D3.5 Decision Support System

Version 2

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D3.5 Decision support system – Version 2

Summary

This deliverable presents the updated and final version of the ICARIA Decision Support System (DSS), building on the first version described in Deliverable D3.4. The DSS integrates climate projections, impact assessment workflows, resilience assessment, and adaptation planning within a single operational environment, with updates informed by system validation and feedback collected during WP4 trial activities.

Deliverable number	Work package	
D3.5	WP3	
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Document history

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List of Acronyms and Abbreviations

AAR	Affected Area Rate
AMB	Barcelona Metropolitan Area
API	Application Programming Interface
ASGI	Asynchronous Server Gateway Interface
AWD	Average Water Depth
BAU	Business-As-Usual
CLC	CORINE Land Cover Classes
CORINE	Coordination of Information on the Environment Product
CRS	Coordinate Reference System
CS	Case Study
CSF	Case Study Facilitator
D	Deliverable
DSS	Decision Support System
EU	European Union
FastAPI	Fast Application Programming Interface
FWI	Fire Weather Index
GIS	Geographic Information System
HTTP	Hypertext Transfer Protocol
KPI	Key Performance Indicator
kV	Kilovolt
OGC	Open Geospatial Consortium
QA	Quality Assurance
RAF	Resilience Assessment Framework
RAT	Resilience Assessment Tool

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SAR	South Aegean
SHP	Shapefile
SLZ	Salzburg
SSP	Shared Socioeconomic Pathways
T	Task
UI	User Interface
UX	User Experience
V	Version
WP	Work Package

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Executive Summary

ICARIA is a HORIZON Research and Innovation Actions project funded by the European Union (EU) under grant agreement 101093806. The project advances asset-level modelling to better capture the direct and indirect impacts of complex, cascading, and compound climate-related hazards, while supporting the identification and evaluation of effective adaptation strategies.

The ICARIA Decision Support System (DSS) (icaria.draxis.gr) serves as the project's central digital output, integrating climate projections, risk and impact assessment workflows, resilience evaluation tools, and adaptation measures into a unified decision-support environment.

Deliverable D3.5 documents the updated and final version of the DSS, consolidating the foundations established in the first version, as documented in Deliverable D3.4, and incorporating refinements and extensions introduced during the final development and validation phase. The second version of the DSS introduces a set of targeted improvements and functional extensions driven by WP4 trial feedback and planned development milestones. These include:

- Integration of new impact assessment workflows, namely the cascading Flooding on Substations workflow and the workflow for Windstorms on Powerlines.
- Formal introduction of differentiated user roles (Technician, Stakeholder, General Public), with structured role-based access control across all system functionalities.
- Enhanced geospatial visualisation of results, including dynamic styling of impact layers, standardised layer naming linked to project and scenario, explicit inclusion of units of measurement, and improved legends and attribute tables.
- Improved transparency and user guidance through downloadable input templates, refined terminology aligned with the ICARIA modelling framework, expanded methodological explanations, updated informational pop-ups, and clearer execution status feedback during impact assessments.
- Support for multi-hazard scenario configuration within the Project Manager, supporting interacting hazards.
- Map Viewer enhancements, including automatic centring on loaded layers, reordered climate projection catalogues by SSP and time horizon, in-map legend display, and administrative layer management tools
- Usability refinements across resilience assessment questionnaires, adaptation measure creation, navigation logic, and reporting outputs.
- Updated documentation and support materials, including a revised User Guide, Frequently Asked Questions, Privacy and Cookies Policy pages, and extended API documentation for Flood (substations) and Windstorm workflows.

By documenting the DSS in its final form, this deliverable supports sustained use of the platform beyond the project's lifetime. It provides a clear reference for future research activities, replication efforts, and potential operational uptake, while ensuring that ICARIA's scientific results remain accessible through a practical and transparent decision-support tool.

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1 Introduction

The ICARIA DSS is designed to support informed decision-making for climate adaptation by integrating risk and impact assessment, resilience evaluation, and adaptation planning within a single platform. It addresses the fragmentation and complexity of conventional tools by enabling structured analysis of climate risks and responses through a unified and accessible environment.

By combining hazard, exposure, and vulnerability information with resilience and adaptation workflows, the DSS supports consistent assessment at both asset and regional scales. Its outputs are designed to be transparent, traceable, and suitable for communication across technical and non-technical contexts, facilitating comparison of scenarios and prioritisation of adaptation options.

Deliverable D3.5 constitutes the updated and final version of the ICARIA Decision Support System documentation, following Deliverable D3.4 (Lavasa et al., 2025). Its primary purpose is to document the evolution of the DSS during the final implementation period of the project, incorporating updates derived from system refinement, testing activities, and feedback collected during the later stages of ICARIA.

Rather than reintroducing the full scope and design of the DSS, which are comprehensively documented in D3.4, this deliverable focuses on highlighting progress, clarifying updates, and ensuring traceability between the two versions. The DSS functionalities, architecture, and workflows are therefore presented selectively, depending on whether changes have been introduced since the initial release.

The updates presented in this deliverable reflect the final development, validation, and consolidation activities carried out for the ICARIA DSS. In particular, they translate observations and feedback gathered during hands-on trial use in WP4 into targeted interface-level refinements, feature additions, improvements in result presentation and interpretability, and confirmations of system behaviour and stability under realistic usage conditions. These changes were deliberately designed to preserve the underlying analytical workflows and methodological foundations established in D3.4, while enhancing clarity, usability, and transparency.

A detailed overview of the specific actions undertaken during this period is provided through updated action lists and documented adjustments corresponding to the final phase of DSS development and validation.

1.1 Comparison to Deliverable 3.4

Deliverable 3.4 provides a complete and detailed description of the ICARIA DSS, including its objectives, system architecture, core functionalities, user workflows, and deployment setup. That content remains the baseline reference for the DSS.

In the present deliverable, the following documentation approach is applied:

- **Sections that have been updated** since Version 1 are explicitly revised, with changes clearly

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described and contextualised.

- **Sections that remain unchanged** are not repeated in full. Instead, they are briefly summarised and explicitly referenced to D3.4, accompanied by a clear statement indicating that the corresponding functionality or configuration remains the same.

This approach allows the deliverable to clearly communicate what has evolved since D3.4, while maintaining a transparent link to the original documentation.

1.2 Deliverable Structure

The deliverable is structured into eight (9) distinct chapters:

- Chapter 1: Serves as an introduction, explaining the interconnections with other work in ICARIA and providing a summary of the DSS action plan.
- Chapter 2: Describes updates in the methodology of the DSS.
- Chapter 3: Revises the key user groups and outlines the system's core services.
- Chapter 4: Walks through the key changes of the DSS's interface following version 1.
- Chapter 5: Summarises the system's architecture, technology stack, and data integration.
- Chapter 6: Summarises the deployment setup and introduces the updated user permissions.
- Chapter 7: Presents the main insights from the ICARIA case studies testing.
- Chapter 8: Provides the main purpose of the DSS after the project closure.
- Chapter 9: Offers an overview of the key outcomes and insights from the DSS updated version.
- Appendices:

The following appendices were included in D3.4 and remain valid as reference material documenting the DSS design and conceptualisation phases: Appendix 1 - User Scenarios, Appendix 2 - User Stories and Requirements, Appendix 3 - Design Mock-ups, Appendix 4 - User Testing Scripts, and Appendix 5 - Resilience Assessment Framework (RAF) Assessment Questions. These appendices are not reproduced in the present deliverable.

Instead, the current deliverable retains and updates the following appendices, which remain relevant for the final version of the DSS:

- Appendix 1 (no.6 in D3.4): User Guide, providing instructions for accessing and using the DSS.
- Appendix 2 (no.7 in D3.4): ICARIA Processing API Documentation for Impact Assessment.
- Appendix 3 (no.8 in D3.4): Data Management Statement.

1.3 Action Plan of the DSS

The development of the DSS followed a structured process, moving from scoping and requirements to technical implementation, Quality Assurance (QA) and Pilot Testing. Table 1 summarises the action plan for the DSS throughout the duration of the project.

Table 1: Action plan of the ICARIA DSS.

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#	Action	Running period
1	Scope definition and implementation plan	M6-M8
2	Requirements elicitation: user stories and requirements documentation from iterative sessions with the coordination team/case study facilitators)	M9-M13
3	Functional design: specification of functional requirements, data requirements, interactive mock-ups (iterative cycles and validation)	M14-M18
4	Data collection: climate projections, impact assessment data for each workflow (hazard data, vulnerability functions, exposure data)	M14-30
5	Technical design: system architecture, technical requirements, development plan, establishing/coordinating connections with external services	M19-M22
6	Documentation of three impact assessment workflows and development of algorithms	M20-32
7	Development (front and backend) of version 1	M25-M33
8	External service integration: Resilience Assessment Tool application, adaptation measures, impact assessment calculation service	M27-M33
9	Internal Quality Assurance testing	M31-M33
10	D3.4 preparation and submission	M33
11	WP4 trials support and structured feedback collection from trial and mini-trial facilitators and stakeholders	M34-M36
12	Case study trials execution: trials across pilot areas	M34-M36
13	Continuous support for service integration	M34-M39
14	Extension and refinement of impact assessment workflows	M34-M38
15	Development and integration of version 2 updates	M36-M38
16	Case study trials execution: mini-trials across pilot areas	M37-M38
17	Quality assurance and validation	M37-M39
18	User guide and technical documentation updates	M38
19	Updated deliverable D3.5 preparation and submission	M38

1.4 Interdependencies with Other Work Packages

The development of the ICARIA DSS is tightly interlinked with work carried out across the project, with Task 3.4 acting as the main integration point that translates ICARIA's scientific outputs into an operational platform. DRAXIS led the technical development and system integration, in close collaboration with the project coordination team led by AQUATEC.

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Based on the theoretical approach defined by the ICARIA holistic modelling framework (WP1), the conceptualisation of the DSS brought together results from risk and impact assessment, resilience assessment, and adaptation measures, ensuring that these components function cohesively within a single platform. AQUATEC, AIT, and NCSR-D, acting as case study facilitators (CSF), defined regional data requirements and contextual needs, while AIT and FIC contributed climate projection data and impact assessment samples. In parallel, ICARIA tool providers supported the integration of established methodologies, with LNEC contributing the Resilience Assessment Framework, NCSR-D the Resilience Assessment Tool, and CETAQUA the adaptation measures portfolio. Building on these inputs, CERTH documented and developed the impact assessment workflows for floods, wildfires, and windstorms, corresponding to the hazards addressed in the case studies.

All major design outputs, including functional requirements, interactive mock-ups, and integration plans, were reviewed and validated by the Project Management Team and the ICARIA consortium, ensuring alignment with project objectives and user needs.

From an implementation perspective, the DSS depends on continuous interaction with multiple WPs. Taxonomies, climate projections, hazard models, and vulnerability functions developed in WP1 and WP2 provide the analytical foundation of the system, including representations of cascading and compound events, while WP3 integrates these outputs into the DSS through the resilience tools and adaptation measures. WP5 supports dissemination and stakeholder engagement activities linked to the DSS, and WP6 ensures consistency with data management, quality assurance procedures, and project-wide standards.

Lastly, the DSS features presented in this deliverable have been validated through a series of trial and mini-trial activities carried out under WP4, involving stakeholders from all three ICARIA CS regions. These trials followed a structured and harmonised approach (Figure 1), using guided scripts to test the core DSS workflows, including project and scenario management, risk and impact assessment execution, resilience assessment, map-based exploration of results, and reporting. Across the trials, participants confirmed the relevance and practical value of the DSS for climate risk and adaptation planning, particularly in terms of integrating complex data, supporting scenario comparison, and producing interpretable outputs for decision-making.

