways. These narratives are the stories, values, and worldviews that communities use to frame their understanding of climate risks and the solutions they prioritize. They influence whether communities adopt a mix of adaptation types (institutional, social or technical) or focus on a single approach, and whether they emphasize heritage-based or nature-based solutions, in a second phase.

The user then selects the type of solution they wish to apply, using the criteria selected that fit to their adaptation narratives. A nature-based narrative could favour ecosystem restoration, and a heritage-based approach might revive traditional practices, such as traditional water management techniques, even if they are less cost-effective in the baseline model.

Then the ISDSS will provide:

- Ranked Solution Groups: Each group includes:
    - Total risk reduction (R(x)).
    - Total cost (C(x)).
    - Geographic scale (A).
- Narrative alignment
- Sensitivity Analysis: How changes in budget, scale, or narrative thresholds affect risk reduction and cost.

Once the strategies (or group of solutions) are selected, the solutions that are linked to these groups will be automatically filtered. Then the domain could be selected:

- Adaptive governance solution,
- Creative industries strategy
- Financing and business model strategy
- Nature Based Solutions (NBS)
- Heritage based solution

IMPACT ESTIMATION AND SCENARIO COMPARISONS

Building on the prioritized units of analysis and strategy selection, the methodology advances to impact estimation and scenario comparison, enabling users to evaluate the effectiveness of selected solutions and compare alternative strategies. When the group of solutions is selected, their impact scale will be used on the indicators to recalculate the indexes using SIRVA engine [25]. That would provide the user with the reduction of risk compared to the baseline, offering scenario comparison capabilities.

The impact estimation phase quantifies the effects of selected solution groups on baseline indicators (e.g., Risk Index, Ecosystem Services (ES) Index, Heritage Value (HV) Index). This involves:

- Discrete Impact Scores: As each solution group is assigned a discrete impact score (0–1–3–5) for each indicator, reflecting its effectiveness in reducing risk or enhancing co-benefits. These scores are derived from expert judgment as seen in Section 4.
- Optimization Model: A multi-objective linear program calculates the total risk reduction (R(x)), with a restriction of cost (C(x)), and geographic scale (A) for each solution group. Dynamic Feedback Loops
- Adaptive Adjustments: Users can adjust criteria weights (e.g., prioritizing ES Index over HV Index) to reflect evolving priorities (e.g., a sudden policy shift favouring biodiversity over heritage preservation).

The scenario comparison phase allows users to test and compare alternative strategies, ensuring strategies are resilient to uncertainty and align with local values. The ISDSS ranks solution groups (strategies) based on the criteria that have been selected and the tool recalculates the indexes using the SIRVA tool. Users compare strategies to assess trade-offs in risk reduction, cost, and co-benefits. The ISDSS can tests how changes in budge and risk indexes (Sensitivity Analysis). The ISDSS generates spatial risk maps showing how selected scenarios reduce risk across units of analysis.

Once the strategy is selected, the solutions from the meta-repository linked with these strategies are shown. In a narrative-driven scenario selection, users select scenarios based on adaptation narratives (e.g., nature-based, heritage-based, community-led), which shape the prioritization of solution groups.

PLANNING AND MONITORING

Transforming selected solutions into a structured adaptation pathway begins by leveraging the ISDSS to streamline collaboration, analysis, and decision-making. The ISDSS facilitates the sequential structure of the solutions into a timeline. This sequencing is made intuitive and directly linked with the selected solutions.

Although the importance of monitoring is widely recognized, the practical and scientific development of robust monitoring plans that enable timely and appropriate adaptation remains an evolving area [13]. In the RescueME context, the monitoring approach has been defined in T1.5. To ensure adaptability, the ISDSS will offer functionality to define triggers and indicators for monitoring purposes.

Iteration will be the cornerstone of this process. The ISDSS enables stakeholders to run "what-if" scenarios, like testing the impact of delayed funding or new policy changes, and consequently adjusts the pathway to reflect these changes. This flexibility ensures the pathway remains dynamic and responsive to evolving conditions, while the ISDSS's transparency keeps all stakeholders aligned through visualizations and shared data. The ISDSS reduces complexity, highlights trade-offs, and ensures the pathway can evolve as new information or challenges arise, all while maintaining the community's ownership of the process. The final output is a tailored adaptation pathway that balances scientific robustness, cultural resonance, and financial viability. The following table shows an overview of the methodology at this level, with user stories and data requirement (see Table 4).

