RESCUE ME
RESILIENT CULTURAL LANDSCAPES

D1.6

TRANSFORMATIVE PATHWAYS MONITORING

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Summary

T1.5 – *Transformative pathways monitoring* represents a strategic phase within the broader RescueME project, contributing decisively to the operational implementation of the framework based on the definition of cultural landscapes as **Socio-Ecological-Technical Systems (SETS)** (see *D1.2 - ATLAS of European coastal heritage landscapes typologies and climate change impacts* [1]).

SETS based on five interconnected forms of capital:

- **Natural Capital**: refers to natural resources and ecosystems that provide benefits and services to local communities. This includes agricultural practices, biodiversity, recreational activities, and traditional practices.

- **Built Capital**: pertains to human-made infrastructure, such as monuments, traditional buildings, industrial heritage, roads and connectivity systems, as well as energy and water supply systems, all of which contribute to shaping the unique character of the landscape.

- **Social Capital**: concerns the networks, relationships, and trust within a community, which influence how people contribute to the conservation and sustainable development of cultural landscapes. It includes community engagement practices, the sharing of traditional knowledge, advocacy activities, and governance mechanisms that involve communities in decision-making processes.

- **Human Capital**: refers to the skills and capabilities of local communities, emphasizing how these can be enhanced through lifelong learning, education, and training.

- **Financial Capital**: represents the economic contribution of cultural landscapes to local communities, as well as the resources and funding available for their maintenance, management, and enhancement – including revenues from tourism and cultural events.

This approach enables the creation of typologies of cultural landscapes based on their similarities across these various dimensions and to assess measurement objectives such as **sensitivity, coping, adaptive and transformative capacity**.

Specifically, T1.5 develops the methodological and operational tools required to move from the theoretical definition to the empirical validation of transformative resilience pathways (TRP). These pathways are conceived in RescueME as sequences of actions that can be progressively implemented over time to manage uncertainty and rapid change, with a specific focus on **coastal areas**, which have historically been centers of human settlement and are now particularly exposed to the effects of climate change, natural hazards, and other

anthropogenic pressures such as pollution and overtourism. The goal is to support communities in building landscape resilience, safeguarding cultural heritage and landscapes, and enabling the transition towards a greener society and economy that foster resilient, cohesive, and nature-connected communities. This approach allows progress towards resilience objectives in the target territories to be concretely measurable, assessable, and monitorable.

Within this context, T1.5 plays a central and enabling role, as it is dedicated to the **development of a dynamic monitoring system**, aimed at continuously and adaptively assessing the effectiveness of the TRP and designed to be responsive to evolving socio-environmental conditions, providing informed and up-to-date support to decision-making processes, both in the short and long term.

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List of acronyms

ACRONYM / ABBREVIATION	DESCRIPTION
CL	Cultural Landscapes
CCLs	Coastal Cultural Landscapes
D	Dynamic Adaptive Policy Pathways
DAPP	Area of Interest
ISDSS or DSS	Incremental Spatial Decision Support System
R-LABs	Resilience Historical Labscapes
ST	Subtask
T	Task
TRP	Transformative resilience pathways
WP	Work Package

1 Introduction

This document provides an overview of the activities carried out under T1.5

Chapter 1: Introduction
Serves as a preface to the document.

Chapter 2: State of the art
Presents a review of current approaches to monitoring, with a focus on the DAPP framework:

- **Section 2.1** reviews the literature on monitoring systems.
- **Section 2.2** explores the relevance and application of the DAPP method in the context of cultural landscapes, integrating its cycle with the RescueME framework.
- **Section 2.3** concludes with a reflection on the gaps and limitations of the DAPP.

Chapter 3: Identification of Monitoring Indicators
Describes the process adopted to identify indicators within the integrated RescueME-DAPP framework:

- **Section 3.1** outlines the methodology for collecting indicators, starting from the RescueME meta-repository of resilience solutions.
- **Section 3.2** describes the testing of this methodology during the fifth RescueME General Assembly in Zadar, involving the R-Labs.
- **Section 3.3** presents the quantification of values for signals, triggers, and adaptation thresholds, based on inputs provided by the R-Labs during the workshop.
- **Section 3.4** outlines the validation phase with the R-Labs concerning the quantified values.

Chapter 4: Towards a Structured System for Monitoring Transformative Pathways
Proposes a theoretical extension of the approach developed during the T1.5 workshop, aiming for its application in contexts involving multiple solutions.

Chapter 5: Conclusions and Future Perspectives
Summarises the key points of the document:

- DAPP supports decisions under uncertainty through adaptive planning
- DAPP uses indicators, signals, triggers, and thresholds for effective monitoring.
- Integrated with RescueME, DAPP enhances resilience planning.
- Monitoring indicators can be selected using the RescueME meta-repository.
- R-Labs help identify context-specific monitoring indicators.
- The framework is validated through literature and R-Labs input.

The chapter also provides insights for future developments.

2 State of the art

This chapter provides a critical overview of the state of the art concerning monitoring approaches for transformative pathways, with a particular focus on their applicability in complex and uncertain contexts such as coastal cultural landscapes.

Section 2.1 presents a systematic literature review of existing monitoring approaches, highlighting key criteria for the design of effective, salient, and adaptive systems. Special attention is given to the DAPP framework (Haasnoot *et al.*, 2013 [2]), recognized as one of the most promising tools for planning under deep uncertainty. Its principles, operational steps, and real-world applications are explored in detail.

Section 2.2 focuses on the relevance and application of the DAPP approach in the context of cultural landscapes. This section examines how the DAPP framework can support the development and implementation of transformative resilience pathways by integrating monitoring systems, participatory processes, and flexible risk management.

The analysis concludes with a critical reflection on the methodological and practical challenges of applying the DAPP framework (**section 2.3**), offering insights for future developments and applications.

2.1 Literature review of monitoring approaches

The review of existing transformative pathways monitoring approaches is here unfolded in 2 phases.

The research was conducted using the freely accessible search engine *Google Scholar*[1], which, through specific keywords, allows the identification of academic and scientific texts such as articles, theses, books, and technical reports.

[1] Google Scholar. (n.d.). *Google Scholar*. Retrieved July 9, 2025, from *https://scholar.google.com/*

Phase 1

Initially, the search focused on various combinations of the following keywords: “Coastal Cultural Landscape”; “Transformative Pathways Monitoring”; “Indicators.”

From the analysis of the methodologies emerging from this initial research phase, it was observed that the described pathways adopt a **flexible approach**. This trend placed significant emphasis on the concept of **resilience**, highlighting that the primary goal was **adaptation to climate change**.

Early warning and decision-support monitoring systems play a pivotal role in enabling adaptive processes. In this regard, several authors (Haasnoot et al., 2018 [3]; Kavale, 2022 [4]; Lawrence et al., 2020 [5]; Raso et al., 2019 [6]; Sparkes & Werners, 2023 [7]; Trewhella et al., 2022 [8]) have put forward a range of criteria. These contributions collectively converge on five key criteria, which together represent a comprehensive synthesis of the proposals and serve as a valuable reference framework for designing and evaluating monitoring systems that are not only effective and robust, but also aligned with the specific needs of decision-making contexts:

1. Salience: the system must be relevant to the needs of end users. Within this criterion, three specific aspects are identified:
    - **Measurability**: the ability to concretely observe the information outputs generated by the system.
    - **Timeliness**: the system’s ability to detect changes at an early stage, enabling proactive responses.
    - **Reliability**: the accuracy of the system, understood as a low likelihood of missing or erroneous signals.
2. Credibility: this refers to the scientific and technical robustness of the information provided. This criterion includes:
    - **Convincingness**: the degree to which the information is accepted by users, particularly when consistent with other available data sources.
    - **Institutional connectivity**: the political credibility of the outputs, meaning their sensitivity to the political and social context in which they are received.
3. Legitimacy: it concerns the system’s acceptance by users and the perceived fairness in its functioning. It is essential that the interests of stakeholders are adequately represented and considered.
4. Completeness: this refers to the system’s ability to comprehensively monitor all critical uncertainties that could affect the success of public policies or intervention strategies.
5. Parsimony: emphasizes the importance of an efficient approach, in which the volume of data used and produced is limited to what is strictly necessary to ensure completeness, avoiding unnecessary duplication or complexity.

Moreover, this first analysis of the monitoring approaches reveals several commonalities that are essential to their effectiveness.

First, a fundamental step shared across approaches is the **identification of hazards and indicators**. This involves recognizing potential risks and determining the specific elements to monitor, which serve as early warning signs or benchmarks to assess progress and anticipate challenges (Allison *et al.*, 2023 [9]; Haasnoot *et al.*, 2013 [2]; Haasnoot *et al.*, 2018 [3]; Kavale, 2022 [4]; Lawrence *et al.*, 2020 [5]; Raso *et al.*, 2019 [6]; Trewhella *et al.*, 2022 [8]).

The sources analysed highlight a wide range of risks and uncertainties that decision-makers must face, particularly in the context of climate crisis, where the central challenge is deep uncertainty. This refers to situations in which neither the probabilities of future outcomes, nor the impacts of decisions, nor the preferences of decision-makers are known (Haasnoot *et al.*, 2013 [2]; Raso *et al.*, 2019 [6]).

This uncertainty, in addition to being driven by climate change, is also fuelled by other external factors, such as population growth, technological innovation, economic evolution, and the changing values and social preferences over time (Haasnoot *et al.*, 2013 [2]; Haasnoot *et al.*, 2018 [3]; Kavale, 2022 [4]; Sparkes & Werners, 2023 [7]).

In the face of such complexity, traditional planning approaches—based on static scenarios or on a "most likely" future—prove inadequate, as they are unable to effectively respond to unexpected developments (Haasnoot *et al.*, 2013 [2]; Raso *et al.*, 2019 [6]).

The main climate hazard identified for coastal areas is **Sea Level Rise (SLR)**, which is critical for coastal and river basin management, though its timing remains uncertain (Allison *et al.*, 2023 [9]; Haasnoot *et al.*, 2013 [2]; Haasnoot *et al.*, 2018 [3]; Kavale, 2022 [4]; Lawrence *et al.*, 2020 [5]).

Types of indicators used to analyse and support risk management include:

1. Performance indicators
   These measure the **performance of systems in achieving objectives** (e.g., extent of flood damage, frequency of extreme events) (Haasnoot *et al.*, 2018 [3]).
2. Environmental or contextual indicators
   These monitor **external conditions that may pose threats or offer opportunities** (e.g., sea level, river discharge, precipitation intensity, anthropogenic pressures, technological developments, changes in social values and behaviours) (Haasnoot *et al.*, 2018 [3]; Trewhella *et al.*, 2022 [8]).
3. Socio-economic and cultural indicators
   These capture aspects such as demographic changes, land use, risk perception, insurance premiums, maintenance costs, area desirability, population vulnerability or

adaptation levels, and the financial constraints of institutions. These indicators are particularly useful for **decision-making when physical indicators are insufficient** (Allison *et al.*, 2023 [9]; Haasnoot *et al.*, 2018 [3]; Lawrence *et al.*, 2020 [5]; Trewhella *et al.*, 2022 [8].