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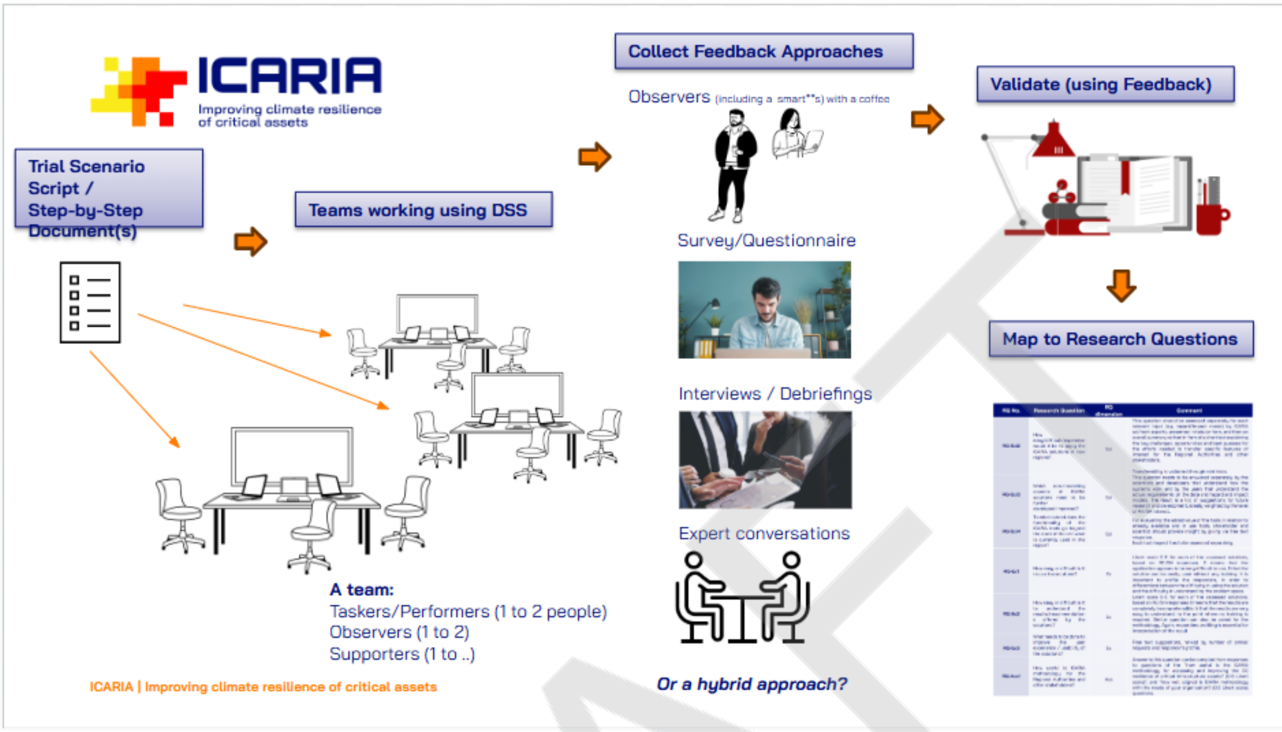

Figure 1: Trial activities high-level description.

The trials also provided consolidated feedback on usability and system behaviour. Overall, users found the main workflow logic understandable and the analytical outputs meaningful, while identifying areas for incremental improvement such as clearer system feedback during long-running processes, enhanced contextual guidance, and refinements to visual navigation elements. These insights informed minor interface-level adjustments and confirmations documented in this deliverable. Detailed descriptions of the trial execution and case-specific findings are provided in D4.2 (de la Cruz et al., 2026) and summarised in the dedicated trial sections in Chapter 7.

Through these interdependencies, the DSS functions both as an integrator of ICARIA's scientific results and as their practical interface, enabling coordinated use of the project's methods, data, and tools within a single decision-support environment.

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2 Methodological Basis of the DSS

The ICARIA DSS is based on four core pillars (risk and impact assessment, resilience assessment, adaptation measures, and climate projections), which are used within a single framework that supports climate adaptation planning and comparison of options.

The system evaluates adaptation, impact, and resilience using project-defined indicators, and applies them across baseline, business-as-usual and adaptation conditions. This allows users to compare results across scenarios and indicators and identify adaptation strategies that perform well under different future conditions. The overall framework is illustrated in Figure 2.

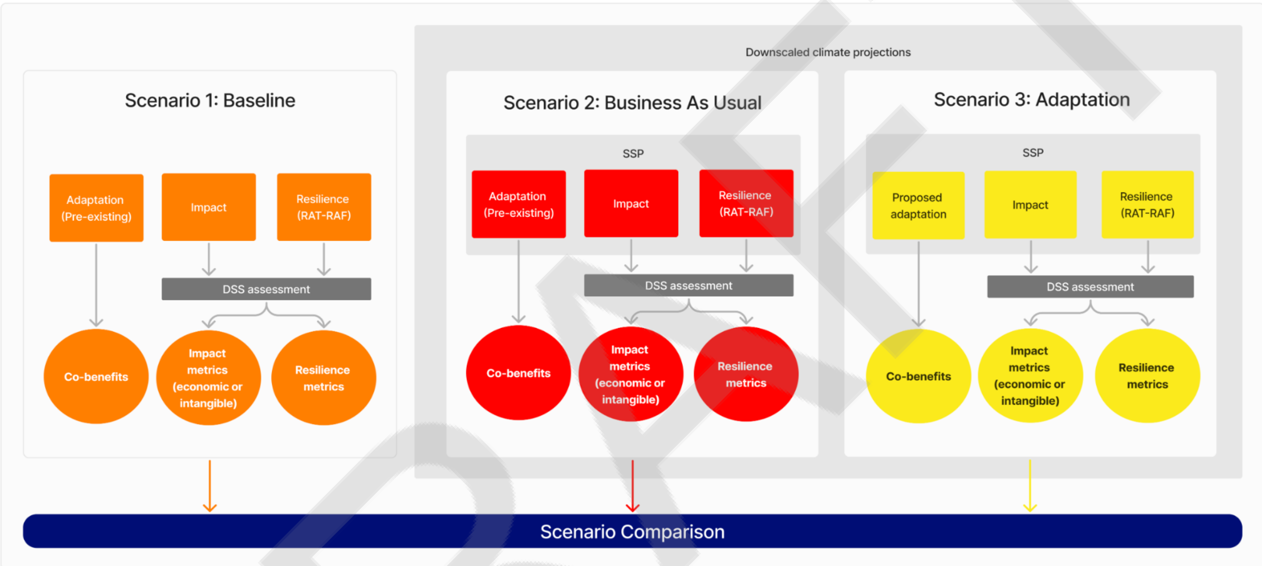

Figure 2: ICARIA DSS methodology.

2.1 Risk/Impact Assessment

This section describes the DSS backend workflows, outlining the data inputs, processing logic, and outputs used to compute exposure and vulnerability from single events across three subregions: (Barcelona (floods), Salzburg (windstorms), and Rhodes in South Aegean (wildfires) (Leone et al., 2025; Turchi et al., 2024). The backend supports flexible, user-defined inputs via the UI and delivers receptor-specific, spatially explicit outputs for hazard management. Furthermore, as an addition to the previous work in D3.4, the DSS has been updated to take into account compound events scenarios (as a new baseline entry) to be compared to single hazard ones and cascading effects produced by climate related hazards on electricity systems, namely a cascade input pipeline workflow has been implemented for flood substations scenarios, enabling the processing of flood-related cascade event inputs within the DSS backend.

The backend implementation of the impact assessment process during trial supports 3 hazards and 7 risk receptors in the following pairings:

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- Floods
  - Properties
  - Substations (cascading effects)
- Windstorms
  - Electricity towers
  - Powerlines
- Wildfires
  - Natural areas
  - Population
  - Buildings

As Deliverable D3.4 already documented the workflows for all the above, this section covers only the new addition, namely the Flood on Substations workflow which was developed to showcase cascading effects of flood in case of failure of drainage system.

2.1.1 Entry Points to Impact Assessment

The ICARIA DSS provides the user-facing environment for Risk/Impact Assessment, guiding users step by step through data submission, offering instructions and validation, linking assessments to scenarios, and integrating results as styled map layers with legends and appropriate units for interpretation and comparison. The ICARIA Processing API is the execution layer that performs the impact assessment workflows and produces consistent, GIS-ready outputs. The DSS connects to the ICARIA Processing API to trigger assessments and ingest results, while the Processing API can also be used independently by expert users who already have the required inputs and do not require guided interaction or visual decision-support features. This separation allows workflows that benefit from strong user guidance and interpretative support to be exposed through the DSS, while others can remain available as backend processing services.

The flow can be better illustrated in Figure 3 below. Within the current DSS version, most impact assessment workflows are available through the user interface (UI), covering at least one workflow of interest for each CS, and validated via trials and mini-trials in WP4. Of the above workflows, all are available through the UI for DSS users, while 2 cases, Wildfires on Population and Wildfires on Buildings, have been approached as a solely backend service accessible via CERTH's Processing API. Users may consult the relevant API documentation which is available on Appendix 7 of D3.4 and continues in Appendix 2 of the present deliverable for guidance on how to run the workflows programmatically through the API.

For the current DSS version, prioritising UI integration for certain workflows ensured that development effort could be focused on workflows whose characteristics required explicit support at the DSS interface level (notably the cascading effects workflow). At the same time, exposing the remaining wildfire workflows through the Processing API guarantees full methodological coverage and reproducibility, while preserving flexibility for expert/programmatic use and aligning implementation effort with the overall project timeline. The Processing API is considered a key integration for the ICARIA DSS and thus is maintained together with the DSS, in a joint effort between DRAXIS and CERTH.

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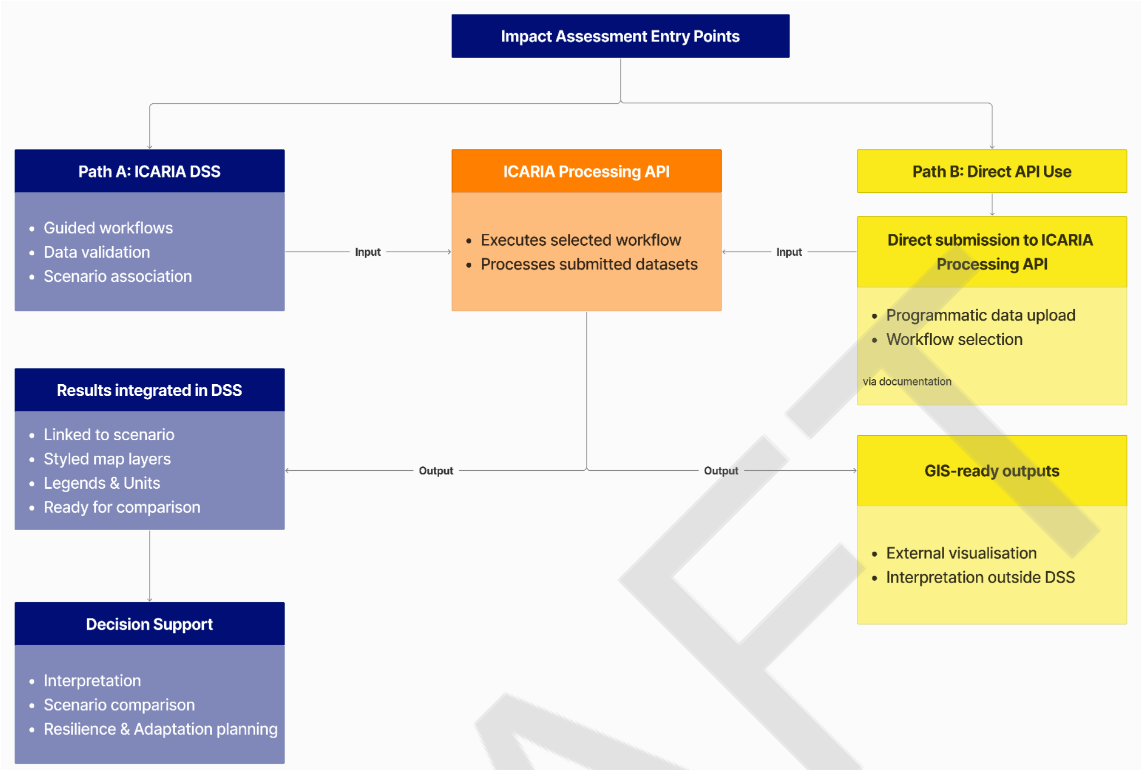

Figure 3: Impact Assessment entry points.

2.1.2 Workflow A2: Pluvial Floods (substations)

2.1.2.1 Summary and objectives of the flood on substations workflow.

This section describes the backend workflow for assessing flood-related risks and costs to electric power substations in the DSS. This workflow can be considered as a subsection of Workflow A (described in D3.4), as it is also designed to evaluate risks and costs from pluvial floods, with the substations being the risk receptor, instead of the buildings. Based on a vector shapefile with flood hazard data and a point shapefile with the substations, the backend implementation calculates the failure probability, repair cost, and repair time for each element-substation. The implementation scheme is designed to support modular features, extensibility, and straightforward connection with the UI.