Module Name	Purpose	Functional Requirements	Data Requirements	Outputs	User Role	User Goal (I want to...)	Benefit (So that...)
Baseline Risk Assessment	Calculate initial risk levels for each cultural landscape.	Import predictive climate models Integrate spatial data layers Calculate Risk HV, ES Indexes Generate spatial risk maps Allow expert weight input.	GIS layers for hazards Indicators data	Risk maps HV Index ES Index	Climate Analyst Local Expert Decision-Maker	upload predictive climate models and spatial data layers assign weights to vulnerability and exposure indicators view spatial risk maps	I can calculate baseline risk, heritage value, and ecosystem service indexes the risk maps reflect local knowledge and priorities I can understand which areas are most vulnerable
Unit Prioritization	Rank units of analysis within each landscape	Display ranked units Enable unit selection Show graphics for the selected unit and compare with the average		Dynamic ranking of units Selected unit for strategy design	Planner Stakeholder User	perform pairwise comparisons of criteria (Risk, ES, HV, KE) adjust the weights of prioritization criteria dynamically see a ranked list of units of analysis	I can prioritize units of analysis based on project goals I can explore different prioritization scenarios I can choose where to begin strategy development
Strategy Selection & Optimization	Select optimal solution groups for prioritized units	Filter solution groups Assign impact scores Compare solutions Run multi-objective linear programming Allow narrative selection		Ranked solution groups comparative dashboard export analysis	User Technical Expert Decision-Maker Community Representative	filter solution groups based on geographic scale and unit characteristics assign impact scores to solution groups run an optimization model that balances risk reduction, cost, and narrative alignment choose an adaptation narrative (e.g., nature-based, heritage-based)	I only see relevant strategies their effectiveness in reducing risk is quantified I can select the most suitable strategy the strategy reflects local values and traditions
Impact Estimation & Scenario Comparison	Evaluate and compare effectiveness of selected strategies.	Recalculate indexes using SIRVA Display scenario comparisons		Updated indexes Scenario comparison dashboard	User Planner Stakeholder	recalculate indexes using selected solution groups compare multiple scenarios side-by-side adjust criteria weights and re-run scenarios	I can see how much risk is reduced compared to the baseline I can evaluate trade-offs in cost, risk reduction, and co-benefits I can test the robustness of different strategies
Meta-Repository Integration	Link strategies to specific solutions.	Filter solutions based on strategy Categorize solutions by domain 8coloured).		Filtered solution sets by domain	User Planner	filter solutions based on selected strategy groups browse solutions by domain (e.g., NBS, heritage-based)	I can find actionable interventions I can align strategies with local priorities
Planning & Monitoring	Develop and track adaptation pathways.	import selected strategies Timeline builder Define monitoring indicators and triggers Run what-if scenarios Update pathways dynamically.		Adaptation pathway Monitoring plan	Project Manager Monitoring Officer Stakeholder	sequence selected solutions into a timeline define triggers and indicators for each solution run 'what-if' scenarios (e.g., funding delays)	I can build a structured adaptation pathway I can track progress and adapt plans as needed I can see how changes affect the adaptation pathway

Table 4: Overview of the methodology at DM II

6.2.2 Level DMI: Coastal Cultural Landscape (CCL) Assessment

The previous DM level was designed to support territorial risk assessment and adaptation planning through the integration of spatial data, including GIS layers, predictive climate models, and risk maps. However, in contexts where such spatial data is unavailable or incomplete, the methodology can be effectively adapted to operate through a structured, indicator-based methodology. This alternative approach maintains the core logic of the system, assessing risk, prioritizing units, and selecting strategies, while replacing spatial inputs with user-provided data collected via questionnaires and scoring matrices that will be implemented in the ISDSS.