4. Derived (proxy) indicators
   These are **indirect but representative measures**, such as the average summer flow of a river used as an indicator of drought conditions (Haasnoot *et al.*, 2018 [3], Raso *et al.*, 2019 [6]; Trewhella *et al.*, 2022 [8]).

Another key aspect is the emphasis on a **collaborative approach**. Successful monitoring relies on the active involvement of diverse stakeholders, including public agencies, local communities, and experts from various disciplines. This collaborative effort ensures that the monitoring system benefits from multiple perspectives, fostering a more comprehensive understanding of the context and building shared ownership of the process (Allison *et al.*, 2023 [9]; Bridges, et al., 2015 [10]; Cradock-Henry *et al.*, 2023 [11]; Dicks *et al.*, 2023 [12]; Langendijk *et al.*, 2024 [13]; Lawrence *et al.*, 2020 [5]; Sparkes & Werners, 2018 [7]; Stephens et al., 2018 [14]; Trewhella *et al.*, 2022 [8]).

Lastly, most approaches incorporate **projections and socioeconomic scenarios** to anticipate future conditions. These scenarios allow planners to consider how factors like population growth, economic trends, and technological advancements may interact with environmental changes, helping to design adaptive strategies that are both robust and flexible (Allison *et al.*, 2023 [9]; Chesterman, *et al.*, 2020 [15]; Cradock-Henry *et al.*, 2023 [11]; Dicks *et al.*, 2023 [12]; Haasnoot *et al.*, 2013 [2]; Kandiri *et al.*, 2022 [16]; Kavale, 2022 [4]; Langendijk *et al.*, 2024 [13]; Lawrence *et al.*, 2020 [5]; Sparkes & Werners, 2023 [7]; Stephens et al., 2021 [17]; Stroombergen & Lawrence, 2021 [18].

Phase 2

During the second phase of the review, focus was placed on the Dynamic Adaptive Policy Pathways (DAPP) framework (Haasnoot *et al.*, 2013) [2].

Unlike traditional methodologies, DAPP is explicitly designed for decision-making under deep uncertainty, avoiding reliance on a single forecast and instead supporting decisions that remain effective across a range of potential futures. Its dynamic and adaptive planning approach allows policies to evolve in response to emerging information and events, rather than adhering to a static plan with predefined contingencies.

By using **pathways**, flexible sequences of actions aimed at achieving long-term goals, the framework facilitates strategic transformation rather than rigid planning. Additionally, DAPP integrates a **continuous monitoring system** as a crucial element, enabling timely and proactive adjustments.

The resulting strategies are robust, designed to perform satisfactorily across multiple future scenarios, thereby increasing the resilience of policy choices in uncertain and evolving contexts.

The method was originally developed to support adaptation planning for flood risk management in the Netherlands, specifically in the Lower Rhine Delta (Haasnoot et al., 2013 [2]). Since then, it has been applied in various contexts around the world, including the United Kingdom—for London's water resources (Kingsborough et al., 2016 [19]) and for flood risk management in the Thames Estuary (Ranger et al., 2013 [20]), as well as in Australia for coastal flooding (Ramm et al., 2018 [21]). However, its most extensive use to date has been in real-world decision-making processes in New Zealand, where it has been employed to address risks related to flooding, coastal hazards, and sea-level rise (Allison et al., 2023 [9]; Dicks et al., 2023 [12]; Kavale, 2022 [4]; Lawrence et al., 2013 [22]; Lawrence et al., 2019 [23]; Stroombergen & Lawrence, 2022 [18]).

The DAPP approach, as outlined by Haasnoot et al., 2013 [2], consists of the following 8 steps (Figure 1):

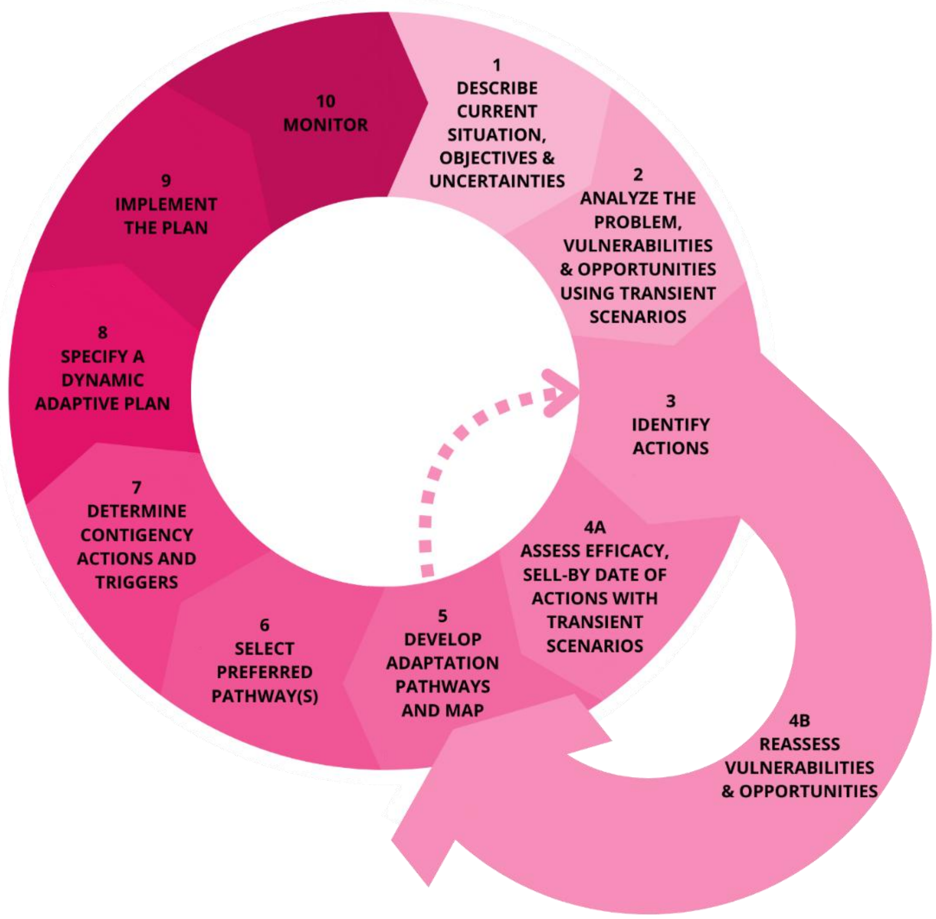

Figure 1: Development of DAPP as outlined by Haasnoot et al., 2013 [2]

1. Description of the study area: this initial step involves describing the characteristics of the system, its objectives, the constraints in the current situation, and potential constraints in future situations. The result is a **definition of success**.

2. Problem analysis: in this phase, the current situation and possible future situations (reference cases, scenarios) are compared with the specified objectives to identify potential **gaps** (indicating the need for action), **opportunities** (developments that help achieve objectives), and **vulnerabilities** (developments that hinder the achievement of objectives).

3. Identification of possible actions: possible actions that can be undertaken to achieve the defined success are identified, considering the identified opportunities and vulnerabilities. The goal is to build a rich **set of potential actions**.

4. Assessment of actions: the effects of each individual action are assessed to identify their "**sell-by date**," meaning the point at which they no longer meet the objectives. Ineffective actions are discarded.

5. Development and mapping of adaptive pathways: using information from the previous steps, pathways are assembled. A pathway consists of a sequence of actions, where a new action is triggered when the previous one can no longer achieve the defined success. The result is an ***Adaptation Map*** summarising the logical potential pathways to success.

6. Selection of one or more preferred pathways: pathways that align well with a specified perspective are selected. These pathways form the foundation of a dynamic adaptive plan.

7. Determination of contingency actions and triggers: to keep each preferred pathway on track toward success, contingency actions are defined and linked to a **monitoring system**. Actions can be of three types:
   - **Defensive actions:** measures taken to clarify the baseline plan, preserve its benefits, or address external challenges without altering the baseline plan.
   - **Corrective actions:** adjustments to the baseline plan.
   - **Capitalisation actions:** measures taken to seize opportunities that can improve the performance of the baseline plan.
   - **Plan reassessment:** initiated when critical analyses and assumptions underlying the plan's success are no longer valid.

8. Specification of a dynamic adaptive plan: the results of the previous steps are translated into a plan that answers the question: *given the uncertainties about the future, what actions/decisions should we take now (and which ones can be postponed)?* The plan summarises the results (objectives, issues, potential and preferred pathways) and specifies the actions to be taken immediately, those to be taken now to keep future adaptation options open, and the monitoring system.

9. Implementation of the dynamic adaptive plan: the initial actions specified in the plan (those to be taken immediately) are implemented.

10. Monitoring: the monitoring system, defined in Step 7, is established.

Monitoring within a DAPP framework is grounded in a series of key elements (Figure 2), namely: indicators, signals, triggers and adaptation thresholds.

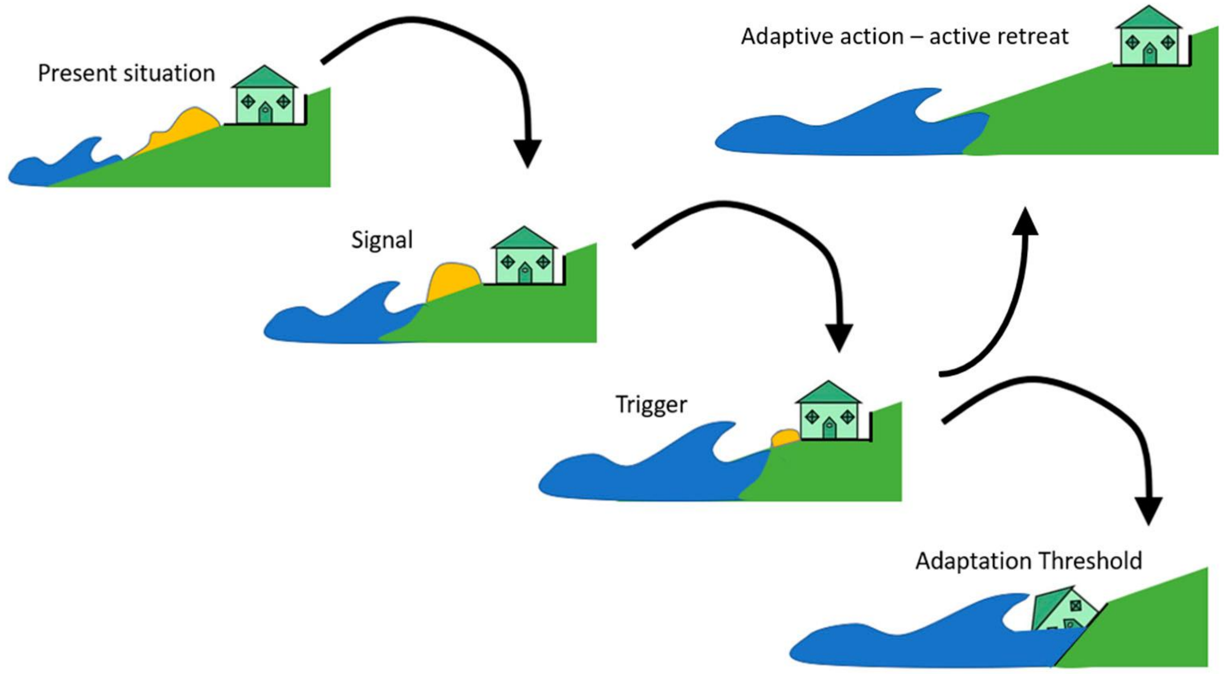

Figure 2: An example sequence of events under climate change.
DAPP uses the trigger to instigate a change in action to avoid the adaptation threshold occurring (Allison et al., 2023 [9])

Indicators, also referred to as "signposts," are elements monitored to signal when a potential risk or trigger is approaching or to assess whether the plan is achieving its intended objectives (Allison et al., 2023 [9]).