The conceptual methodology to perform this kind of risk assessment is based on previous work carried out within the EU RESCCUE project (Sánchez-Muñoz et al., 2020) and has been updated within ICARIA following the specific content included in the D3.1 (Guerrero Hidalga et al., 2024).

Table 2: General structure of the Flood on Substations workflow.

Workflow summary

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Hazard	Shapefile (with polygon-type geometry elements) describing water depth across affected areas.	**Exposure**	Shapefile (of point-type geometry) presenting the substations and containing the required substation information.
Vulnerability	Hardcoded functions in the back-end code.	**Input/Output**	The input section includes polygon (hazard) and point (exposure) shapefiles, while the output section includes point-geometry shapefiles showing substations, with failure probability, repair cost, and repair time per substation.

2.1.2.2 Pipeline Procedure

An example scheme of a flowchart of assets is listed below in Figure 4. The workflow begins by validating the user-imported input shapefiles. Risk receptors (*substations.shp*) and hazard (*flood_hazard.shp*) must be uploaded, each containing the required geometry and the necessary columns (defined by column name and value types) in the attribute table (details defined in the input specification section). If one of the shapefiles is missing or invalid, the workflow will end without producing outputs, and a message will appear to the end user. Since the shapefiles have been uploaded and validated the alignment of the hazard map with the risk receptors is checked. If the hazard elements do not intersect with an area around the substations' points on the map, the workflow ends without producing outputs and a relative message appears to the end user. Since two or more substations are associated with hazard elements, the procedure enters the calculations phase. Exposure metrics, average water depth (*awd)* and affected area rate (*aar*) are calculated per substation and then used in predefined, hardcoded functions based on empirical data, to estimate failure probability and repair cost and time for each substation. At the conclusion of the process, all successfully generated outputs, *output_substations* shapefiles are returned to the user.

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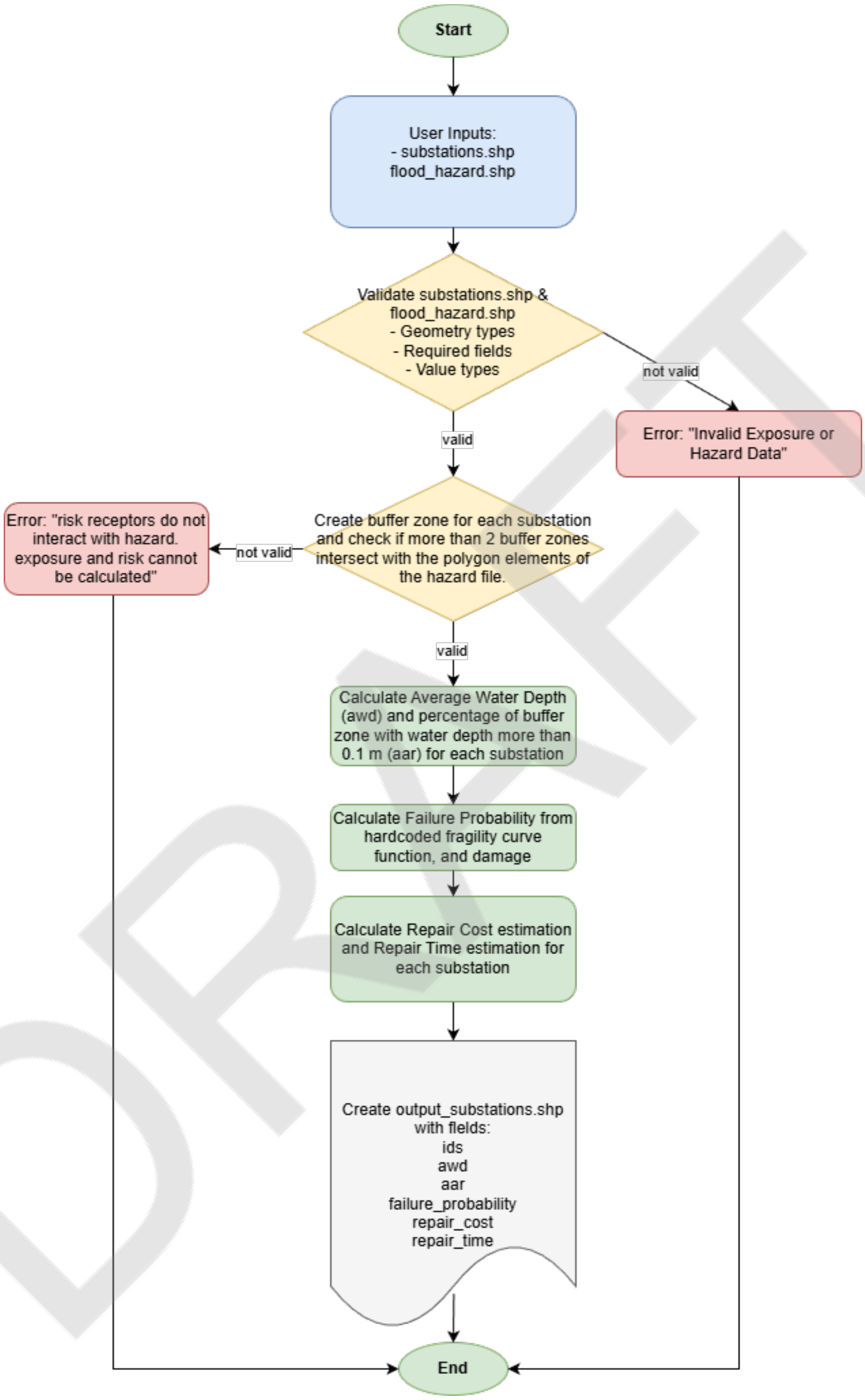

Figure 4: Example flowchart for the Flooded substations workflow.

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2.1.2.3 Input Specification

Hazard input

The hazard input for this workflow is the same as for the workflow A at D3.4.

- The flood hazard input must be provided in the form of a shapefile named (or mapped as) "*hazard_map.shp*" or "*flood_hazard.shp*".
- The shapefile must contain polygon-geometry elements
- The attitude table must contain a column named "*DEPTH2D*" with float values, with the water depth that corresponds to its polygon element of the shapefile.
- Spatial coverage must fully encompass the exposure layers.

Exposure input

The exposure component consists of a point shapefile representing electrical power substations, named '*substations.shp*' by the user. Description: "*substations.shp*" – Electrical power substations:

- Geometry: a point.
- Description: each point represents the position of a substation.
- Required attributes: '*Voltage*', '*voltage*', '*VOLTAGE*': voltage value of each substation (in kV[1]). An int or float value.
- Optional attributes: "*id*", "*ids*", "*ID*", "*IDS*", "*substation_id*", "*substation_ids*": unique identifier (*str* or *int*) for referencing the tower in external systems.

Specific input requirements (input types, descriptions, and requirement status) for this workflow can be found summed up in Table 3 below:

Table 3: Overview of input requirements for the Floods substations workflow.

Input requirements				
Input field	**Risk receptor (all)**	**Input type**	**Input description**	**Necessary / Optional**
"*flood_hazard.shp*"	All	Shapefile (Polygon)	Shapefile containing water depth (DEPTH2D named column, values: *float*), per polygon area of the affected map.	Necessary
"*substations.shp*"	Substations	Shapefile (Point)	Point geometries representing electrical substations; must include voltage values (int or float), may include ids (*str* or *int*).	Necessary

2.1.2.4 Core Process

Exposure Estimation

[1] kV refers to kilovolt.

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The system estimated the flood exposure for each substation element. A buffer zone is created for each substation point, with radius depended on its voltage. The intersection of those buffer zones with the hazard polygons of the flood affected areas is calculated for each substation. Localised estimates of the average water depth and the percentage of the buffer with water depth larger than 0.1 m (*aar*) are assigned to each substation. Those exposure metrics are used in subsequent risk and cost calculations.

Vulnerability Assessment

The vulnerability component of the workflow is implemented using predefined, hardcoded functions. All substations are assigned the same vulnerability model, with failure probability and damage values being functions of the *awd* and *aar* metrics.

Risk/Impact Calculation

The system calculates a failure probability for each element using a predefined function that relates exposure metrics (*awd* and *aar*) to the probability of damage. The exact form of this function is currently based on empirical data. In addition, for each substation element, a repair cost estimation (in euros) is assigned as such as a repair time estimation (in hours), using hardcoded functions of failure probability, *awd* metric, and substation voltage, based also on empirical data.

2.1.2.5 Output Description

Table 4: Summary of the output data for the Flood substations workflow.

Output Description			
Output file	**Format**	**Content**	**Availability condition**
"*output_substations.shp*"	Shapefile (Point)	Includes substation *id (str or int)*, failure probability (float), repair cost (float/euros), repair time (float/hours), and two metrics (*awd* and *aar*) described at the methodology (float)	Generated only if the "substations.shp" and "*flood_hazard.shp*" are provided and valid, and their elements (polygons with water depth and substation points) are sufficiently close on the map.

Data Availability

The backend implementation does not source any data autonomously. All required inputs, namely the water depth and the substations shapefiles, must be uploaded by the user. No pre-populated or pre-generated datasets or any external data links are used at this part of the DSS. As such, the completeness and accuracy of the output depend directly on the quality and coverage of the submitted inputs. The

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workflow does not execute any computation for a receptor type if the corresponding input shapefile is not present.

<u>Specifications to Consider</u>

- All shapefile inputs should be provided in the same coordinate reference system (CRS) to ensure spatial alignment.
- The voltage values at the substation shapefile must be within the limits of the current EU standards (3kV < voltage <4 50kV) to be considered accurate.
- While the field names in the shapefiles are not case-sensitive, their values must match one of the accepted variants defined in the system to ensure proper matching and identifier preservation in the outputs.
- Additionally, to the validity of the input files, a necessary condition for the production of accurate outputs is that the affected areas of the flood hazard file intersect with the buffer zones of the substation points.

<u>Example Output</u>

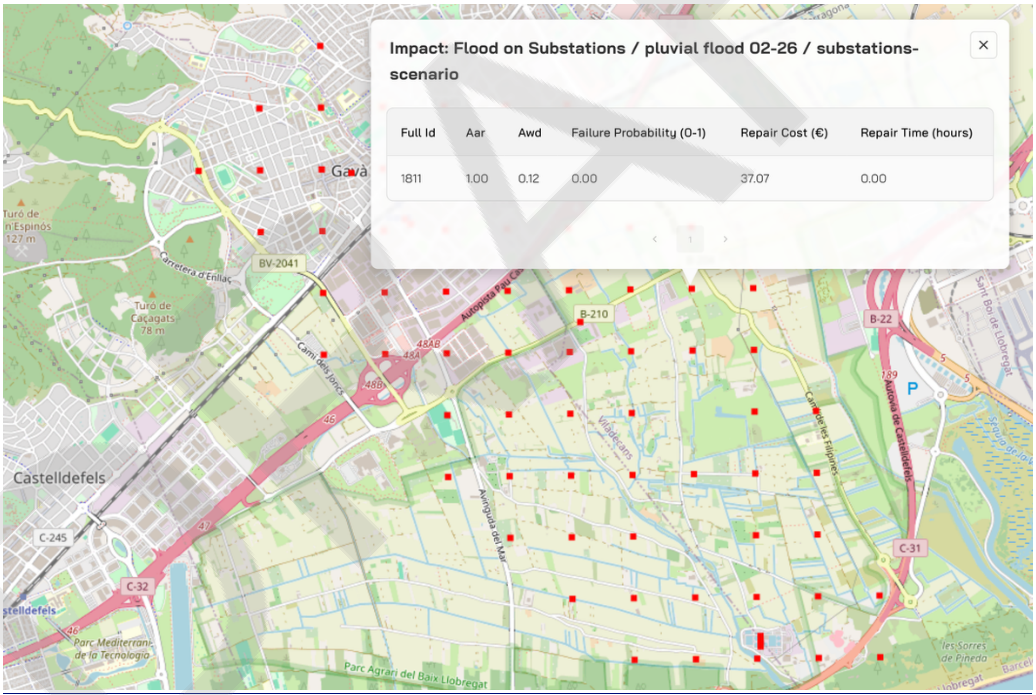

Figure 5: Example output for the Flood on Substations in Barcelona.