In this level, the risk assessment is conducted by collecting values for a set of predefined indicators related to exposure, vulnerability, heritage value, and ecosystem services. These indicators are selected to reflect the dimensions of risk and value that would otherwise be derived from spatial overlays and will be selected from the indicators used in the previous level, depending on the scale, hazard and unit of analysis of the CL[5]. Users will input data through guided forms. Experts can assign weights to indicators to reflect local priorities and knowledge, ensuring that the assessment remains context-sensitive and participatory. The information will be completed with the information from the ATLAS at NUTS2 level.

The system calculates composite indexes for risk, heritage value (HV), and ecosystem services (ES) based on the weighted indicators. These indexes are then used to rank units of analysis within each CL. The prioritization process remains dynamic, allowing users to adjust weights and explore different scenarios. Strategy selection and optimization modules operate on these rankings, filtering and scoring solution groups based on relevance, cost, and alignment with local narratives.

Scenario comparison and monitoring are also adapted to this framework. Instead of updating spatial risk maps, the system recalculates indexes and presents results through comparative dashboards and charts. Monitoring indicators and triggers are defined based on the selected solutions, enabling users to track progress and simulate “what-if” scenarios without relying on geospatial data.

This level significantly broadens the applicability of the ISDSS. It enables deployment in data-poor environments, enhances accessibility for non-expert users, and fosters inclusive decision-making by emphasizing local knowledge and values. While it does not provide spatial visualizations, it offers a robust, transparent, and flexible alternative for territorial risk assessment and adaptation planning.

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[5] The final indicators will be selected though an iterative process with R-labs in T3.5

The following table shows an overview of the methodology at this level, with user stories and data requirement

Module Name	Purpose	Functional Requirements	Outputs	User Role	User Goal (I want to...)	Benefit (So that...)
Baseline Risk Assessment	Calculate initial risk levels for each cultural landscape.	User input forms for hazard indicators	Risk indicator-based	Climate Analyst	upload predictive climate models and indicator-based data indicator-based	I can calculate baseline risk, heritage value, and ecosystem service indexes
		Integrate indicator-based data indicator-based	HV Index	Local Expert	assign weights to vulnerability and exposure indicators	the risk indicator-based reflect local knowledge and priorities
		Calculate Risk	ES Index	Decision-Maker	view indicator-based risk indicator-based	I can understand which areas are most vulnerable
		HV, ES Indexes Generate risk scores from indicators Allow expert weight input.				
Unit Prioritization	Rank units of analysis within each landscape	Display ranked units	Dynamic ranking of units	Planner	perform pairwise comparisons of criteria (Risk, ES, HV, KE)	I can prioritize units of analysis based on project goals
		Enable unit selection	Selected unit for strategy design	Stakeholder	adjust the weights of prioritization criteria dynamically	I can explore different prioritization scenarios
		Show graphics for the selected unit and compare with the average		User	see a ranked list of units of analysis	I can choose where to begin strategy development
Strategy Selection & Optimization	Select optimal solution groups for prioritized units	Filter solution groups	Ranked solution groups	User	filter solution groups based on geographic scale and unit characteristics	I only see relevant strategies
		Assign impact scores	comparative dashboard	Technical Expert	assign impact scores to solution groups	their effectiveness in reducing risk is quantified
		Compare solutions	export analysis	Decision-Maker	run an optimization model that balances risk reduction, cost, and narrative alignment	I can select the most suitable strategy
		Allow narrative selection		Community Representative	choose an adaptation narrative (e.g., nature-based, heritage-based)	the strategy reflects local values and traditions
Impact Estimation & Scenario Comparison	Evaluate and compare effectiveness of selected strategies.	Recalculate indexes using updated indicator inputs	Updated indexes	User	recalculate indexes using selected solution groups	I can see how much risk is reduced compared to the baseline
		Display scenario comparisons	Scenario comparison dashboard	Planner	compare multiple scenarios side-by-side	I can evaluate trade-offs in cost, risk reduction, and co-benefits
				Stakeholder	adjust criteria weights and re-run scenarios	I can test the robustness of different strategies
Meta-Repository Integration	Link strategies to specific solutions.	Filter solutions based on strategy	Filtered solution sets by domain	User	filter solutions based on selected strategy groups	I can find actionable interventions
		Categorize solutions by domain		Planner	browse solutions by domain (e.g., NBS, heritage-based)	I can align strategies with local priorities
Planning & Monitoring	Develop and track adaptation pathways.	import selected strategies Timeline builder	Adaptation pathway	Project Manager	sequence selected solutions into a timeline	I can build a structured adaptation pathway
		Define monitoring indicators and triggers	Monitoring plan	Monitoring Officer	define triggers and indicators for each solution	I can track progress and adapt plans as needed
		Run what-if scenarios		Stakeholder	run 'what-if' scenarios (e.g., funding delays)	I can see how changes affect the adaptation pathway
		Update pathways dynamically.				