Adaptation thresholds, also called "adaptation tipping points," are critical failure thresholds that must be avoided, as they indicate the point beyond which current strategies are no longer sustainable or effective in meeting the plan's objectives. These thresholds are linked to the performance of the system of concern and are often defined in relation to extreme events that could cause significant social disruption (Allison et al., 2023 [9]; Stephens et al., 2018 [14], 2021 [17]).

Triggers, also referred to as "decision points," are values reached by an indicator that represent critical decision-making moments. At these points, the effectiveness of ongoing actions must be reviewed, and, if necessary, new adaptive pathways and actions should be selected to avoid reaching the adaptation threshold or critical limit. A trigger defines the conditions under which pre-established actions must be undertaken to adjust the plan (Allison et al., 2023 [9]; Lawrence et al., 2020 [5]; Haasnoot et al., 2013 [2]).

Signals, also known as "early warning signals," are values of indicators suggesting significant changes that a trigger may be approaching. These act as alarms, enabling decision-makers to prepare for necessary actions (Allison et al., 2023 [9]).
Signals and triggers are chosen relative to the adaptation threshold, based on the likelihood that they will occur before the adaptation threshold is reached (Lawrence et al., 2020 [5]).

2.2 The Relevance of the DAPP Approach in the Context of Cultural Landscapes

Cultural landscapes, understood as areas whose character results from the historical interaction between natural and human factors and that hold significant cultural value for the communities inhabiting them, are complex systems that face increasing threats related to climate change, natural hazards, and additional stressors such as pollution and over-tourism (see *D1.3 - Policy report on Climate Change impacts on European Coastal Cultural Landscapes* [24]). The imperative to protect and enhance the resilience of these landscapes in the face of an uncertain future highlights the relevance of adopting flexible and dynamic planning approaches, such as the DAPP methodology.

The DAPP approach is specifically designed for planning under deep uncertainty. Rather than proposing a single, rigid plan, it promotes the development of **flexible and adaptive strategies (pathways)**. This aligns with the RescueME objective of developing Transformative Resilience Pathways, sequences of incremental actions that address urgent short-term challenges while steering toward long-term transformative change. These pathways integrate disaster risk management and adaptation actions, with **monitoring** as a key component.

Therefore, the integration of the DAPP methodology within the RescueME framework provides a structured approach to planning and monitoring resilience in cultural landscapes.

Building on the ten steps of the DAPP framework, this integration unfolds as follows (Figure 3):

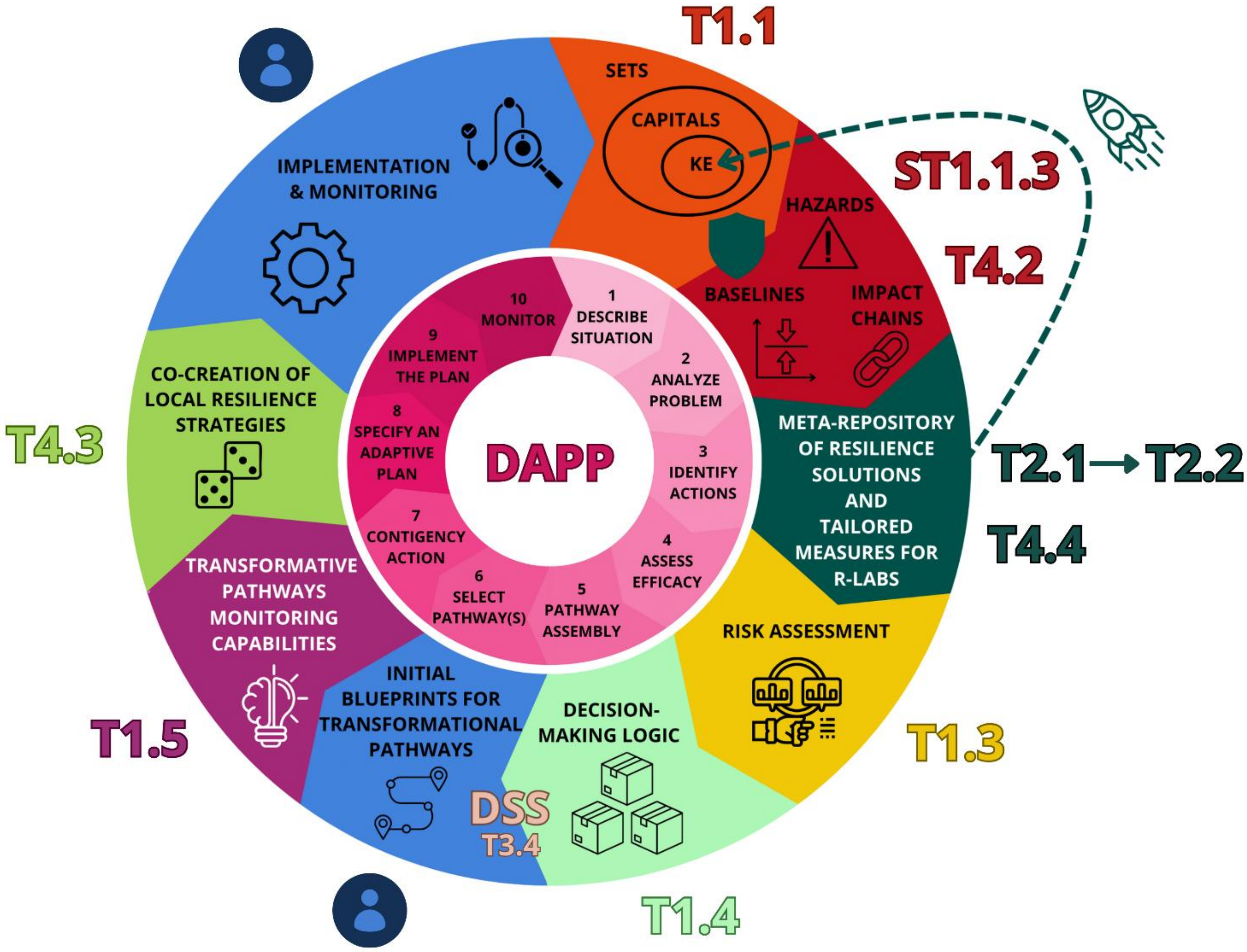

Figure 3: The diagram illustrates the integration of the DAPP methodology within the RescueME framework

1. Description of the study area/system: in RescueME, this corresponds to the conceptualization of cultural landscapes as SETS, described through the five **capitals** and the identification of **key elements** that enhance their resilience. This foundational work is carried out under **T1.1 -** ***Structure of the model & indicators and metrics for characterisation of European CL, hazards and climate scenarios***, which defines the fundamental guidelines of the project (see *D1.1 – Actionable resilient historic landscape framework* [25]).

2. Problem analysis: in RescueME, this involves characterising **hazards** and stressors (e.g., climate change, natural hazards, pollution, over-tourism) that may affect capitals and their key elements. This is addressed in **ST1.1.3 -** ***Hazard and stressor characterisations and climate scenarios***, which is responsible for providing a database of indicators to characterise hazards (such as climate change and natural hazards) and stressors (e.g. air pollution and over-tourism) and their interconnectedness (see *D1.1 – Actionable resilient historic landscape framework* [25]). **T4.2 –** ***Co-creation of resilience baseline***

and Impact Chains also contributes to this phase, as its main objective is to develop, implement, and assess a resilience baseline and to co-create impact chains with each R-Lab, which are integrated and used by different WP1 tasks ensuring that the analyses and strategies developed are deeply rooted in the specificities and needs of local communities. A resilience baseline is an initial assessment of the health and capacity of a system to cope with and recover from adverse events or changes. In the context of the RescueME project, it serves to identify the current state of resilience in Coastal Cultural Landscapes. Impact chains, on the other hand, are cause-effect relationships that describe the pathways through which a climate risk or stressor leads to specific impacts on elements of the cultural landscape and the corresponding adaptation responses (see D4.3 - *Local resilience baseline and local Impact Chains for R-labs* [26].

3. Identification of potential adaptive actions: RescueME focuses on identifying and characterising **Resilience Solutions**, which may be heritage-based, nature-based (NBS), rooted in the circular economy, cultural and creative sectors (CCSI), or involve financial and governance innovation. These solutions are collected, mapped and systematised in **T2.1 - *Meta-repository of resilience solutions for Cultural Landscape*** and **T2.2 - *Strategies from Cultural Industries and Innovative resilience financing***. Resilience solutions are defined in RescueME as practices, products, processes, actions, and initiatives available from both previous research projects that represent innovative, cooperative, and applicable strategies for resilience, closely connected to culture and the environment, aimed at addressing climate change, natural hazards, and societal and other crises. T2.2 integrates and systematizes the knowledge developed in T2.1, exploring replicable approaches to include the Cultural and Creative Sectors (CCS) in transformative resilience strategies. It also identifies economic and financial models capable of attracting regenerative capital for heritage conservation, thereby reducing reliance on public funding. The identified best practices are analyzed for their adaptability and replicability, taking into account resources, governance, local challenges, territorial impacts, and stakeholders (see *D2.1 - RescueME resilience meta-repository* [27]). At this stage, **T4.4 - *Co-creation of local resilience measures and solutions*** can also be integrated. The task focuses on identifying, collecting, and co-developing context-tailored resilience measures, building on solutions from the meta-repository that address the key issues identified in the five R-Labs, and co-creating new measures through consultations with these.
4. Assessment of actions' effectiveness under different scenarios: in *RescueME*, this is carried out in **T1.3 - Multiscale risk and resilience assessment of coastal cultural landscape**, which aims to quantify the impacts of climate change and natural hazards on cultural landscapes, as well as on their heritage values and ecosystem services. The overall objective is to develop a risk assessment based on predictive models, to better understand how climate events affect the different components of resilience, including both tangible and intangible assets (see *D1.4 - Predictive models of R-labs* [28]).

5. Pathway assembly: RescueME supports this step through **T1.4** - ***Decision making for pathways blueprints***, that aims to develop an integrated methodology to support the decision-making process aimed at enhancing the resilience of CCLs. Specifically, T1.4 involves the definition of innovative packages of measures, grouped according to their compatibility and effectiveness. The selected measures are drawn from the solution meta-repository developed in T2.1 and are linked to the predictive impact modelling carried out in T1.3, in order to quantify their expected effects. This methodology will be implemented within the Incremental Spatial Decision Support System (ISDSS), a digital platform developed in **T3.4 - *One stop shop for resilience in cultural landscapes & Incremental SDSS***.