From Figure 5 demonstrating an example output of this workflow, it is possible to understand for a given substation the failure probability, a repair cost estimate (euros), and the repair time estimate (hours).

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2.2 Resilience Assessment

The DSS includes resilience assessment functionalities that allow users to evaluate how regions and infrastructure assets respond to climate-related disruptions, supporting adaptation planning through structured and comparable results. Resilience is assessed using two complementary approaches. These approaches are based on the methodologies developed in D3.2 (Brito et al., 2024) and remain unchanged.

At the urban and regional scale, the DSS integrates a simplified version of the Resilience Assessment Framework (RAF) developed by LNEC, focusing on a limited set of core questions that capture organisational, spatial, functional, and physical dimensions of resilience. This reduced implementation maintains alignment with the full framework while ensuring usability and relevance for decision-support purposes. Results are presented in an aggregated visual form that highlights overall resilience maturity.

For critical infrastructure, the DSS provides access to the Resilience Assessment Tool (RAT) developed by NCSR-D through direct API integration. The tool is included in full and evaluates infrastructure resilience across key capacities related to anticipation, absorption, coping, recovery, and adaptation. Assessment results are synthesised into an overall resilience index and visualised to support interpretation and planning.

2.3 Adaptation Measures

The ICARIA DSS incorporates a portfolio of 320 adaptation measures provided by CETAQUA through API integration, forming the basis of the platform's adaptation planning functionality. This portfolio covers a wide range of climate-related hazards and supports both regional and asset-level planning.

Each measure is described using a structured set of attributes that allows users to assess applicability and potential effects across different cases. These attributes capture a number of criteria such as the type of adaptation action, the assets and areas it applies to, the spatial scale, cost considerations etc. The underlying methodology is defined in D3.3 (Guerrero Hidalga & Couce Rodriguez, 2024) and remains unchanged. Within the DSS, this functionality supports the identification and evaluation of adaptation strategies that are aligned with local conditions and informed by evidence.

2.4 Climate Projections

Climate projections integrated into the DSS were developed within Task 1.2 and are based on two complementary downscaling approaches that remain unchanged from the initial system release. Statistical downscaling was carried out by FICLIMA and Dynamical downscaling was performed by AIT.

Together, these approaches produced a comprehensive set of high-resolution climate projection layers covering both mean climate variables and a range of extreme indicators relevant to climate risk assessment.

The full set of nearly 900 climate projection layers is integrated into the DSS Map Viewer. The datasets were processed and styled by DRAXIS, including the addition of legends and metadata, to ensure

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consistent visualisation alongside other spatial layers within the platform. This integration allows users to explore past and future climate conditions for each CS region independently of the hazard maps, while maintaining transparency regarding the climate data used in subsequent assessments.

The underlying climate datasets are openly available and documented in D1.2 (Paradinas Blázquez & Bügelmayer-Blaschek, 2024) which provides a detailed description of the projection methodologies and indicators, including both the statistically downscaled datasets and the dynamically downscaled regional climate projections.

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3 DSS Overview

This chapter provides a concise overview of the users, use cases, and core capabilities of the ICARIA DSS, as originally documented in Deliverable D3.4. The overall scope, target audience, and functional intent of the DSS remain unchanged and are therefore summarised here to maintain continuity with the updated structure of this deliverable.

The ICARIA DSS is designed to support climate risk and adaptation planning by enabling users to assess climate impacts, evaluate resilience, and explore adaptation options within a single, integrated environment. It supports the handling of complex and heterogeneous datasets while guiding users through structured workflows that promote transparency, consistency, and evidence-based decision-making.

The platform primarily serves technical users involved in climate risk analysis and adaptation planning. These include professionals responsible for assessing and managing risks to critical infrastructure, as well as researchers and academic experts working on climate impact modelling and adaptation strategies. In addition, the DSS is used by public authorities and infrastructures operators involved in regional and local planning, civil protection, infrastructure management, and advisory services, who rely on the platform to interpret results and support planning and communication processes.

The DSS supports a set of core use cases that reflect these needs. Users can analyse climate risks and impacts by combining hazard, exposure, and vulnerability information under defined scenarios, allowing targeted assessments across assets and regions. The platform also enables resilience assessment through integrated tools addressing both governance-related and infrastructure-specific dimensions, supporting the identification of strengths and gaps. In addition, users can explore, compare, and prioritise adaptation measures linked to specific hazards and impact contexts, supporting structured evaluation of response options.

To support these use cases, the DSS integrates a coherent set of functionalities covering project and scenario management, risk and impact assessment workflows, resilience evaluation, adaptation measures management, interactive geospatial visualisation, results exploration, and reporting. Access control, user management, and in-app guidance mechanisms are incorporated to support collaboration, reduce user error, and ensure consistent use across different application contexts.

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4 DSS Interface

This chapter presents the main new or updated features and UI of the ICARIA DSS. As the core functionalities and workflows of the system remain unchanged since D3.4, the overall structure and content of this chapter is a continuation of the original documentation.

The main purpose of this updated chapter is to highlight updates introduced to the DSS after the initial release, based on the DSS trial and mini-trial activities carried out in WP4. Only screenshots reflecting changes in the UI are included in the current version, while unchanged views are not repeated. Where updated screenshots are presented, the corresponding changes (for example, visual adjustments such as colour updates or refinements in navigation elements) are explicitly described to ensure transparency and traceability with respect to version 1.

All other features, workflows, and interaction patterns described in Deliverable D3.4 remain valid and continue to apply to the current version of the DSS.

Users can access the DSS via the following link: icaria.draxis.gr[2].

4.1 Feedback Collected

Based on the trials conducted in WP4 as well as feedback from ICARIA partners, the following feedback was collected for the second version of the DSS. The feedback was documented by the CS facilitators, other ICARIA partners or extracted directly from D4.2 which reports the results of the trials in the CS regions. Table 5 below summarises what was proposed as corrections and additions together with a status to indicate whether the request was taken forward and, if not, a justification.

Table 5: Requested new features, corrections or problems found by ICARIA stakeholders for v2.

Requested by (Trials, CSF, Partner)	Feedback description	Feedback category	Impact/ importance	Status
CSF/Trials	Correct the units for "Ra - Yearly and seasonal rainfall relative change" climate projection layers are represented	Problem/bug	Medium	Addressed
CSF/Trials	Reorder climate projections in the map viewer catalogue so they are organised by SSP and time period	Correction	Low	Addressed

[2] Please note that upon registration, users are assigned the Stakeholder role by default (with permissions as defined in Chapter 6.1). Please contact icaria@draxis.gr to be upgraded to the high-access role of Technician.

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LNEC	In the final download of the RAF results include a table with the questions/answers/development level so the user can understand which are their weaknesses and strengths	New feature	Medium	Addressed
CSF/Trials	Add colours of the results aggregation polygons dynamically relative to maximum impact for flood workflow	New feature	Medium	Partially addressed via fixed categories linked to specific colours to be applied into the polygons
CSF/Trials	Rename the impact assessment results layers based on Project and Scenario to more easily distinguish them	Correction	High	Addressed
CSF/Trials	Show only two decimals in impact assessment results (layer)	Correction	Low	Addressed
CSF/Trials	Update terminology in Risk/Impact status (e.g. change 'in queue' to 'in progress')	Correction	Low	Addressed
DRAXIS	Add clear instruction on what input file format is expected (e.g. .zip)	New feature	Low	Addressed
CSF/Trials	Add units of measurement in impact results on the map and report	New feature	High	Addressed
DRAXIS	Add styling for calculated impact layers based on a static scale for all workflows	New feature	High	Addressed
CSF/Trials	Reorder the steps (Risk/Impact Assessment, Resilience Assessment, Adaptation Measures) in the scenario editor	Correction		Addressed
CSF/Trials	Add cost/m2 in flood impact results	New feature	Medium	Not taken forward due to scope and time constraints as it requires an extension of the flood workflow
CSF/Trials	Add total cost in flood impact results	New feature	Medium	Not taken forward due to scope and time constraints as it requires an extension of the flood workflow

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CSF/Trials	Attribute table in map viewer is not always visible for elements on the top right	Problem/bug	Low	Not needed as the user can drag the map to view the entire table
AIT	Replace certain climate projection layers which were re-calculated with improved accuracy	Correction	High	Addressed
CSF/Trials	Add further methodological documentation for impact assessment so that users understand how the process works	New feature	Medium	Addressed
CSF/Trials	Increase explainability of RAF results	New feature	Medium	Addressed
CSF/Trials	Increase clarity on how and when the Risk/Impact assessment status updates	Problem/bug	Medium	Addressed
DRAXIS	Add "View Results" button to Risk Impact Manager that redirect to completed project's results view	New Feature	Low	Addressed
DRAXIS	Automatically adjust the Map Viewer to centre on the geographic area covered by the loaded layer	New Feature	Low	Addressed
DRAXIS	Improve content of informational pop-ups on next to impact assessment input fields	Correction	Medium	Addressed
UNINA	Align Hazard-Exposure-Vulnerability terminology with the DSS	Correction	High	Addressed

Complementing the above table, further functionalities were added to the DSS as part of the planned actions for the second version, as indicated already in D3.4. These planned additions include:

Table 6: Planned new features and updates for v2.

Requested by (Trials, CSF, Partner)	Feedback description	Feedback category	Impact/ importance	Status
CSF	Impact assessment workflow for Windstorms on Powerlines	New feature	High	Addressed
ICARIA GA	Impact assessment workflow for cascading effects of Flood on Electrical Substations	New feature	Critical	Addressed
ICARIA GA	Ability to create multi-hazard scenarios	New feature	High	Addressed

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ICARIA GA	Creation of Stakeholder and General Public user roles with appropriate permissions across all functionalities of the DSS	New feature	High	Addressed
DRAXIS	Updated user guide with more detailed step-by-step instructions and the added new features	New feature	Medium	Addressed
DRAXIS	Addition of privacy policy/cookie policy and Frequently Asked Questions	New feature	Low	Addressed
DRAXIS	General improvements to user experience identified through internal testing	Correction	Low	Addressed

4.2 Functionalities updates

The changes described in this section apply primarily to the Technician role, as the most high-access role of the DSS with ability to utilise all functionalities. They constitute a continuation of the respective section presented in D3.4. For the corresponding changes related specifically to the new Stakeholder or General Public role, who by design have more restricted capabilities on the DSS, please refer to sub-section 4.2.9.

4.2.1 Project Manager

In the Project Manager, during the scenario creation process, the system has been updated to allow indication of whether the scenario addresses a single hazard or multiple interacting hazards (Figure 6). The primary hazard, together with the selected risk receptor, defines the input data required to run the impact assessment. The influence of secondary hazard(s) is assumed to be incorporated within the requested hazard input data (e.g., flood-depth information included in a hazard map).