Table 5: Overview of the methodology at DM I

6.2.3 Level DM0: Regional Solution Selection

The level DM0 provides a decision making using the assessment carried out at NUTS3 level that is structured in the ATLAS.

BASELINE CALCULATION

The baseline risk calculation for European coastal NUTS3 regions was performed using a semi-quantitative approach based on spatial indicators, as described in Deliverable D1.3 [26]. These indicators, aligned with the IPCC AR5 and AR6 frameworks, were assigned to the core risk components: hazard, exposure, and the sub-components of vulnerability — sensitivity and adaptive capacity. Sensitivity indicators represent factors that increase vulnerability with higher magnitude, while adaptive capacity indicators reflect those that reduce it. A series of composite indices, scaled from 1 (very low) to 2 (very high), were generated to express the relative risk of each NUTS3 unit. This methodology was applied iteratively across eight hazard types affecting cultural landscapes: pluvial floods, river floods, landslides, coastal floods, droughts, wildfires, heat waves, and poor air quality. Indicators were normalized, rescaled, and aggregated to form indices for sensitivity, adaptive capacity, vulnerability, exposure, hazard, and overall risk. Risk levels were assessed under a reference period (1981–2010) and three future climate scenarios (RCP 2.6, RCP 4.5, RCP 8.5) for 2071–2100, excluding poor air quality. Results are displayed in the RescueME ATLAS[6] were risk maps and evolution maps, were used to compare relative risk levels across NUTS3 units and track changes over time, using color codes to highlight regions with increasing, stable, or decreasing risks.

The analysis of risk components shows distinct risk profiles across different hazard types (see[26]). Looking at the 25 most endangered NUTS3 regions, some hazards, such as river floods and droughts are primarily driven by a very high hazard component, and others, such as landslides and wildfires, by a very high or high hazard component. Wildfires are particularly notable, with 96% of regions also showing high or very high vulnerability. In contrast, the risk from coastal flooding is mainly associated to high or very high sensitivity and exposure, suggesting the need for targeted strategies addressing these factors across all coastal cultural landscapes. Similarly, heatwaves present widespread risk, with high vulnerability and significant exposure. Pluvial floods and poor air quality display more balanced risk profiles across components. Recognizing and analyzing the different risk profiles across regions enables the selection of targeted and effective resilience strategies.

[6] https://appwerescuemep01.azurewebsites.net/

STRATEGY SELECTION

NUTS3-level assessments offer a broad regional overview of risk from a cultural landscape perspective. This scale helps identifying main adaptation priorities and shaping regional resilience strategies that align with broader socio-political and administrative frameworks. To support decision-making at this level, users will be able to explore solutions through two main pathways. First, the Place-Based Solutions (PBS) included in the meta-repository, which are solutions geographically tied to specific implementation contexts, will be visualized within the ATLAS, enabling stakeholders to view existing practices in their own NUTS3 region or identify regions with similar risk and resilience profiles that have already implemented relevant strategies. This encourages knowledge transfer and peer learning among regions facing comparable challenges. Second, users can access the meta-repository directly and filter solutions by hazard type, solution type, and subgroup categorization. For users with a clearer understanding of which resilience dimensions (e.g. social, natural, financial, human, or built capitals) require prioritization, additional filtering options are available. Once filtered, users can browse a variety of solutions and access detailed factsheets that provide information on their objectives, implementation contexts, responsible actors, and indicative costs. Each solution entry is characterized using a structured set of descriptive fields that reflect data availability and support consistent comparison. This allows supporting informed decision-making tailored to regional needs.