6. Selection of preferred pathways: the decision-making logic developed within T1.4 will enable end users to build *initial blueprints for a Transformational Pathway*, which can be customized based on the local context, innovation capacity, and the specific needs of the territories involved.

7. Identification of contingency actions: this aspect is addressed in **T1.5**, which identifies the **methodology for selecting monitoring indicators** capable of tracking resilience progress for key elements within each R-Lab as the pathways are implemented. For each indicator, values for **signal**, **trigger**, and **adaptation threshold** must be defined, in accordance with the DAPP monitoring system.

8. Specification of an adaptive plan: in RescueME, this is strongly supported by **T4.3** - ***Application and co-evaluation of the Resilient Landscapes serious game for co-creation of resilience strategies in the case studies*** focuses on the co-creation of local resilience strategies with stakeholders using a **serious game**, which integrates some key problems identified in T4.4.

9. Implementation: the concrete implementation of these solutions takes place at the local level, where users employ the Incremental Spatial Decision Support System (ISDSS) and the solutions identified in the meta-repository to design and implement the most appropriate measures for their specific context.

10. Monitoring: to assess the effectiveness of the implemented strategies, local stakeholders carry out continuous monitoring based on the capabilities provided through T1.5.

2.3 Gaps and Limitations of the DAPP Approach

The DAPP methodology, although widely acknowledged as a valuable instrument for planning under conditions of deep uncertainty, presents several conceptual and practical challenges that may limit its effective application:

- **Lack of specificity and prescriptive guidance**: as a high-level framework, DAPP can be operationalized in a variety of ways. While this flexibility may be advantageous in some contexts, it can also reduce clarity regarding how to design a detailed and actionable plan suitable for real-world implementation (Haasnoot *et al.*, 2013 [2]).
- **Difficulties in representing complexity and uncertainty**: one of the core challenges lies in accurately capturing the multifaceted nature of uncertainty and complexity, both in terms of scientific knowledge and data, and in relation to the social and institutional dimensions of decision-making processes (Cradock-Henry *et al.*, 2023 [11]).
- **Complexity in defining threshold values**: the identification of adaptation thresholds and trigger points is inherently complex, as it requires the anticipation of how climate change and other dynamic factors will affect specific indicators over time (Allison *et al.*, 2023 [9]).
- **High resource intensity**: The application of DAPP typically demands significant investments in time, expertise, and coordination. This includes access to technical specialists, the development of context-specific tools such as surveys or models, and thorough processes to ensure internal coherence and validity (Dicks *et al.*, 2023 [12]; Kandiri *et al.*, 2022 [16]).
- **Not a "quick and easy" solution**: particularly in complex domains, such as river flood risk management, DAPP implementation is neither simple nor immediate. It often encounters institutional, technical, and procedural barriers that may hinder its integration into planning practices (Lawrence *et al.*, 2020 [5]).

In conclusion, while the DAPP framework offers a structured and adaptive approach to decision-making under uncertainty, its application requires careful consideration of context-specific constraints and a substantial commitment of resources. To fully realize its potential, further methodological refinement and institutional support are essential.

3 Identification of monitoring indicators

This chapter outlines the process of identifying monitoring indicators within the integrated RescueME-DAPP framework. The adopted methodology is based on the RescueME meta-repository (see *D2.1 – RescueME resilience meta-repository* [27]), a tool for mapping existing solutions, and develops through an integrated selection of hazards, solution categories, capitals, and key elements. The goal is to identify, within a given solution, the aspects capable of strengthening the resilience of the considered key element, and based on these, to define the corresponding monitoring indicators (**section 3.1**).

The applicability of this methodological approach was tested on a small scale during the fifth RescueME General Assembly, held in Zadar from February 18 to 20, 2025. For each R-Labs, two solutions were selected from the meta-repository, chosen from those originally identified by that R-Labs. During the workshop, each R-Lab worked on identifying, for at least one of the two selected solutions, monitoring indicators accompanied by signals, triggers, and adaptation thresholds (**section 3.2**).

Based on the contributions collected, a quantification of the indicators was carried out, including threshold values for signals, triggers, and adaptation thresholds. Examples that emerged include: the reduction of expected damage in the event of a flood (HAM), soil moisture content (IDEON), civic participation during festivals (LNV), deformation velocity for landslide monitoring (PV5T), and atmospheric pollutant concentration (ZADAR). These analyses highlighted the versatility of the DAPP model and its applicability across diverse contexts (**section 3.3**).

Finally, the validation phase with the R-Labs confirmed the methodological robustness of the proposed framework, while allowing for further refinement of the indicators based on the feedback received, thus improving their alignment with local contexts (**section 3.4**).

3.1 Methodology for Monitoring Indicators' collection

To initiate the process of identifying monitoring indicators within the RescueME framework, it was deemed appropriate to start with one of its core components: the meta-repository. This tool was designed to map and systematise existing solutions aimed at strengthening the resilience of cultural landscapes, both at the community and systemic levels. The collected solutions are made accessible to support adaptive planning and foster continuous improvement.
Starting from this tool and taking into account the approach defined during the review phase, it was possible to advance the activities of T1.5 by outlining a series of steps for

identifying indicators capable of measuring the effectiveness of solutions in strengthening the resilience of key elements.

The first step involves the integrated **selection of three fundamental components**: one solution category, one hazard and one capital. This initial combination allows for a clear definition of the operational scope of the monitoring process.

Subsequently, the selected solutions are analysed to identify **the specific aspects that directly impact the considered key elements of the selected capital**. These aspects are then grouped into macro-themes, understood as coherent sets of actions or approaches that holistically contribute to enhancing resilience.

For each macro-theme, **specific monitoring indicators are defined**, aimed at measuring the impact of the implemented solutions on the resilience of the identified key elements. Each indicator is associated with the three fundamental components of monitoring according to the DAPP approach: signals, triggers, and adaptation thresholds.

For example, as illustrated in the Figure 4 diagram, following the selection of a specific solution category (Nature-Based Solutions, NBS), one hazard (pluvial flood), one type of capital (human), and one key element (education), the aspects of the solutions within the NBS category that influence the key element “education” within human capital are identified. For illustrative purposes, three solutions are considered: (1) the development of green spaces through a participatory approach, research projects, and on-site training activities; (2) the design of an urban park aimed at educating the population through direct experience and seminars on climate risks; (3) the regeneration of a degraded area that included participatory processes. In this simplified case, the educational and training-related aspects of the solutions are grouped into five macro-categories: participatory approach, research projects, seminars, in-site training, and experiences in green spaces. Based on these macro-categories, monitoring indicators are defined. For instance, for the macro-category “in-site training,” the proposed indicators are the “number of training activities” and the “participation rate.” These indicators enable the monitoring of progress, or regress, regarding the resilience of the key element “education.” For each indicator, early warning signals (e.g., decreasing participation), decision triggers (e.g., significant decline), and adaptation thresholds (e.g., persistent decrease) are identified, in line with the DAPP approach.

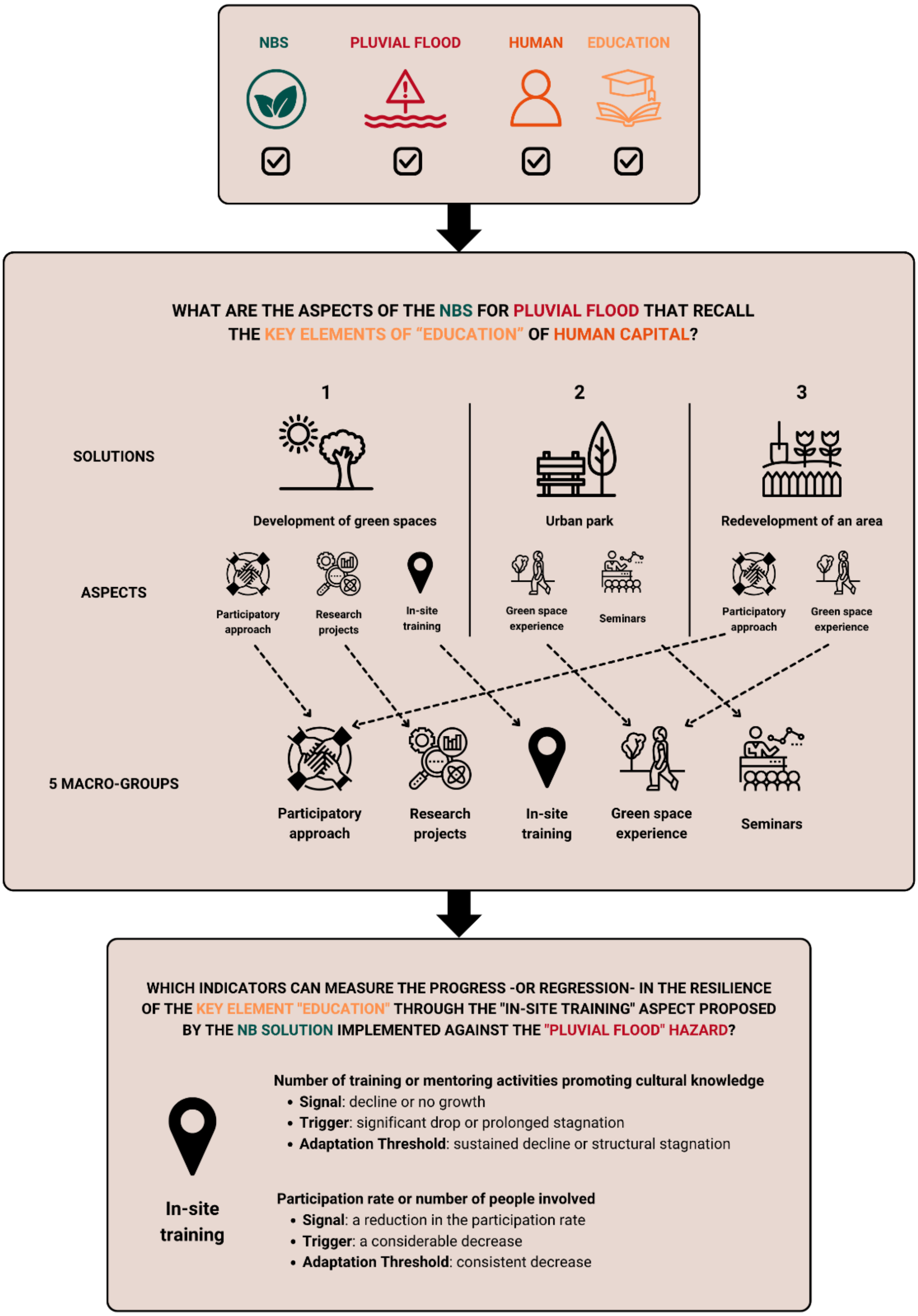

Figure 4: The diagram illustrates an example of a methodological pathway for identifying monitoring indicators based on the solutions included in the meta-repository

The applicability of this methodological framework was tested during the **fifth RescueME General Assembly, held in Zadar from 18 to 20 February 2025**.