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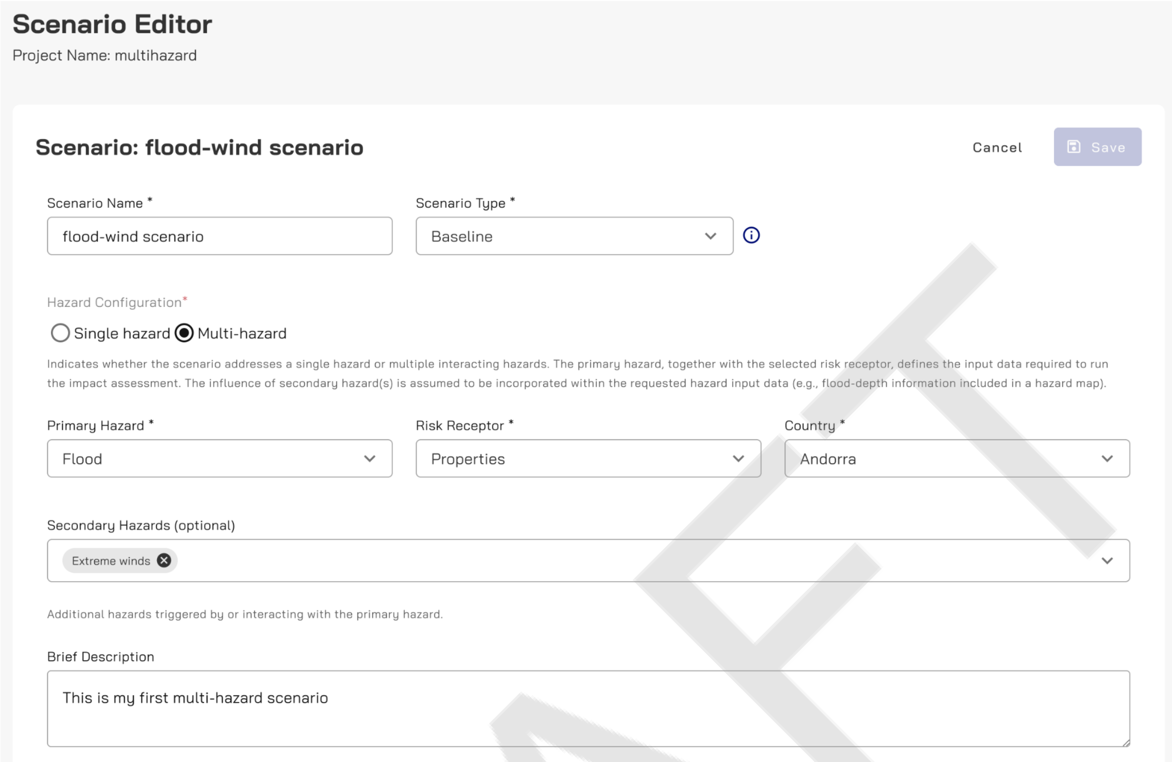

Figure 6: Project Manager - Ability to define multi-hazard scenarios update.

The Scenario Previewer has been updated to allow project details to be collapsed via a dedicated toggle (Figure 7). Users can hide these details when not required, enabling a more focused view of the scenario content. At the same time, in cases where the scenario is multi-hazard, the system provides an additional indicative tag, next to that of the scenario type (e.g. baseline) which was already present.

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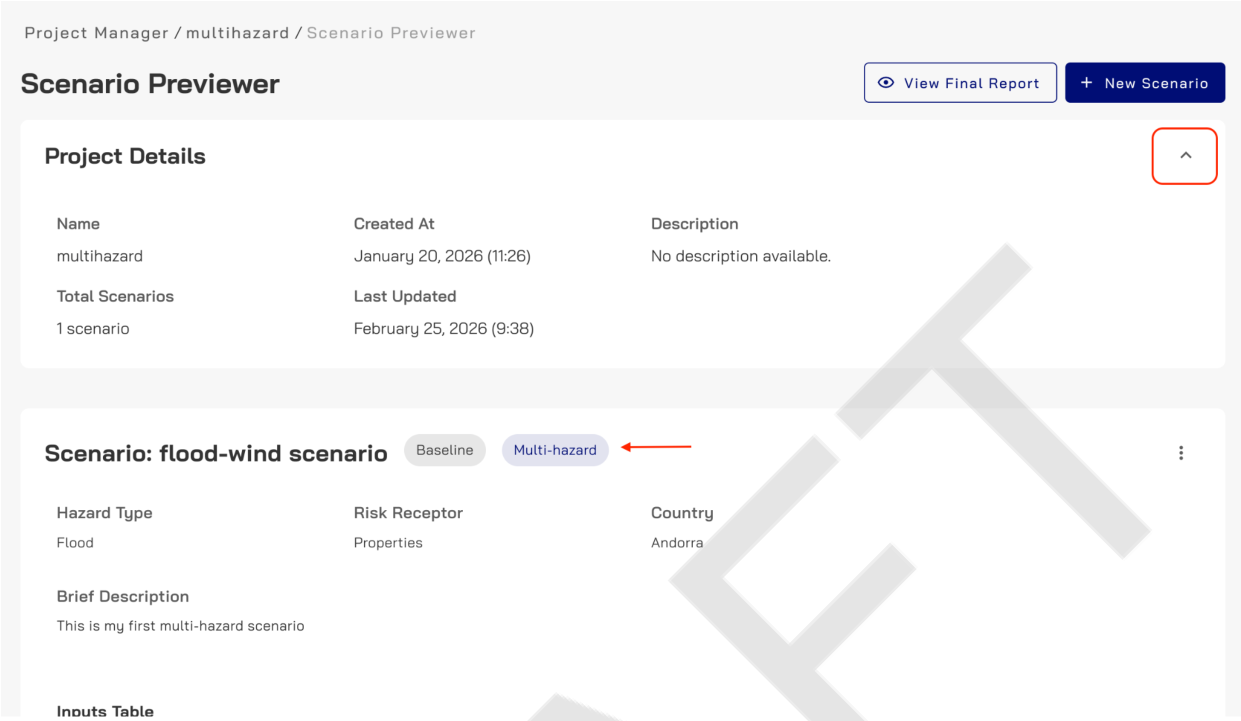

Figure 7: Project Manager – Scenario previewer update.

The project sharing popup has been updated to include explanatory text describing role-based access restrictions. Furthermore, users can now view the role assigned to each collaborator prior to sharing a project (Figures 8 & 9).

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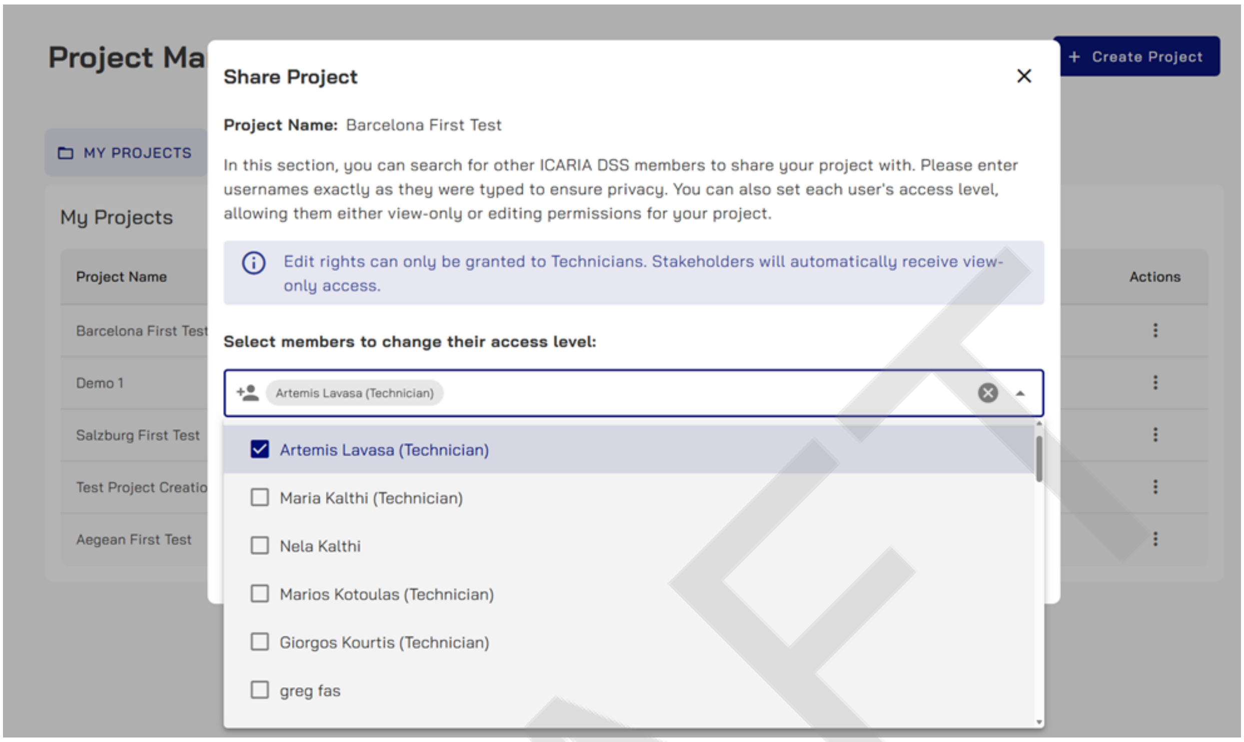

Figure 8: Project Manager - Sharing update (1).

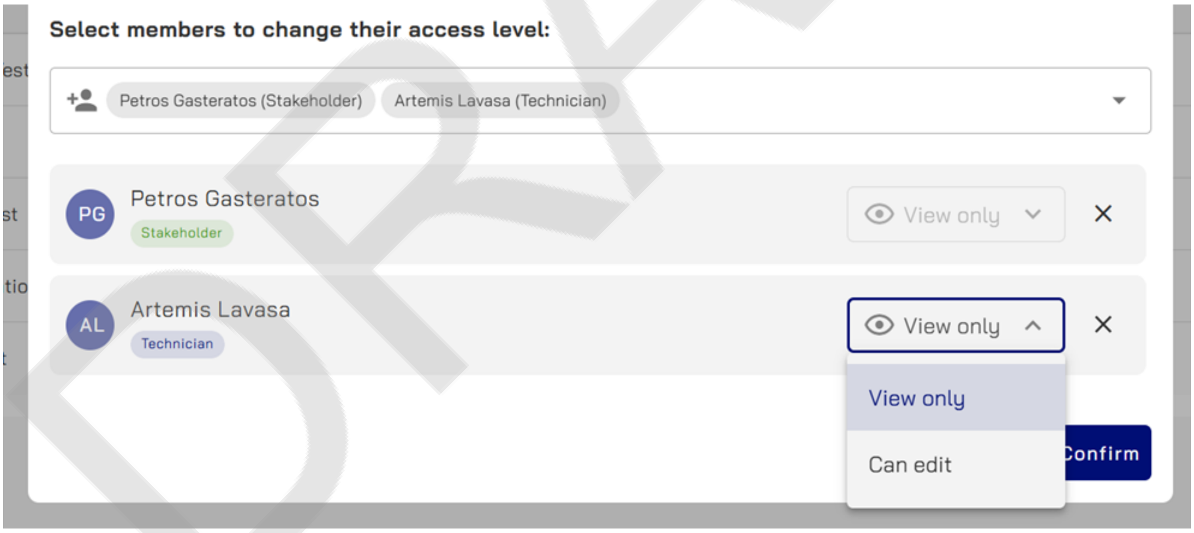

Figure 9: Project Manager - Sharing update (2).

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4.2.2 Risk/Impact Assessment

Within a selected scenario, the ordering of functionalities has been revised so that the Risk/Impact Assessment is now displayed first, as this is the logical sequence of events. In addition, a brief instructional parenthesis has been added next to the file upload title, indicating the expected file format (e.g. zip file). These expected files and instructions are dynamically updated for each input based on the impact assessment workflow currently being evaluated (Figure 10).

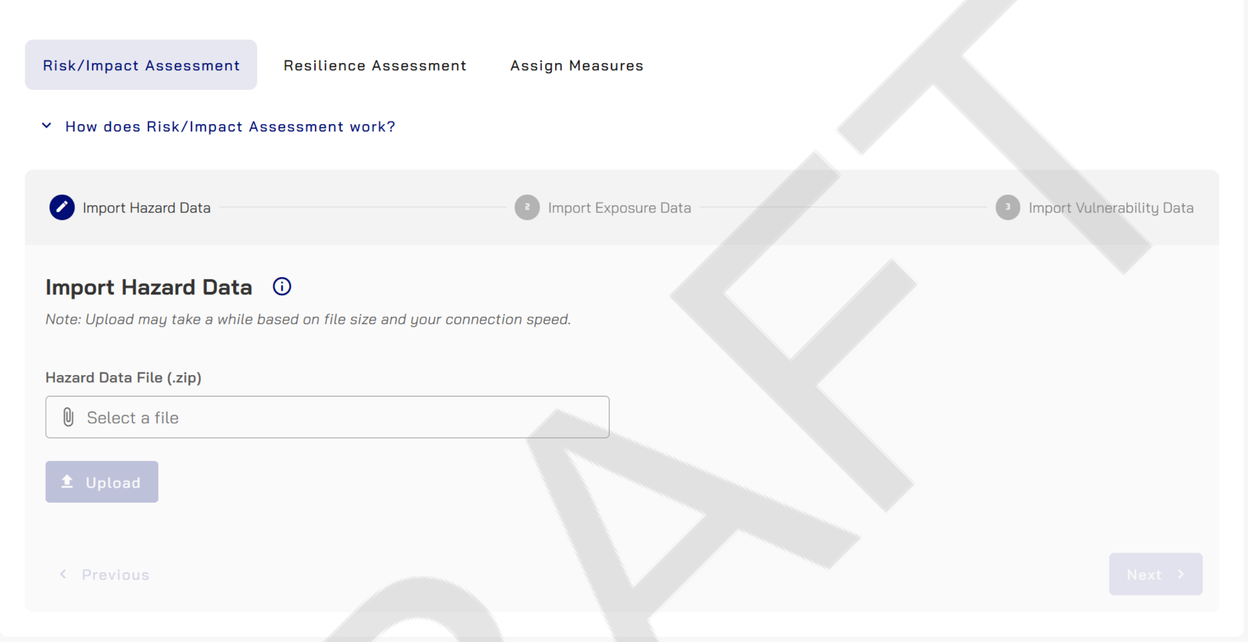

Figure 10: Risk/Impact Assessment - Steps reordering update.