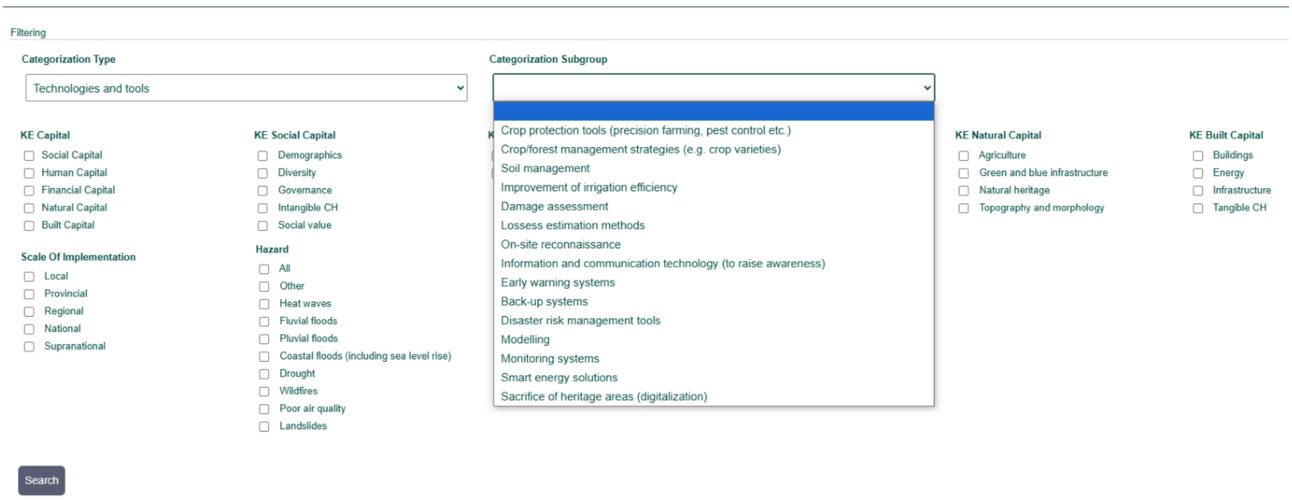

Figure 9 Screenshot of the meta-repository filtering options

7 CONCLUSION & FUTURE RESEARCH

The report outlines the development of a methodology to select resilience-improving strategies for Coastal Cultural Landscapes (CCLs), building on the RescueME project's previous work. This framework integrates risk assessments, stakeholder priorities, and a meta-repository of over 1,000 resilience solutions. The approach will be implemented in the Incremental Spatial Decision Support System (ISDSS) and validated through co-creation with the five R-Labs (Crete, Neuwerk, Cinque Terre, l'Horta de València, Zadar) in the last stage of the project (Task 3.5). These R-Labs will serve as testbeds to refine the methodology, ensuring it aligns with local conditions, heritage values, and community needs. The results will be documented in D 3.5 (Report on digital tool fine-tuning) and D4.2 (Framework including evaluation and lessons learnt (v2)).

While the current methodology provides a robust foundation, several research directions are critical to enhance its scalability, adaptability, and real-world effectiveness.

- Within the project validation with R-Labs remains a priority. This will require iterative feedback loops between the ISDSS and R-Lab stakeholders to validate assumptions and adjust models. Future work should also address data gaps, particularly in contexts where heritage prioritization is contentious. Developing participatory frameworks to define context-specific priorities will be essential for balancing heritage preservation with resilience goals. The methodology's success hinges on its real-world application, particularly in quantifying the effectiveness of measures.
- To improve the meta-repository's usability, future research could explore Natural Language Processing (NLP) techniques (e.g., topic modelling) to make more accessible the information from the meta-repository.
- Application and scalability must be addressed. The methodology will be tested in the five R-Labs to tackle site-specific challenges. Task 3.5 will document these applications, and results will feed into Task 4.5 for validation of the results. Future research could explore scaling the framework to other CCLs, particularly in regions facing similar socioecological pressures.
- Broader research opportunities include expanding the back-testing framework to diverse geographic and socio-economic contexts to strengthen the methodology's generalizability. If artificial intelligence (AI) techniques are adopted, Explainable AI (XAI) methods (e.g., SHAP values, LIME) should be prioritized to ensure solution clusters are interpretable for planners and policymakers.