The workshop was conceived as a small-scale **methodological exercise**, not intended to implement solutions directly, but to test the applicability of the DAPP approach within the RescueME project framework. At the same time, it served to evaluate the capacity of the five R-Labs to identify effective monitoring indicators based on the solutions compiled in the project's meta-repository.

By engaging the R-Labs in this methodological test, the project strengthens its overarching objective: contributing to the development of more resilient, aware, and sustainable territories in the long term. Each R-Lab functions as a key demonstrator and validation site, located in diverse European contexts:

- Neuwerk, Germany (**HAM**)
- Psiloritis UNESCO Global Geopark, Greece (**IDEON**)
- L'Horta de València, Spain (**LNV**)
- Portovenere, Cinque Terre & the Islands, Italy (**PV5T**)
- Zadar, Croatia (**ZADAR**)

For each R-Labs, two solutions from the meta-repository were selected, chosen specifically from those originating from the R-Labs themselves. In the selection process, an effort was made to cover a wide variety of key elements, also considering the feasibility of the exercise within the limited context of the workshop.

The selected solutions underwent the methodological steps previously described for the identification of monitoring indicators. Specifically, for each solution, one hazard, one capital and one key element were selected. Subsequently, relevant aspects of the solutions were identified that could contribute to enhancing the resilience of the selected key elements for the considered capital in relation to the identified hazard.

During the workshop, each R-Lab was asked to identify, for at least one of the two solutions selected, monitoring indicators, accompanied by signals, triggers and adaptation thresholds.

3.2 R-Labs' contributions and links with other defined indicators

The activity carried out during the in-person workshop represented a key moment in the collaborative process with the various R-Labs. The responses that emerged from direct discussions were recorded on a virtual whiteboard on Conceptboard[2], a tool that enabled the immediate and visual collection of contributions. However, the work did not end with the physical meeting: additional time was granted to the R-Labs to continue asynchronously, online, even after the General Assembly. This allowed each R-Lab to further develop their reflections, adapting to local timing and specificities, thereby strengthening the collaborative dimension of the entire process.

The information collected was subsequently systematised in an Excel file (appendices 1-5), which included not only general data related to each solution (identified risk, involved capital, key element), but also a first attempt at mapping the indicators identified by the R-Labs and those already identified within the RescueME project (particularly the **Resilience Indicators defined in the *D1.1 – Actionable Resilient Historic Landscape Framework*** [25] and those modelled in the **T1.3**), as well as the **Key Performance Indicators (KPIs) from RURITAGE project** (Egusquiza et al., 2020 [29]). This systematisation phase aimed to support methodological alignment and to create operational connections among the various local experiences.

Overall, the activity produced satisfactory results. Despite the limited availability of structured data or technical documentation to support the solutions – often reduced to a few qualitative descriptions – the exercise was well understood and enabled the collection of valuable contributions for the future definition of resilience monitoring indicators. At the same time, the numerous interactions with the R-Labs highlighted certain challenges, particularly the difficulty of defining quantitative values for alert, activation, and adaptation thresholds. These limitations, however, were not seen as obstacles but rather as opportunities to refine approaches and tools, in the spirit of a shared and progressive construction.

In conclusion, this activity highlighted the value of a **collaborative and multi-level approach**, where each R-Labs was able to contribute based on their own knowledge, expertise, and data availability. The process supported the emergence of local indicators capable of interfacing with the project's methodological references, laying the groundwork for a shared, flexible, and context-adaptable resilience monitoring system. Despite the inevitable challenges, the commitment and active engagement of the R-Labs, even beyond the workshop, served as a concrete example of co-creation, strengthening not only the quality of results but also the sense of ownership and legitimacy of the project's actions.

[2] Conceptboard (2025). *Visual Collaboration Platform*. Available at: *https://conceptboard.com*

3.3 Quantification of Values for Signals, Triggers, and Adaptation Thresholds

This paragraph outlines the approach adopted for the **definition and quantification of specific monitoring indicators**, developed based on inputs gathered during the workshop or, where appropriate, by linking to indicators already defined in this or other projects.

For each R-Lab, a representative indicator of the dynamics of interest was identified, selected according to its relevance, the robustness of the available bibliographic references, and the possibility of obtaining measurable parameters even in the absence of direct data from the local context, thereby maintaining the analysis at the level of a methodological exercise. For each indicator, signals, triggers, and adaptation thresholds were then defined, primarily derived from the analysis of scientific sources. These values play a key role in monitoring the effectiveness of the proposed solutions, enabling the early detection of potential issues and guiding, when necessary, the adoption of corrective measures.

HAM

For HAM, the focus was placed on **reducing building damage caused by flood events**, specifically using the indicator "Expected damage reduction" (Table 1).

The sources consulted (Galasso, Pegnolato & Parisi, 2021 [30]; Gnan et al., 2022 [31]; Leal et al., 2021 [32]; Paprotny et al., 2021 [33]) extensively discuss the use of hydrological and hydraulic simulations aimed at modelling water depth and velocity during flood events, alongside the analysis of damages observed from past events to derive fragility and vulnerability curves. These simulations were considered in the evaluation process as being applied to progressively higher levels of solution implementation (e.g., green roofs).

Within this process, the statistical evaluation of expected damage reduction plays a crucial role. In particular, the importance of using appropriate statistical tools to determine whether observed changes are statistically significant emerges. To this end, the p-value was used, a central concept in statistical hypothesis testing.

The **p-value** represents the probability of observing a result at least as extreme as the one obtained, assuming that the null hypothesis is true. In this context, the null hypothesis corresponds to the ineffectiveness of the strategy in reducing damage. A very low p-value (typically below a significance threshold, e.g., 0.05) suggests that the observed result is unlikely under the null hypothesis, justifying its rejection.

In this case, the p-value was considered a statistical tool for monitoring the effectiveness of the adopted solution over time. Specifically, it was established that a failure to achieve a significant damage reduction, evidenced by a persistently high p-value (e.g., > 0.05), may indicate that the implemented strategy is inadequate and that an update of the planned actions is necessary. In line with the DAPP framework, such a situation constitutes an adaptation threshold, signalling the need to revise the strategic plan or adopt corrective measures.

MONITORING INDICATOR	SIGNAL	TRIGGER	ADAPTATION THRESHOLD
Expected Damage Reduction	**Early Signs show limited/unclear impact** Preliminary analysis of monitoring data (e.g., updated hydrological/hydraulic simulations that account for the green roofs installed to date, or analysis of observed damages if events have occurred) or statistical evaluation of expected damage reduction indicates a trend toward a lower-than-expected reduction for the current implementation phase. Alternatively, there may be a change in expected reduction that appears to be trending toward statistical significance or near-significance, but has not yet reached the conventional threshold (e.g., p-value close to 0.05, such as 0.06 or 0.075)	**No significant impact midway** Analysis of data over a longer time period, or after a significant portion of the strategy has been implemented (e.g., after planting 50 out of 100 planned hectares), shows that the reduction in expected damage is not statistically significant (p-value greater than 0.05)	**Full implementation shows no effect** Despite full or near-full implementation of the 100 hectares of green roofs, the expected damage reduction remains negligible or not statistically significant over a long monitoring period (e.g., p-value consistently well above 0.05, or even a p-value < 0.05 indicating a negative impact, although this is unlikely in this specific context)

Table 1: Values quantification starting from HAM T1.5 workshop inputs

IDEON

In the case of IDEON, the indicator used was the **Volumetric Water Content (VWC) of the soil**, with specific reference to the surface layer (Table 2).

This measure represents an indicator of soil moisture conditions (Wang et al., 2025 [34]; Yu et al., 2021 [35]). The relevance of the surface layer is widely acknowledged in scientific literature, as it exhibits the greatest variability in soil moisture and provides an adequate representation of overall water conditions. Moreover, it shows significant correlations with deeper soil moisture (Wang et al., 2025 [34]). Therefore, surface soil moisture is often used as a representative indicator of the overall water status of the soil, with measurements typically covering the 0–10 cm and 10–30 cm layers (Fu et al., 2022 [36]; Wang et al., 2025 [34]).

The reviewed sources emphasise the identification of soil drought through standard deviations from the historical mean of moisture (Wang et al., 2025 [34]), and the importance of measurements conducted at different depths (Fu et al., 2022 [36]; Oorthuis et al., 2023 [37]; Rasheed et al., 2022 [38]; Wang et al., 2025 [39]).

A central concept in the above studies is the **critical soil moisture threshold (*Θcrit*)**, defined as the moisture level below which plant water stress begins to significantly limit soil transpiration and evapotranspiration (ET) (Fu et al., 2022 [36]). Once this threshold is crossed downward, even a marginal decrease in moisture leads to a reduction in evapotranspiration and an increase in sensible heat flux, marking the onset of water stress conditions.

The threshold ***Θcrit*** has also been associated with water stress affecting photosynthetic processes, which tend to manifest concurrently with limits on evapotranspiration (Fu et al., 2022 [36]).

It is important to note that ***Θcrit*** values vary significantly across different biomes and climatic contexts. The global average is estimated at 14.0% ± 0.9%, indicating that values between 8% and 20% are plausible for a wide range of ecosystems (Fu et al., 2022 [36]).

MONITORING INDICATOR	SIGNAL	TRIGGER	ADAPTATION THRESHOLD
Soil moisture	**Soil moisture decrease below historical average** Volumetric Water Content (VWC) of the soil measured in the surface layer (e.g., 0-30 cm) decreases by a percentage corresponding to 1 standard deviation below the historical average for the same period	**Critical soil moisture threshold and vegetation water stress** Attainment of the critical soil moisture threshold (Θcrit). Θcrit defines the point at which evapotranspiration begins to be significantly limited by the availability of water in the soil. A further decrease in soil moisture leads to a reduction in evapotranspiration and an increase in sensible heat flux, indicating the onset of water stress for vegetation. For Mediterranean ecosystems, it is hypothesized that this critical threshold (Θcrit) in the surface layer (0-30 cm) may range between 8% and 20% of the soil volumetric water content (VWC)	**Exceeding the critical soil moisture threshold (Θcrit)**
	Sustained monthly decline in soil VWC across multiple depths Continuous decrease in VWC of at least 5-10% on a monthly basis for three or more consecutive months, measured by sensors at different soil depths		

Table 2: Values quantification starting from IDEON T1.5 workshop inputs

LNV

Regarding LNV, the validation activity began with a preliminary reflection on **how to measure human capital**. Traditionally, human capital has been quantified through schooling-related indicators, such as average years of education or school enrolment rates. The *United Nations Human Development Index* (HDI), one of the most internationally recognized indices, also uses schooling as a proxy for human capital (Angrist et al., 2021 [39]).

However, the implicit assumption that mere school attendance translates into actual learning is often problematic, as it does not always correspond to the expected returns according to theoretical growth models. To overcome these limitations, Angrist et al. (2021) [39] propose an approach that integrates schooling with the direct measurement of **competencies acquired**, through the use of standardised tests.