Also, a new collapsible informational section has been added under the Risk/Impact Assessment tab, which provides further guidance to users in terms of how the impact assessment works on the DSS (Figure 11). At the end of this informational text, the user can now find example files which can be downloaded to be used for the impact assessment, either as templates or as they are. Depending on the hazard-risk receptor selection, the files provided are dynamically updated so that the user does not need to sift through all the files each time (e.g. if the user has created a flood on properties workflow, only the relevant files to that will be visible for download).

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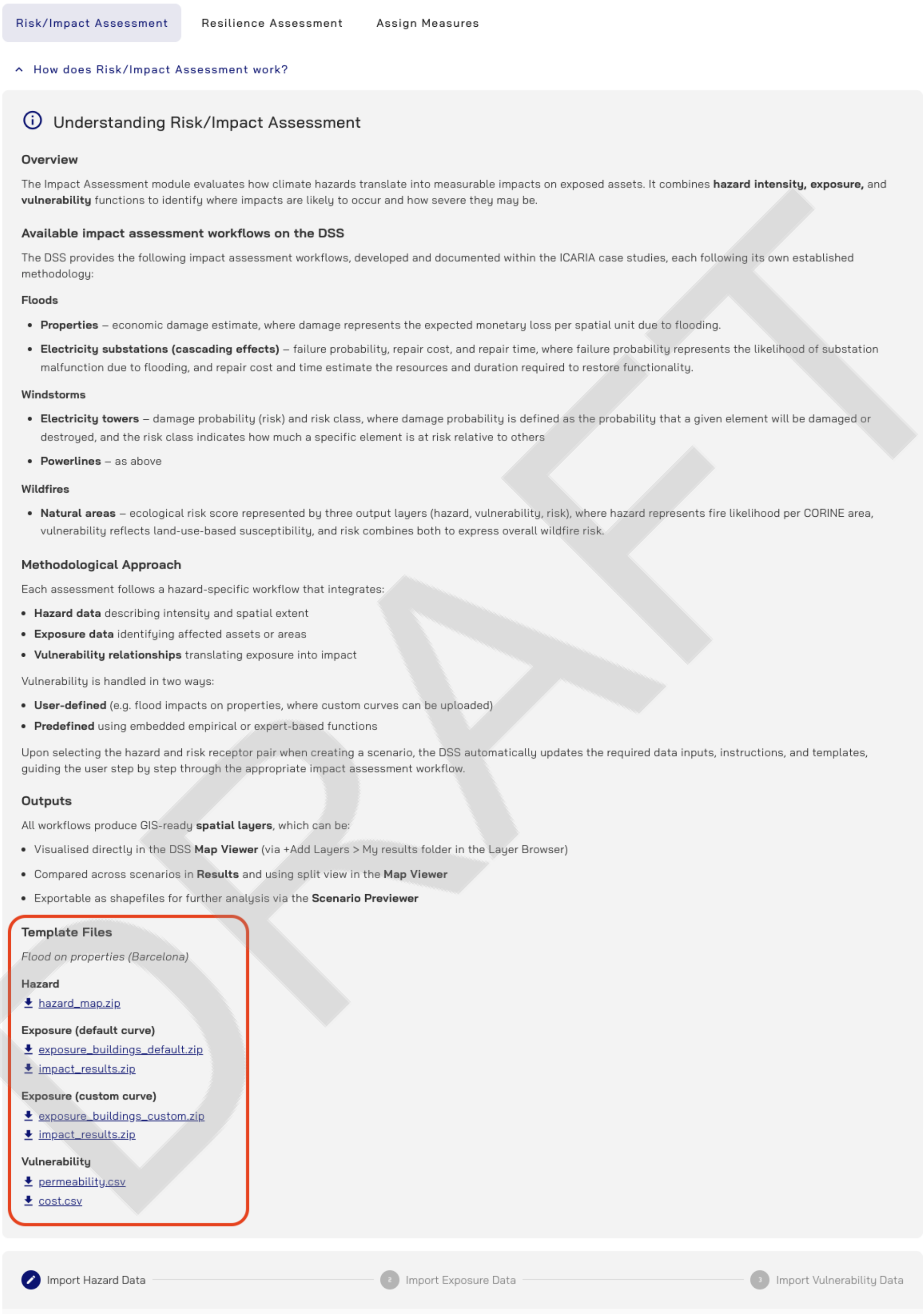

Figure 11: Risk/Impact Assessment - Added guidance update and templates.

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Moreover, the associated informational popups next to the data input boxes have also been updated as far as the content is concerned to better guide the users for data preparation. In the example below (Figure 12), the instructions were updated to explain what the Fire Weather Index (FWI) 50 represents in the DSS methodology. The instructions on these popups dynamically update depending on the type of hazard and risk receptor (corresponding to the different impact workflows).

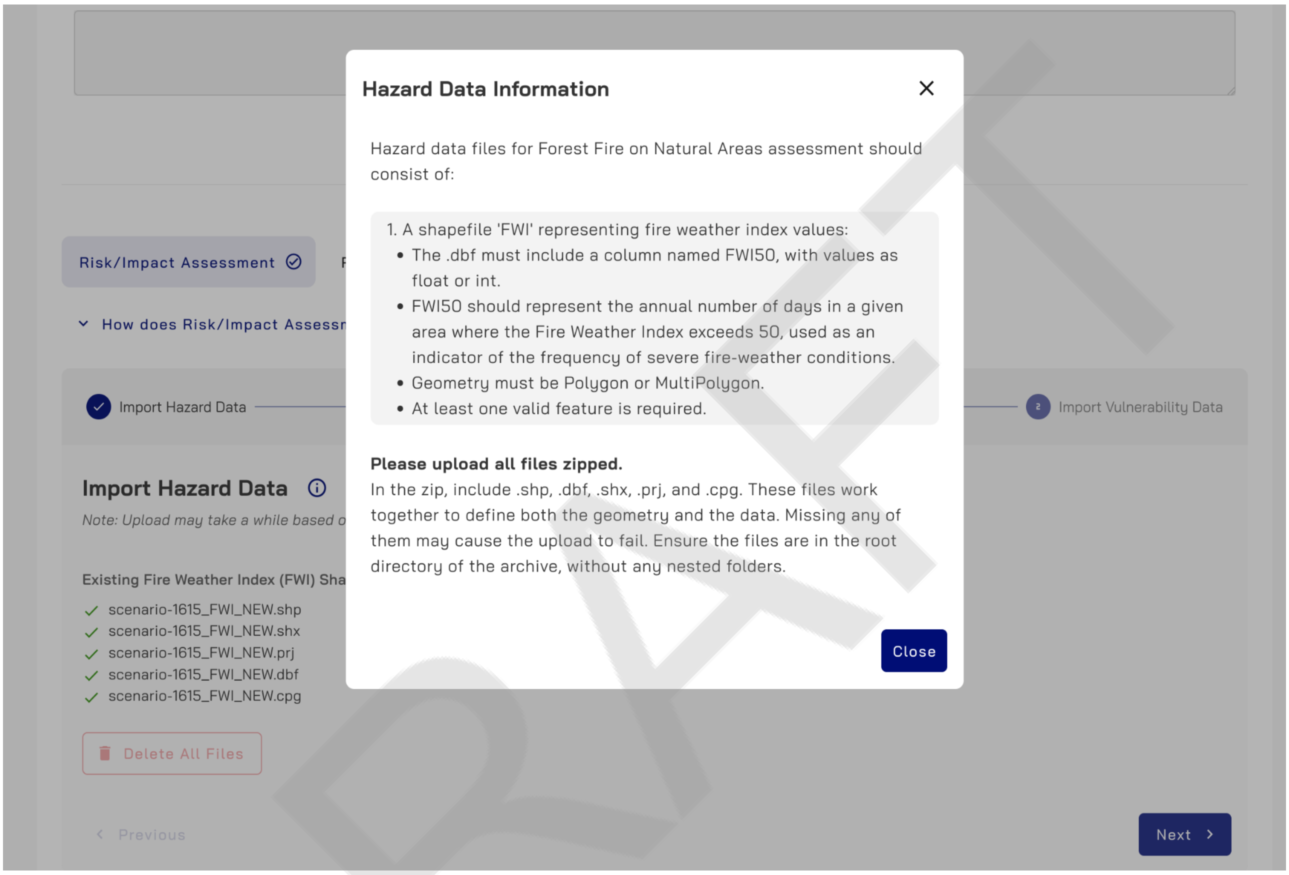

Figure 12: Risk/Impact Assessment - Popup info update.

Another change is that the Risk/Impact results are now also available via the status pop-up in the header (Figure 13). The results become available once the assessment has been completed, allowing users to navigate directly to the project results page. The status now also dynamically updates without having to close and re-open the pop-up, as the system checks every 10 seconds the status of the impact assessment. Users can grab and move the popup window to place it in whichever area on the screen is comfortable for them to monitor the status.

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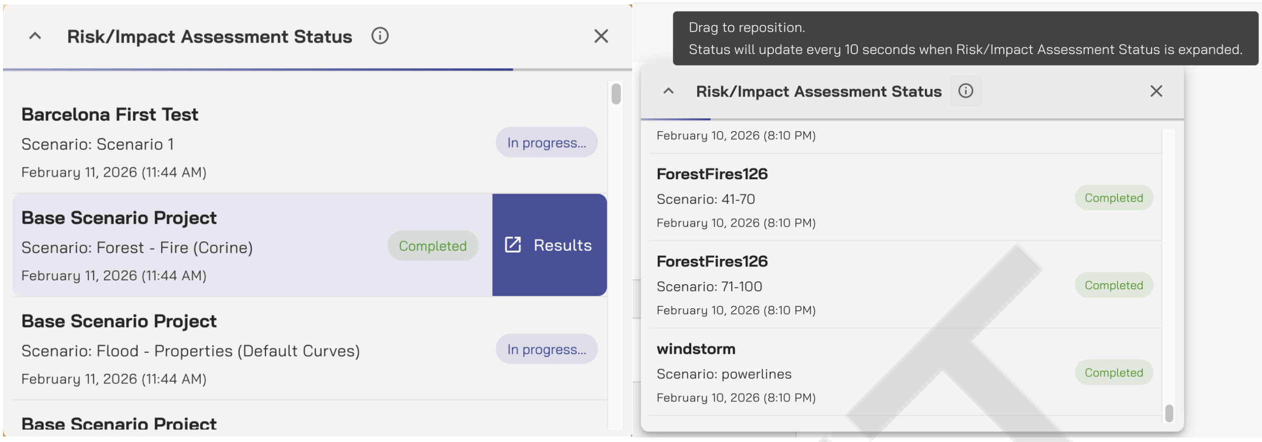

Figure 13: Risk/Impact Assessment - Status interaction update.

The final changes in this area are reflected in the appearance of the risk/impact assessment results within the Map Viewer. Importantly, the impact layers are dynamically styled following the impact assessment calculation, which includes custom colour styling and legend depending on the type of hazard and risk receptor (Figure 14).