In summary, future research must focus on validating the methodology in R-Labs, addressing data gaps and heritage prioritization conflicts, refining impact assessments, and scaling the framework to new contexts. By prioritizing real-world application and stakeholder collaboration, the RescueME project can ensure its approach remains flexible, context-sensitive, and aligned with the long-term resilience of Europe's cultural landscapes.

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9 APPENDICES

R-Lab characterization in terms of Key Elements and Capitals, Hazards, Scale of Implementation and Indicators.

		Description	LNV	Ham	PV5T	IDEON	Zadar
Key Elements	**Demographics**	Relative importance of the measure to engage the population in awareness-raising, training, governance, citizen science, or general climate action activities to improve the resilience of natural-cultural landscapes (socio-ecological perspective)	X	X	X	X	X
	Diversity	Relative importance of the measure to engage diverse populations, including vulnerable groups	X	X	X	X	X
		Relative importance of the measure to work on climate social justice (rights, participation, diversity of access to measures)	X	X	X	X	X
		Relative importance of the measure to improve equity in access to resources for addressing climate change.	X	X	X	X	X
	Governance	Relative importance of the measure to improve interinstitutional coordination for implementing resilience measures.	X		X		
		Relative importance of the measure to improve civil society participation in the development of climate policies and cultural & natural heritage policies.	X	X	X	X	X
	Intangible CH	Relative importance of the measure to integrate traditional knowledge and cultural practices into resilience strategies.	X		X	X	
		Relative importance of the measure to conserve and promote intangible cultural heritage in the context of climate adaptation.	X		X	X	
	Social value	Relative importance of the measure to improve the sense of belonging of local inhabitants.	X	X	X	X	X
	Training	Relative importance of the measure to technically train key local stakeholders to address climate risks associated with natural or cultural heritage	X		X		
		Relative importance of the measure to improve population self-management in response to extreme climate events.	X	X			
	Education	Relative importance of the measure to raise awareness among the population about climate risks and their impact on heritage.	X	X	X	X	X
	Economy	Relative importance of the measures to directly or indirectly protect the local economy from the impact of extreme (or chronic) climate events.				X	
		Relative importance of the measures to diversify local income sources against climate risks.			X	X	
		Relative importance of the measures to promote sustainable and resilient business practices.					X
		Relative importance of the measures in mitigating economic losses from climate events				X	
	Tourism	Relative importance of the measures to promote sustainable and resilient tourism.		X	X	X	X
	Agriculture	Relative importance of the measures to promote sustainable and resilient agriculture.	X		X	X	
		Relative importance of the measures for soil and water conservation for agricultural production (this could or should be separated into two measures).	X		X	X	
		Relative importance of the measures to enhance traditional agricultural practices (considered intangible heritage).	X		X	X	
		Relative importance of the measures to enhance crop resilience.	X		X	X	
		Relative importance of the measures to protect and restore biodiversity.	X	X	X	X	