Although the study is based on global-scale datasets, an attempt was made to apply these concepts to the specific context of the "Miradors de l'Horta" festival, with the aim of monitoring the **level of education**, one of the KPIs foreseen by the RURITAGE project, which showed a possible connection with the indicator "Participation of civil society in festivals" identified by the R-Lab during the workshop.

Hence, the hypothesis of introducing, during the festival, a testing activity related to the cultural landscape of the Horta of Valencia. The proposed indicator for evaluation is the average score obtained and its variation over time, across different editions of the festival, in order to detect any improvements or deteriorations in the quality of acquired skills.

MONITORING INDICATOR	SIGNAL	TRIGGER	ADAPTATION THRESHOLD
Average score obtained in a test on acquired skills	**Average score remains the same**	**Consistent average score across festival editions** The average score remains the same even after several editions of the festival	**Highly Significant Results** If the p-value drops further, for example, $p \leq 0.01$, the result is considered highly significant. This indicates that the observed drop has only a 1% chance or less of being due to chance, making it a very strong signal. In this case, one can seriously consider adapting strategies or interventions, because the variation in scores is very likely real and important
	Near-Threshold *p-Values* *p-value* close to 0.05 (i.e., 5%), such as 0.06 or 0.07, which means that the value isn't yet beyond the threshold to consider the change "statistically significant," but it is close	**Significant decrease in average score over time** A statistically significant decrease in the average score, that is considered when, across multiple evaluation cycles (i.e., at later points in time), the average score drops and the p-value is below the established significance level, typically 0.05	

Table 3: Values quantification starting from LNV T1.5 workshop inputs

PV5T

As for PV5T, the analysis began with the element related to **landslides**, identified as a potential signal during the workshop. A review of the literature highlighted that **surface deformation velocity** — i.e., the rate at which the Earth's surface moves or deforms — is a key parameter for identifying, monitoring, and forecasting landslide phenomena, and is therefore essential for risk management (Casagli et al., 2023 [40]; Genevois, Tecca & Genevois, 2022 [41]) (Table 4).

This can be measured using Synthetic Aperture Radar Interferometry (InSAR) technology, which enables millimetric ground displacement measurements, providing deformation rates useful for monitoring instability. In particular, a slight acceleration in ground movement, detected through InSAR time series and exceeding normal seasonal variations, may represent an early warning signal of instability. These time series can detect acceleration signals even prior to a potential collapse (Cai et al., 2023 [42]), making this parameter a critical element for activating mitigation measures.

MONITORING INDICATOR	SIGNAL	TRIGGER	ADAPTATION THRESHOLD
Surface Deformation Velocity	**Slightly accelerating surface deformation detected by insar** The surface deformation velocity, measured through InSAR or local monitoring, shows a slight acceleration detected via InSAR that exceeds normal seasonal fluctuations (e.g., shifting from a stable average velocity to a consistent slight increase, while remaining < 15 mm/year)	**Deformation velocity exceeds a predefined trigger threshold** Based on the Varnes classification, a consistent exceedance of 15 mm/year (the upper limit for "extremely slow") could act as a trigger, or a significant acceleration even at lower velocities	**Threshold of Monitoring Capability Loss** A deformation velocity indicating an imminent risk of collapse or movement exceeding monitoring capability (e.g., "complete loss of coherence" in InSAR data, meaning the coherence between two SAR images is so low that no reliable displacement measurement can be made for that time interval. The signal has become too noisy or has changed too much to be effectively compared). For landslides considered "active" but slow-moving, this threshold could be significantly higher than the trigger levels (e.g., consistent exceedance of high velocities)

Table 4: Values quantification starting from PV5T T1.5 workshop inputs

ZADAR

Finally, in the context of ZADAR, the selected indicator was the **annual average concentration of air pollutants attributable to road traffic**, using the World Health Organization's Air Quality Guidelines (AQGs) [43] as adaptation threshold values. To assess the statistical significance of observed variations over time, the *p-value* was applied (Table 5).

The WHO AQGs are evidence-based recommendations. They define threshold concentrations for specific air pollutants, associated with an averaging time, below which adverse effects on human health are negligible or significantly reduced. The AQGs differ from air quality standards, which are legally binding regulations set by regulatory authorities. In addition to setting threshold levels and reference times, standards also include guidance on monitoring techniques and data management.

The WHO AQGs serve as a support tool for designing policies and measures aimed at protecting public health and reducing pollutant emissions. Although not legally binding, they are an authoritative and evidence-based reference for policymakers and public health authorities in member countries.

MONITORING INDICATOR	SIGNAL	TRIGGER	ADAPTATION THRESHOLD
Annual concentration of PM2.5, PM10, NO2, and CO.	**Stable pollutant levels** After a certain amount of time from the implementation of the measure, a trend of stability is detected	**No significant reduction in pollutant concentrations** After a longer period of time, the observed decrease in pollutant concentrations is not statistically significant, as indicated by a *p-value greater* than or equal to 0.05. This suggests that any change from the previous year may be due to random fluctuations rather than a true improvement in air quality.	**Exceeding the limits set by the WHO** For too many days a year, air quality poses a health risk

Table 5: Values quantification starting from PV5T T1.5 workshop inputs

In conclusion, the quantification of signal, trigger, and adaptation threshold values represented a **key step in transforming the R-Labs' inputs from the workshop into measurable information**, thereby facilitating the understanding of the **practical dynamics of the DAPP methodology**.

3.4 R-Labs' validation of Values Quantification

The five R-Labs were involved in the validation phase of the methodological proposal concerning the quantification of the values for the signal, trigger, and adaptation thresholds. The objective of this phase was to verify the consistency and relevance of the choices in relation to the local solution contexts, within the framework of a methodological exercise.

Three R-Labs (**HAM**, **IDEON**, and **ZADAR**) confirmed the validity of the proposed analysis, expressing a favourable opinion without raising significant concerns.

LNV, while acknowledging the methodological soundness of the approach, highlighted some operational issues, particularly related to the difficulty of measuring certain learnings and skills acquired through evaluation tests administered to "free" participants in a festival setting. Following a clarifying exchange, in which it was reiterated that the exercise was methodological rather than implementational in nature, and that the chosen pathway was selected for its feasibility based on existing literature, LNV confirmed that there were no further comments and considered the work overall to be well-structured and well-founded.

PV5T, on the other hand, expressed a concern regarding an apparent misalignment between the proposed indicator (surface deformation rate) and the specific objective of the STONEWALLSFORLIFE solution, which is focused on the restoration of dry-stone terraces. In response, it was clarified that:

- The choice of the indicator stemmed from the emergence of the "landslides" issue during the workshop.
- Although the local project focuses on dry-stone walls, it aims to counteract landslide phenomena in terraced landscapes.
- Surface deformation rate was selected due to its traceability and the availability of scientific references.

Subsequently, an additional specific indicator related to the "degradation rate of dry-stone walls" (Agnoletti, et al., 2015 [44]) was incorporated (Table 6), following which PV5T expressed its agreement with the proposed framework.

MONITORING INDICATOR	SIGNAL	TRIGGER	ADAPTATION THRESHOLD
Rate of collapse or structural alteration of dry-stone walls Measures the frequency and extent of damage (such as collapses, deformations, or landslides) affecting dry stone walls within a specific area and time period.	**Rising minor damages signal approaching threshold** Increase in the number of reports of minor damage or small-scale failures along dry-stone walls. This indicates that, although there are no major collapses yet, the frequency or severity of minor issues is increasing, suggesting that the indicator (rate of collapse/alteration) is approaching a threshold where the current strategy becomes ineffective	**Annual collapse threshold exceedance** The annual collapse rate reaches or exceeds a predefined threshold, for example, if a significant percentage of wall segments (e.g., ≥15%) within a management unit experience collapse within a year	**Collapse of dry-stone walls threatens terraced agriculture** Widespread collapse and severe structural alteration of dry-stone walls lead to significant loss or irreversible abandonment of the terraced agricultural area they support

Table 6: The additional specific indicator related to the "degradation rate of dry-stone walls" added for PV5T during validation of value quantification work

Overall, the validation phase confirmed the robustness of the adopted methodological framework, while also highlighting certain critical aspects, such as the difficulty of measurability in practice or the apparent non-linearity of the monitoring indicators identified with the local context. The feedback received made it possible to further refine the indicators, improving their alignment with local contexts.

4 Towards a structured system for monitoring transformative pathways: an extension of the T1.4 methodological framework

In the context of the Cultural Landscapes, the ability to monitor the evolution of adopted pathways in a structured and continuous manner is crucial to ensuring the effectiveness and adaptability of intervention strategies.

Building on the experimental approach developed on a small scale within the methodological exercise of the T1.5 workshop, this chapter proposes a theoretical extension that enables its application to more complex and articulated contexts.

Given the plurality of solutions and aspects to be integrated, there is a clear need for a conceptual framework capable of supporting the construction and monitoring of adaptive and transformative strategies, in alignment with the theoretical framework developed under **T1.4**.

This chapter therefore presents such a framework, structured according to the DAPP methodological cycle, and outlines its main operational elements.

4.1 The conceptual framework: structure of the DAPP cycle

As Figure 6 diagram illustrates, the process begins with a **systematic description of the study area**, corresponding to Phase 1 of the DAPP cycle, dedicated to context analysis. In this initial phase, a thorough reading of the cultural landscape is carried out. Each form of capital is graphically represented by dark orange circles and is further broken down into key elements, which highlight its specific features and transformative potential.

This is followed by Phase 2 of the DAPP cycle, focused on problem analysis. In this phase, the main external threats and pressures (**hazards**) that could undermine the resilience and sustainability of local systems are identified.

The analysis of these hazards serves as a prerequisite for activating the DSS which integrates solutions from the meta-repository.

The DSS is conceived as a dynamic and adaptable tool, aimed not only at selecting the strategies most consistent with the identified context and risks, but also at progressively integrating advanced monitoring capabilities. This integration is intended to ensure that the governance system remains adaptive over time, with the ability to recalibrate interventions in response to ongoing transformations.

The user accesses the DSS through the ATLAS access point, developed within the framework of **T1.2 -** ***ATLAS of European Coastal Heritage Landscapes Typologies and Climate Change Impacts***, and conceived as an online interactive visualization platform designed to present, in a user-friendly manner, knowledge related to the typologies of European coastal cultural landscapes, based on the five "capitals", and their impacts associated with climate change and other threats (see *D1.2 - ATLAS of European coastal heritage landscapes typologies and climate change impacts* [1]).

The output of the decision-making phase is the definition of a **strategic blueprint**, understood as an integrated configuration of strategy packages (visualised as mint green squares), selected based on their internal consistency and transformative potential.

From the blueprint, the **implementation phase of the transformative pathways begins**, in which each package is monitored through a set of indicators, selected to detect relevant signals of change.

When the trigger point of one or more indicators is reached, a reorientation mechanism is activated, restarting the DAPP cycle. This **iterative logic**, graphically represented by circular arrows, ensures the progressive adaptability of the decision-making system and the possibility to learn from the outcomes of the strategies already implemented.