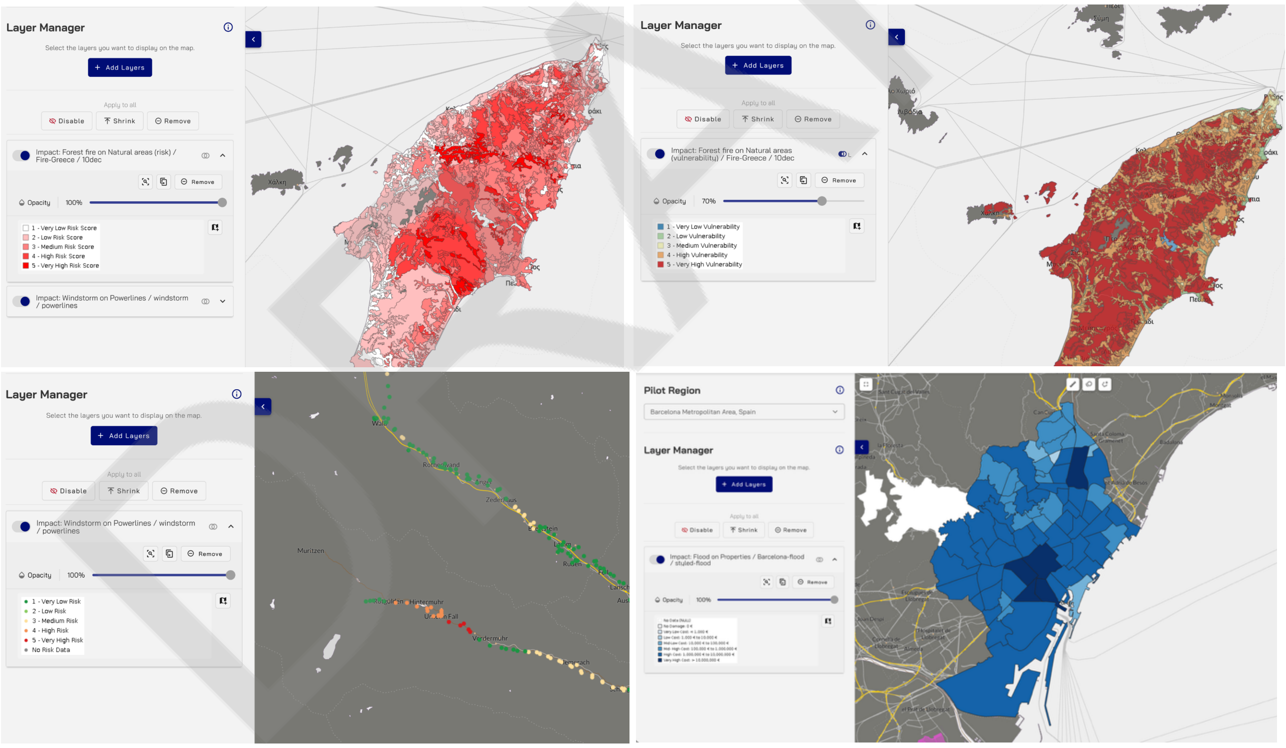

Figure 14: Risk/Impact Assessment - Styling examples for Wildfire, Windstorm and Flood.

Also, the attribute table layout has been revised from a vertical to a horizontal presentation of results to allow for better presentation of the layer title and attributes (Figure 15). Units have been added to the table, so that together with the added legends users better understand the results. Decimals have been

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reduced to two foreach result of the attribute table, making the appearance of results much clearer.

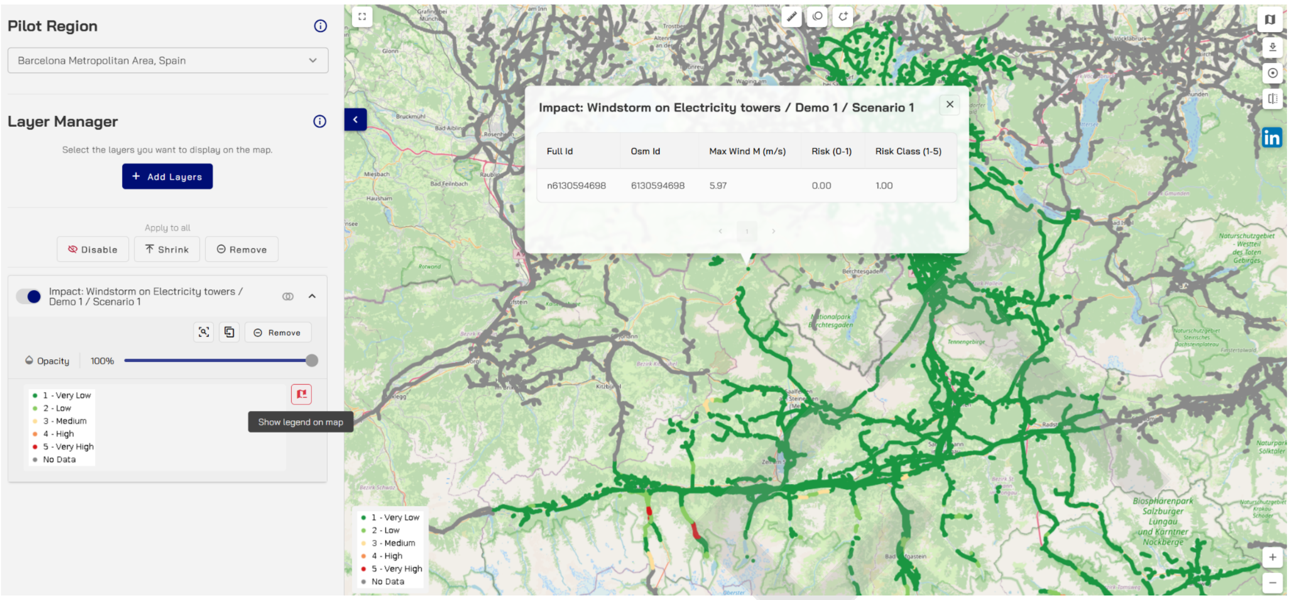

Figure 15: Risk/Impact Assessment - Results update (1).

At the same time, the names of the impact assessment layers have been standardised to ensure consistency and improve clarity when browsing and comparing results across scenarios, by explicitly indicating the impact workflow (hazard and risk receptor) as well as the associated project and scenario to clearly identify the origin of each layer (Figure 16).

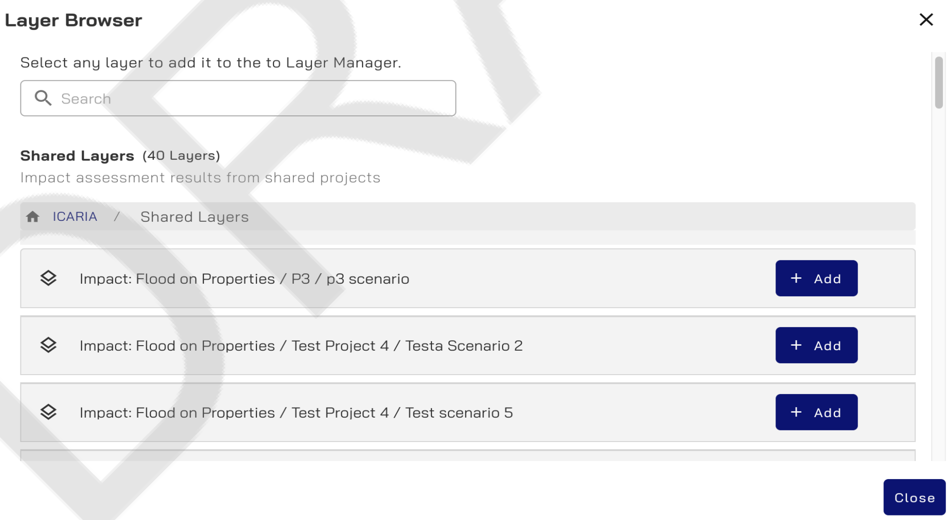

Figure 16: Risk/Impact Assessment - Results update (2).

Finally, there have been slight adjustments to the semantic use of the concepts of Hazard-Exposure-Vulnerability to better align the terms with the ICARIA modelling framework from WP1 with the rest of the project. After reviewing all the uses of these terms on the DSS, one adjustment was made for the case of

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the Wildfire methodology. Specifically, the Wildfire hazard is calculated in relation to two main components: FWI and fuel type (based on CORINE land cover). In the previous version, one of the output layers of the Wildfire impact assessment was named "exposure" (as documented in D3.4) and corrected to “hazard” in the current version. This is reflected in the layer title and the legend, as well as in the first column of the attribute table when opened (Figure 17).

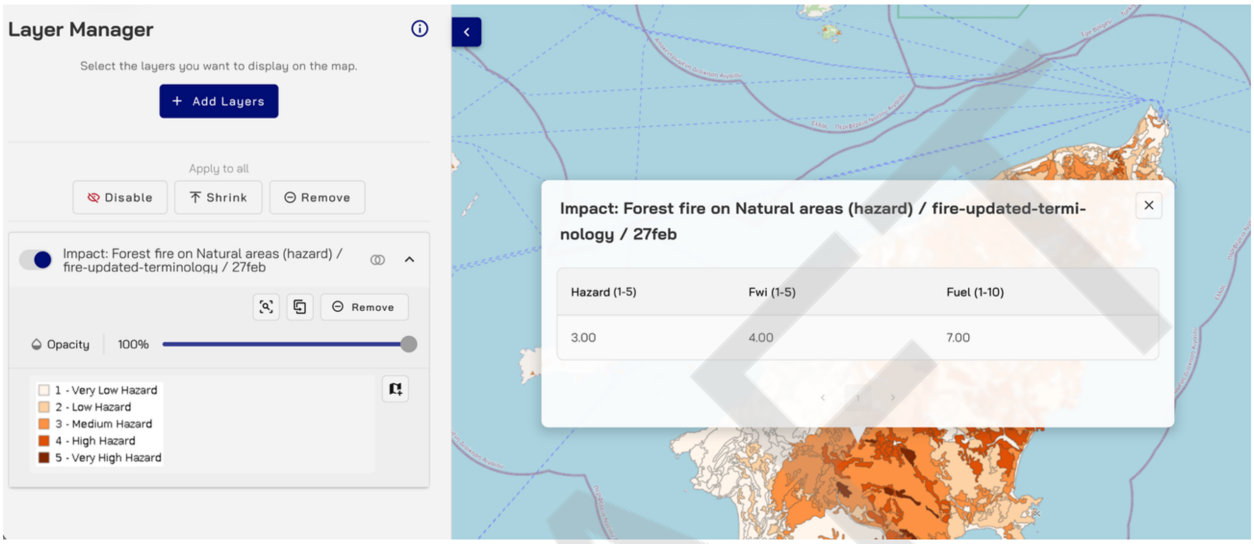

Figure 17: Risk/Impact Assessment - Terminology update.

The DSS user guide (Appendix 1) includes step-by-step instructions on how to run the impact workflows.

4.2.3 Resilience Assessment

The changes in the Resilience Assessment concern the RAF, specifically aimed at increasing the explainability of the RAF results (Figure 18). The RAF results chart now includes an expandable section

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"How to interpret the RAF results" which provides information about the development levels in order to help users understand the results more easily.

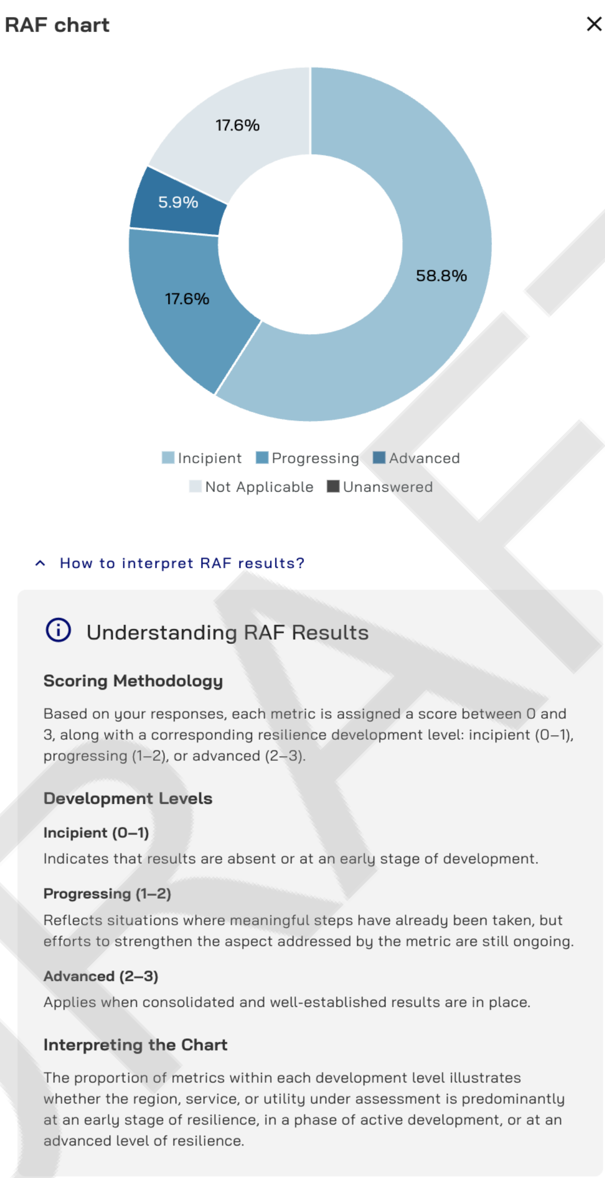

Figure 18: Resilience Assessment - RAF chart explanation update.