	Green and blue infrastructure	Relative importance of the measures to protect and restore blue-green infrastructure from climate challenges (e.g., quality, connectivity, etc.).		X			
	Natural heritage	Relative importance of the measures to raise awareness about the importance of preserving protected natural areas from climate risks.	X			X	
		Relative importance of the measures to conserve and restore protected natural areas from climate risks.	X	X		X	
	Topography and morphology	Relative importance of the measure to modify land cover and use to minimize climate risks.	X		X		
	Buildings	Relative importance of the measures to enhance the adaptive capacity of urban buildings to changing temperatures and climatic conditions while maintaining their heritage value.					X
		Relative importance of the measures to enhance the adaptive capacity of urban buildings to changing temperatures and climatic conditions.					X
		Relative importance of the measures to adapt urban planning and construction norms to climate change.					X
	Energy	Relative importance of the measures to improve the resilience of energy infrastructure against extreme events (storms, floods, etc.).		X		X	
		Relative importance of the measures to ensure accessibility and reliability of renewable energy in climate emergency situations.	X	X	X	X	X
	Infrastructure	Relative importance of the measures to improve the resilience of critical infrastructure against extreme events (storms, floods, etc.).	X	X	X	X	X
		Relative importance of the measures to improve resilience and thereby ensure basic services associated with critical infrastructure.	X	X	X		X
	Tangible CH	Relative importance of the measures to improve the adaptation and resilience of tangible heritage while maintaining its significance.		X	X	X	X
Hazards		Coastal Flood		X			
		Landslide					X
		Changing Precipitation Patterns	X				
		Rising Temperatures					
Scale		building level					
		cadastral lot			X		
		municipal	X		X		X
		submunicipal			X		
		regional	X				X
Indicators		Population density				X	
		Population number	X		X		X
		Population change					X
		Employed persons					
		Unemployment rate	X				X
		Proportion of population aged 65 years and more					
		Arrivals at tourist accommodation establishments per population					X
		Bed places			X		X
		Share of Natura2000 area	X				X
		Share of region with high or very high landslide susceptibility					X
		share of agricultural land			X		

	share of forest land			X		X
	share of natural land+water			X		
	Households with access to the internet at home			X		
	Availability of action plans or adaptation strategies at municipal level	X				
	share of elevation breakdow - low coast					X
	share of elevation breakdow - high coast					X
	share of elevation breakdow - inland					X
	share of elevation breakdow - upland					X
	share of elevation breakdow - mountains					X
	Degree of urbanisation - Share of urban areas					X
	Surface cultivated with vineyards					X
	Surface cultivated with olive trees					X
	Number of Agricultural holdings	X		X		X
	Agricultural area	X				
	Share of agricultural area					X
	Share of holdings with a full-time manager	X				
	Average hydric resources for crops	X				
	Share of employed persons in agriculture, forestry and fishing	X				
	Social Security affiliation in Agriculture	X				
	Public land tenure	X				
	Share of tenant agricultural area					
	Organic farming activities	X				
	Share of arable land	X				
	Share of protected areas surface	X				X
	Share of female farm managers	X				
	Farm manager with agricultural studies	X				
	Centres for agricultural studies	X				
	Municipal budget	X				
	Protected natural and agricultural areas with international designation exposed to landslides					X
	Number of cultural facilities open to the public and aiming at promoting arts and culture per population			X		
	Owned houses with summer use only			X		
	Incentives for the maintenance of traditional agricultural activities	X				
	Percentage of abandonment of terraces on the total terraced area					X
	Percentage of terraced vineyards on the total land used for viticulture					X
	Number of properties			X		
	Number of emergency operators			X		
	Permanent cultivations surface	X				
	Share of vineyards and olive groves					X
	Number of PDO/PGI agriculture firms	X				
	Number of Bio agriculture firms	X				
	Share of young farmers (25 to 34 years)	X				
	Participation of Municipalities in rural development projects	X				
	Projects on landscape and CH included in the NEXT Generation EU	X				
	Area with outdoor recreation potential			X		
	Share of area with outdoor recreation potential	X				
	Number of water management bodies/structures	X				
	Mid agriculture value	X				

	share of farmers with full or basic agricultural training	X				
	Protected areas under national laws	X				
	Number of sites accessible by people with disabilities					
	Annual number of festivals or cultural events connected to traditions/culinary practices/local products					
	Number of local associations connected to traditions/culinary practices/local products					
	Number of shops, restaurants and tourism facilities selling local products (0 Km)					
	Attendance and participation in cultural activities and events					
	Diversity of landscape (number of landscape typologies)	X				
	Cultural vibrancy - number of cultural sites					
	Cultural vibrancy - number of cultural sites exposed to coastal floods			X		
	Number of educational facilities					X
	tourist accommodation establishments			X		X
	Traditional channels of irrigation	X				
	Area used for traditional cultivations	X				
	Number of architectural and infrastructural elements representing the traditional way of living and cultivating	X				
	Ramsar site area	X				
	Agrarian Municipal Councils	X				
	Runoff Retention	X				
	Cooling Capacity Index					

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