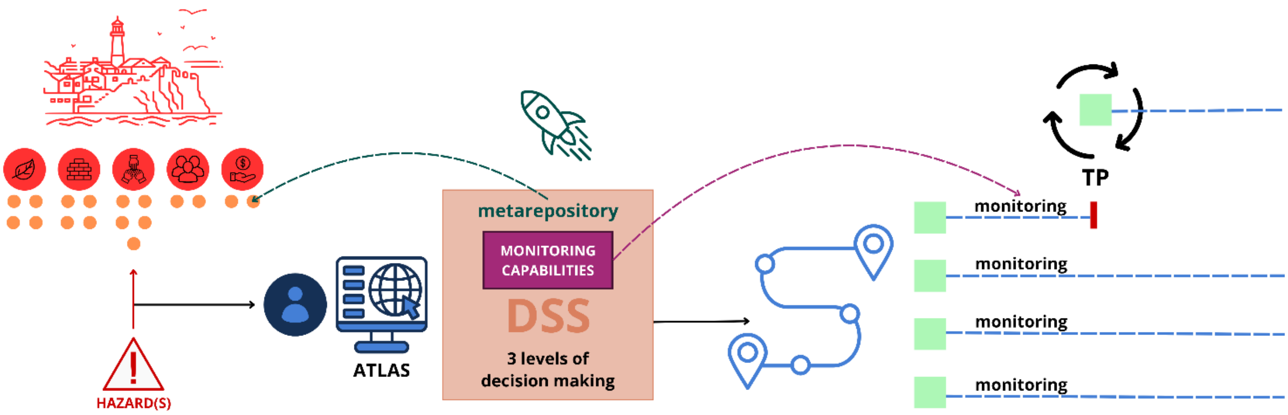

Figure 5: Conceptual framework capable of supporting the construction and monitoring of adaptive and transformative strategies, in alignment with T1.4

4.2 Future perspectives

The adoption of the methodological framework described here enables the structured, coherent, and flexible monitoring of transformative pathways, even in complex and dynamic contexts.

The extension of the approach developed in the T1.5 exercise toward a systemic perspective is grounded in the integration of context analysis, risk assessment, decision support, and continuous adaptation capabilities.

Future activities aim to further consolidate this methodological structure, with particular attention in two main directions: on one hand, the refinement of monitoring tools, both in terms of indicators and evaluation processes; on the other, the strengthening of the transformative nature of the adopted strategies through increased R-Labs interaction.

The **ultimate goal** is to build a monitoring system truly capable of guiding territories along sustainable, resilient, and long-term-oriented trajectories.

5 Conclusion and perspectives

Deliverable D1.6 of the RescueME project has established a robust and adaptive methodological framework for monitoring transformative pathways, with a particular focus on complex and uncertain coastal cultural landscapes.

Key points and main outcomes:

- DAPP Approach: the document thoroughly examined the operational principles of the DAPP approach, highlighting its ability to overcome the limitations of traditional planning and to support effective decision-making across a range of possible futures.
- Core Elements of DAPP Monitoring: the crucial roles of indicators, signals, decision triggers and adaptation threshold were clearly defined, demonstrating how these components work together to enable timely and proactive plan adjustments.
- RescueME-DAPP Integration: the deliverable detailed how the DAPP method aligns with the objectives of RescueME, from conceptualizing cultural landscapes as Socio-Ecological-Technical Systems (SETS) to defining transformative resilience pathways and implementing locally driven actions through community engagement.
- Indicator Identification Methodology: a practical methodology was developed and tested for collecting indicators, based on the RescueME meta-repository. This methodology integrates the selection of solution categories, hazards, capitals, and key elements.
- Engagement with R-Labs: practical activities involving the R-Labs demonstrated the applicability and versatility of the DAPP model across diverse local contexts. These activities facilitated the identification of context-specific resilience indicators and the quantification of signal values, decision triggers, and adaptation thresholds (e.g., flood damage reduction, soil moisture levels, civic participation, ground deformation rates, air quality). Despite challenges in defining quantitative thresholds, collaborative engagement strengthened the quality of outcomes and fostered a strong sense of project ownership.
- Validation of Framework Robustness: The validation phase carried out with the R-Labs confirmed the robustness of the adopted methodological framework, while also enabling further refinement of indicators to better reflect local conditions.

Future Outlook:

The work conducted lays the foundation for the development of a structured, coherent, and flexible monitoring system capable of guiding resilient trajectories. This iterative, learning-based approach is essential to ensure the adaptability of decision-making systems in the face of ongoing transformations.

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7 Appendices

							GA ZADAR - T1.5 WORKSHOP: HAM CONTRIBUTE						
							How to monitor the improvement in the resilience of the considered key elements?				Possible links with other indicators		
Title	ID	Solution domain	Description	Selected hazard	Selected capital	Considered key element	What are the aspects of the solution for the selected hazard that could improve the resilience of the considered Key Elements of the selected capital?	Monitoring Indicators	Signals	Triggers	Adaptation Thresholds	RI D1.1	RURITAGE KPIs	T1.3 indicators
Green roof strategy Hamburg	HAM_05	AGT	The aim of the strategy is to plant a total of 100 hectares of roof area in the city of Hamburg. The green roof strategy means more quality of life in the city. It combines in a new and innovative way the urban development policy goal of sustainable land development with the climate policy objectives of climate adaptation and climate protection.	Pluvial flood	Built	Buildings	**Resilience of existing and future buildings to pluvial flooding through the implementation of green roofs.** This is achieved through: - **Runoff reduction:** Green roofs absorb a significant portion of rainwater, reducing the volume and speed of surface runoff that can cause flooding. - **Improved urban drainage:** Green roofs help alleviate pressure on the urban drainage system, preventing overload and flooding. - **Building protection:** Green roofs can protect buildings from water damage by reducing the risk of infiltration and mold. - **Temperature regulation:** Green roofs help mitigate the urban heat island effect, reducing extreme temperatures and lowering the risk of intense weather events.	Runoff reduction	No/insufficient run-off reduction	Damage occurring (e.g. high volume of surface runoff)	New baseline showing that another different strategy is needed			Flood control service providing area
								Amount of water in drainage system before and after the implementation by comparing similar rainfall events	No/insufficient improved urban drainage	Damage occurring	New baseline showing that another different strategy is needed			
								Building protection	No/insufficient building protection	Damage occurring	New baseline showing that another different strategy is needed			Number of water management bodies/structures Level of conservation of buildings
								Temperature changes before, during and after the implementation of strategy	No/insufficient temperature regulation	Damage occurring	New baseline showing that another different strategy is needed			
Climate information system	HAM_07	AGT	What climatic changes is Hamburg confronted with? How are temperature, precipitation and sunshine developing? The key weather data from the last few decades for observing the climate in Hamburg is compiled here	Pluvial flood Heat waves Drought	Social	Governance	**Disseminating information and raising public awareness about the risks associated with the hazards**, as well as promoting preparedness and adaptation actions. This is achieved through: - **Provision of information:** The system provides up-to-date data and information on the impacts of climate change in Hamburg, including heat waves. - **Impact monitoring:** The system monitors the effects of heat waves on the city and its population, identifying the most vulnerable areas and at-risk groups. - **Communication and awareness:** Through the portal, the system informs citizens on how to prepare and respond to extreme weather events, such as heat waves. - **Research involvement:** The system includes information on ongoing research related to climate and society, fostering a better understanding of climate risks and possible solutions.	Click on website/social media etc	Number of people affected by extreme events/not knowing about the information provided is not improving	Information does not reach residents	Information does not reach residents as they are not prepared => rethink on how to provide residents with the information and improve preparedness		Number of citizens engagement activities and participants	Households with access to the internet at home Households with access to the internet at home Individuals who never use the internet
								Level of preparedness of people for extreme events (via questionnaire)						Participation rate in education and training

Appendix 1: HAM T1.5 workshop inputs

								GA ZADAR - T1.5 WORKSHOP: IDEON CONTRIBUTE						
Title	ID	Solution domain	Description	Selected hazard	Selected capital	Considered key element	What are the aspects of the solution for the selected hazard that could improve the resilience of the considered Key Elements of the selected capital?	How to monitor the improvement in the resilience of the considered key elements?				Possible links with other indicators		
								Monitoring Indicators	Signals	Triggers	Adaptation Thresholds	RI D1.1	RURITAGE KPIs	T1.3 indicators
Psiloritis Enhancement plan	IDEON_04	AGT	Under RURITAGE project Psiloritis UNESCO Global Geopark contacted and implemented an Enhancement Plan aiming to enhance and promote local natural and cultural heritage, together with the excellent quality products, and transform them into a strong and recognizable development tool, that will raise local proud and improve well-being of inhabitants and visitors. The area of Psiloritis UNESCO Global Geopark in collaboration with its partners and stakeholders has established a strong attitude on local resilience mainly against natural induced disasters. The main objectives of this plan are referring to: Develop better living conditions for inhabitants and provide safer and more enriched experiences to the visitors by conserving natural environment and promoting Psiloritis unique landscape; to support local sustainable development through the identification, valorisation, enhancement and marketing of local agricultural, dairy and cultural products; to reveal and exploit the value and development potential of culture and social life of Psiloritis by raising quality and improve management of cultural and social events and ; to increase local resilience in respect to pandemics and other non-identified threats. The plan supported Human, Social, and Natural Capital and the Financial too.	All	Social	Intangible	**Safeguarding, transmission, and enhancement of traditions, knowledge, social practices, rituals, festive events, artistic expressions, and traditional craftsmanship that contribute to the identity and cohesion of rural communities.** This is achieved through: - **Identification and documentation of ICH**: Mapping traditions, knowledge, and local practices at risk of disappearing. - Community involvement: Promoting active participation of community members, especially young people, in the safeguarding and transmission of ICH. - **Support for traditional activities**: Providing assistance to artisans, farmers, and other practitioners who keep local traditions alive. - **Integration of ICH into tourism**: Enhancing ICH as a sustainable tourist attraction, offering visitors authentic and engaging experiences. - **Use of digital tools**: Leveraging digital technologies to document, promote, and transmit ICH to future generations.	Productivity of traditional cultivations	Lower productivity of cultivations (olive oil, wine, fruits)	Loss of traditional cultivation practices	Loss of cultural landscapes and cultural identity	Availability of products with designation of origin or geographical indications (PDO, PGI), traditional specialties guaranteed (TSG)		Incentives for the maintenance of traditional agricultural activities
														Area used for traditional cultivations
Moisture management and rainwater harvesting in olive groves by Cretanthos Olive Park & Museum	IDEON_08	NBS	Gutters from the roof top: 40% of the rainwater ends up in underground tanks in a pit that is closed with insulation. From the tank water is pumped and irrigated for the olive groves. This practice can be applied to businesses with existing canopies or sustainable businesses.	Drought	Natural	Green and blue infrastructure	**Soil Management and Water Conservation**: Organic farming helps preserve soil. Healthy soil rich in organic matter has a greater water retention capacity, reducing the need for irrigation and increasing crop resilience during drought periods. **Biodiversity and Wild Flora**: Organic farming promotes biodiversity. The presence of various plant and animal species helps create a more stable and resilient ecosystem, better able to cope with water stress. **Reduction of Greenhouse Gas Emissions**: Organic farming contributes to reducing greenhouse gas emissions. This can be achieved through carbon sequestration in the soil.	Soil moisture measurements (real-time or periodically)	50% moisture	30%	Insolid soil exacerbated if it is poor in organic matter			
								Ground temperature measurement	Over 30 degrees for 5 continuous days	Over 40 degrees for 5 days + low soil moisture	–			Annual mean temperature
								Ground water level	Drop of more than 30 meters in a month	Continuous drop > 20 meters for 3 months (?)	–			Level of conservation of buildings
								Visual elements in the plants health	Signs of dryness in olive tree's leaves (leaves start to wrinkle). Also, premature change of color of leaves in autumn	Early ripening at a fast pace (especially Koroneiki variety The fruit of the olive becomes intensly purple	The change of color of leaves and leaves falling down early persist all year long. If a fast and sudden water comes in large quantities, and not "irrigation", it can also cause the fruit to fall			
								Biodiversity plant status every year	Loss of more 20%	loss of more than 40%	–	Ecological diversity (Shannon-Evenness index) Green areas of high ecological quality	Value of ecosystem services	Surface cultivated with olive trees Agricultural area of holdings with Mixed crops - livestock Share of agricultural area of holdings with Mixed crops - livestock Green areas of high ecological quality Habitat and species maintenance Share of green areas of high ecological quality Shannon Evenness Index
								Insect presence (bees?) annual monitoring	Loss of 30% of species	Loss of 50% of species	–			Habitat and species maintenance

Appendix 2: IDEON T1.5 workshop inputs

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Title	ID	Solution domain	Description	Selected hazard	Selected capital	Considered key element	What are the aspects of the solution for the selected hazard that could improve the resilience of the considered Key Elements of the selected capital?	GA ZADAR - T1.5 WORKSHOP: LNV CONTRIBUTE How to monitor the improvement in the resilience of the considered key elements?				Possible links with other indicators		
								Monitoring Indicators	Signals	Triggers	Adaptation Thresholds	RI D1.1	RURITAGE KPIs	T1.3 indicators
Horta-Cuina	LNV_12	FBS	Horta-Cuina is a programme aimed at facilitating and consolidating healthy, sustainable and quality food based on a firm commitment to agricultural production in l'Horta de València and neighbouring regions, recognising the school canteen as a key driver for education in values, the guarantee of the right to food, respect for the environment and the enhancement of our territory. It is an organisation of agro-ecological producers who distribute to school canteens in the city of Valencia.	Agricultural abandonement	Financial	Economy	**Supporting the local agricultural economy and creating value by promoting organic, fresh, local, and seasonal agricultural products in school cafeterias**	Number of farmers in Horta-Cuina	Decrease of farmers	<10	Cancellation of contracts with shool canteen enterprises	Total number of farm business Agricultural unempoyment rate		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)
								Decrease of sales	–	< profit margin under ???? Profitable	–			
								Lack of financing for ???	–	–	–			
Miradors de l'Horta - ephemeral art festival whose theme is about sustainable development, food sovereignty and the relationship between agricultural and urban territories	LNV_15	AGT	The festival, already established since 2019, is gaining participation from more and more municipalities in the region. The ephemeral installations that during each month of October are located in different points of crop fields and places related to agriculture connect, on the one hand, citizens in general, farmers and artists from various disciplines who reflect on a different theme each year. . The artistic festival is joined by activities such as local markets, educational workshops and socialization events to bring the problems of farmers, cultivation territory and the enhancement and survival of heritage aspects to a general public. Each year a municipality in the region is chosen to host the main artistic installation, the Agora. In this facility the main activities are carried out, as we have already mentioned local markets, talks, conferences and through art the agrarian and agricultural heritage of the region is made known, which currently suffers from problems of abandonment of crops and loss of traditions due to not continuity of new generations.	Urban degradation and environmental decline leading to a decrease in the quality of life and well-being; changes in socio-cultural context	Human	Education	**Promotion of knowledge, awareness, and the skills necessary to preserve and enhance the cultural landscape of the Horta of Valencia, improving the quality of life and well-being of the community**	Lack of public financing for the event	–	–	–		Number of recreational facilities/events	
								Participation of civil society in festivals	–	–	–	Highly educated working age persons	Level of education	Attendance and participation in cultural activities and events

Appendix 3: LNV T1.5 workshop inputs

<table>
<tr><th colspan="8"></th><th colspan="4">GA ZADAR - T1.5 WORKSHOP: PV5T CONTRIBUTE</th><th colspan="3"></th></tr>
<tr><th rowspan="2">Title</th><th rowspan="2">ID</th><th rowspan="2">Solution domain</th><th rowspan="2">Description</th><th rowspan="2">Selected hazard</th><th rowspan="2">Selected capital</th><th rowspan="2">Considered key element</th><th rowspan="2">What are the aspects of the solution for the selected hazard that could improve the resilience of the considered Key Elements of the selected capital?</th><th colspan="4">How to monitor the improvement in the resilience of the considered key elements?</th><th colspan="3">Possible links with other indicators</th></tr>
<tr><th>Monitoring Indicators</th><th>Signals</th><th>Triggers</th><th>Adaptation Thresholds</th><th>RI D1.1</th><th>RURITAGE KPIs</th><th>T1.3 indicators</th></tr>
<tr><td rowspan="9">Stonewalls4life</td><td rowspan="9">PV5T_01</td><td rowspan="9">H</td><td rowspan="9">Stonewalls4life aims at repairing drystone walls and ensuring their long-term maintenance, to protect the territory and its inhabitants against the effects of extreme weather events. Drystone walls are thus environmentally relevant since they can effectively improve both the resistance and the resilience of the territory to climate change.

Stonewalls4life highlights the social and cultural value of drystone walls and supports their restoration by bringing together experienced builders with migrants and unoccupied people, thus facilitating their job placements and social inclusion. The project develops through 3 steps: 1) vegetation removal in abandoned terraces, 2) restoration of drystone walls and drainage channels, and 3) assignment of the lots for long term productive use and maintenance.</td><td rowspan="9">Landslides</td><td rowspan="9">Natural</td><td rowspan="9">Agriculture</td><td rowspan="9">Restoration and maintenance of dry stone walls as a multifunctional tool for climate change adaptation and the protection of agricultural land.</td><td>Weather patterns (rain quantity, soil humidity,etc)</td><td>–</td><td>–</td><td>–</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Agriculture economic indicators (number of workers, farms, etc)</td><td rowspan="2">–</td><td rowspan="2">Funds to farmers</td><td>Irreversible decline of agriculture sector</td><td>Crops surface</td><td></td><td rowspan="2">Agricultural area</td></tr>
<tr><td>Economic activities conversion (toward tourism)</td><td>Area with arable crops</td><td></td></tr>
<tr><td>–</td><td>Landslides</td><td>–</td><td>–</td><td></td><td></td><td></td></tr>
<tr><td>–</td><td>Flood</td><td>–</td><td>–</td><td></td><td></td><td></td></tr>
<tr><td>–</td><td>% of abandonded terraces/fallen stonewalls</td><td>–</td><td>Large abandonment of terraced areas</td><td>Percentage of abandonment of terraces on the total terraced area</td><td></td><td>Percentage of abandonment of terraces on the total terraced area</td></tr>
<tr><td>–</td><td>–</td><td>Maintenance of pedestrian paths</td><td>–</td><td></td><td></td><td></td></tr>
<tr><td>–</td><td>–</td><td>Monitoring activities by the National Park</td><td>–</td><td></td><td></td><td></td></tr>
<tr><td>–</td><td>–</td><td>Maintenance of terraces and dry stone walls</td><td>–</td><td></td><td></td><td></td></tr>
</table>

Appendix 4: PV5T T1.5 workshop inputs

								GA ZADAR - T1.5 WORKSHOP: ZADAR CONTRIBUTE						
Title	ID	Solution domain	Description	Selected hazard	Selected capital	Considered key element	What are the aspects of the solution for the selected hazard that could improve the resilience of the considered Key Elements of the selected capital?	How to monitor the improvement in the resilience of the considered key elements?				Possible links with other indicators		
								Monitoring Indicators	Signals	Triggers	Adaptation Thresholds	RI D1.1	RURITAGE KPIs	T1.3 indicators
Performance of permeable	ZADAR_03	H	As part of the project ZADAR HERITAGE - Integrated cultural program of the City of Zadar 2020, more than 100 parking spaces were removed from the medieval Walls of the Zadar rebellions and the space was repurposed into a pedestrian zone, i.e. a promenade with landscaped green zones. In addition to the preserved hundred-year-old row of holm oaks, 20 new trees were planted. 2274 seedlings of higher shrubs, 7513 seedlings of lower shrubs, perennials and ground covers.	Heat waves	Financial	Turism	Enhancing the value of historic walls as a **sustainable tourist attraction by offering visitors a more pleasant and comfortable experience while simultaneously mitigating the negative effects of heat waves** and increasing the economic value of the local tourism sector. This is achieved through: - **Creating a cooler microclimate**: expanding green areas (trees, shrubs, ground cover) helps lower the perceived temperature by providing shade and promoting evapotranspiration, thus reducing the impact of heat waves. - **Improving the tourist experience**: establishing a pedestrian zone makes visiting the historic walls easier and more enjoyable, encouraging tourists to spend more time in the area. - **Promoting sustainable tourism**: removing parking spaces and creating green areas encourage the use of alternative means of transportation and reduce the environmental impact of tourism.	Air quality	Continuous decrease in air quality measured on a yearly or other basis	Low air quality	–			Ratio of hours with Air Quality Index (AQI) higher than 2 Annual mean of NOx (NO+NO2) Annual mean of SO2
								Congestion of traffic in the old town	Frequent traffic jams during high season and weekends	High congestion in the city centre	Seasonal traffic jams collapse of traffic during peak tourist season			
								–	–	–	Extreme heatwaves			
Living streets, Zadar	ZADAR_06	AGT	Living Streets is a project financed under the LIFE program in which citizens are helped and at the same time encouraged to temporarily free their own streets from the congestion caused by cars and repurpose it into a street where the citizens themselves create congestion in a way that they can socialize with each other.	Poor air quality	Social	Social value	**Strengthening community ties and promoting social interaction through the reclaiming of public spaces.** This is achieved by creating livable streets, temporarily freed from cars, where residents can experience new forms of socialization, develop a sense of belonging, and actively participate in community life. The project aims to enhance cities' ability to engage citizens in energy issues and urban planning.	Community life activity levels (example, number of social events, gatherings, etc..)	–	–	Complete absnece of social activity		Number of citizens engagement activities and participants Number of participants in formal or informal voluntary activities or active citizenship in the last 12 months	Attendance and participation in cultural activities and events
								Amount of traffic present in the area	Lower air quality may indicate that we will reach a threshold for number of cars	The growing presence of cars, both parked and in traffic, affecting an area's social life and functionality	Extreme levels of traffic congestion. No parking space. No public areas are free			

Appendix 5: ZADAR T1.5 workshop inputs

RES
CUE
ME

8 Partners

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