At the same time, in the Results and Report sections of the DSS, there is a new table which includes all the answers to each RAF assessment question, together with the development level assigned to the answer, so that users can evaluate the areas which may require intervention, such as those with the lowest development level scores (Figure 19).

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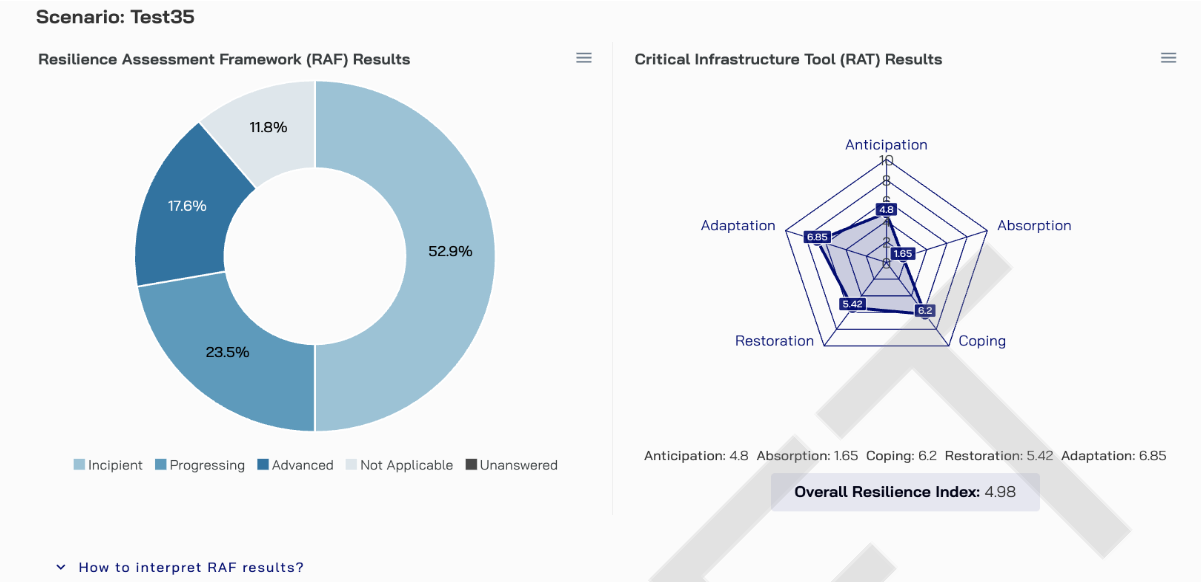

RAF Assessment Details

PI Code	Question	Answer(s)	Development Level
30b - Critical infrastructure plan overview (-)	Is there a critical infrastructure plan or strategy and is it implemented?	Yes, in collaboration with other stakeholders	3
101 - Knowledge of exposure and vulnerability to each hazard (-)	Existence of scenarios setting out area-wide exposure and vulnerability from each hazard level	Partial scenarios exist but are not comprehensive or complete; and/or are more than 18 months old; and/or are not reviewed by a 3rd party	1.2
104 - Potential population at risk of displacement for climate change scenarios (-)	Percentage of population at risk of displacement for three months or longer according to climate change scenarios	Not Applicable	N/A
105- Urban footprint at risk for climate change scenarios (-)	Percentage of urban footprint at risk, according to climate change scenarios	No urban footprint at risk for "most severe" scenario	3
105b- Natural areas at risk for climate change scenarios (-)	Percentage of urban footprint at risk, according to climate change scenarios	Less than or equal to 2.5% natural areas at risk for "most probable" scenario	1
106 - Economic activity at risk for climate change scenarios (-)	Percentage of economic activity at risk from climate change scenarios	Less than 2.5% of economic activities at risk for "most probable" scenario	1
109 - Urban design solutions that increase resilience (-)	Does the city implement urban design solutions tasked to improve resilience?	No use and no interest	0
109b - Implemented design solutions to increase resilience (-)	Do building codes or standards exist, and do they address specific known hazards and risks for the city? Are these standards regularly updated?	Solar panels in most public buildings (over 60%) Solar panels in many private buildings (over 30%)	0.4

Figure 19: Resilience Assessment - RAF assessment details in results.

Finally, user experience (UX) improvements were implemented within the questionnaire interface. The question counter is now displayed at the bottom of the page, along with a navigation button that allows users to scroll directly to the end of each question (Figure 20). In addition, the progress bar is now positioned at the bottom of the interface. Minor visual refinements have also been introduced, including adjustments to button shapes and the appearance of alert messages.

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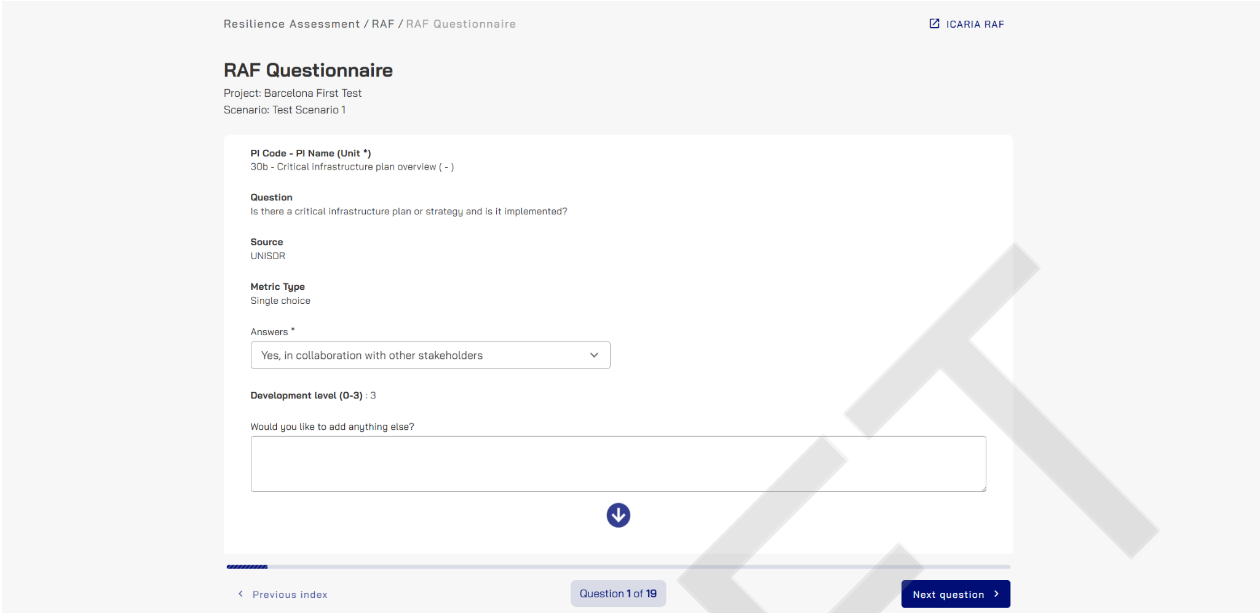

Figure 20: Resilience Assessment - RAF update.

4.2.4 Adaptation Measures

In the Adaptation Measures, the main update concerns the selection of co-benefits when creating a new adaptation measure. The previous dropdown menu has been replaced with a draggable slider, allowing users to more easily adjust the assigned value for each selected co-benefit (Figure 21).

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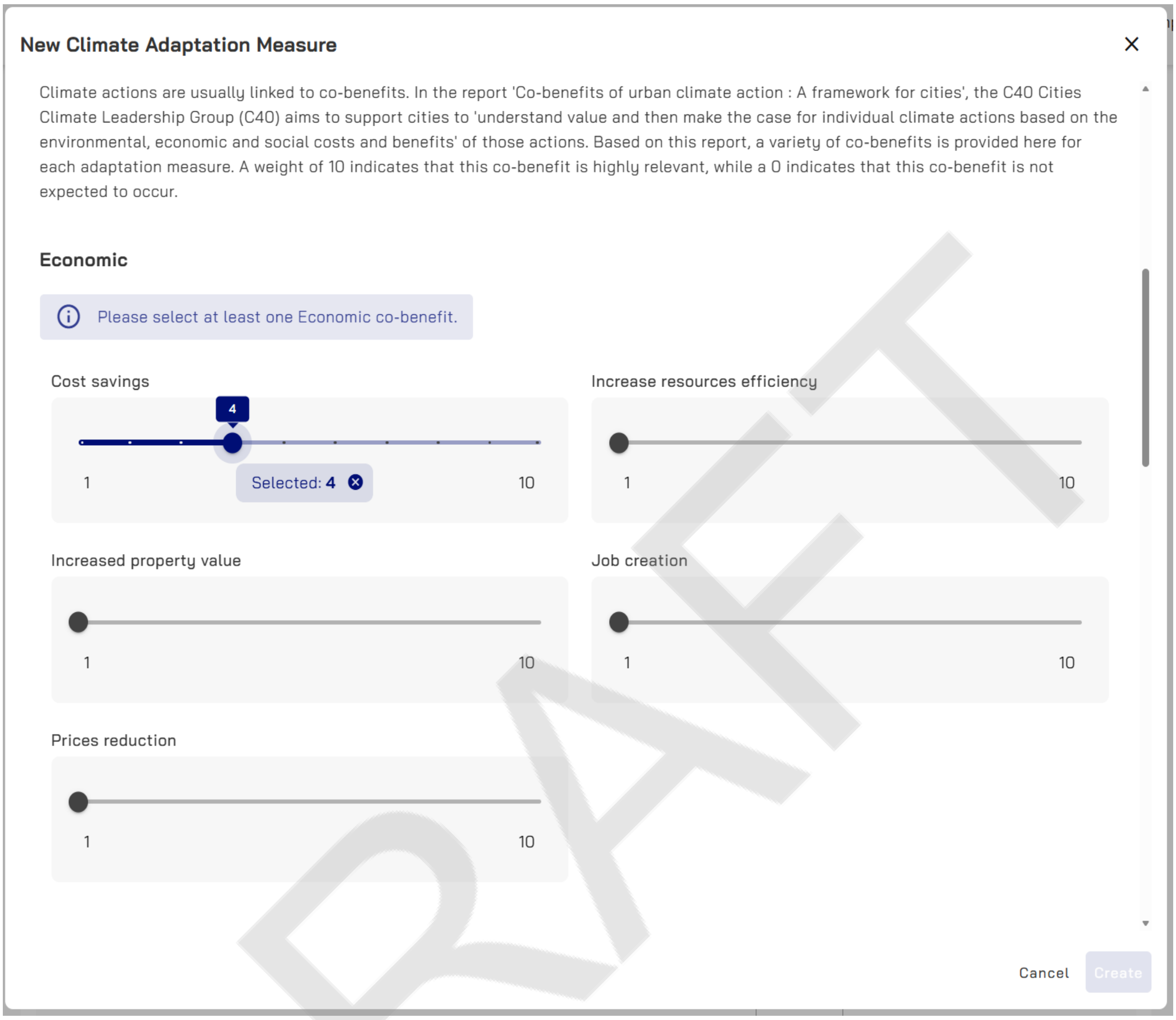

Figure 21: Adaptation Measures - Co-benefit selection update.

4.2.5 Map Viewer

The main change connected to the Map Viewer is the addition of an administration panel, allowing administrators to easily manage all the layers in the Map Viewer, such as editing or deleting existing ones or configuring new ones (Figures 22 & 23).

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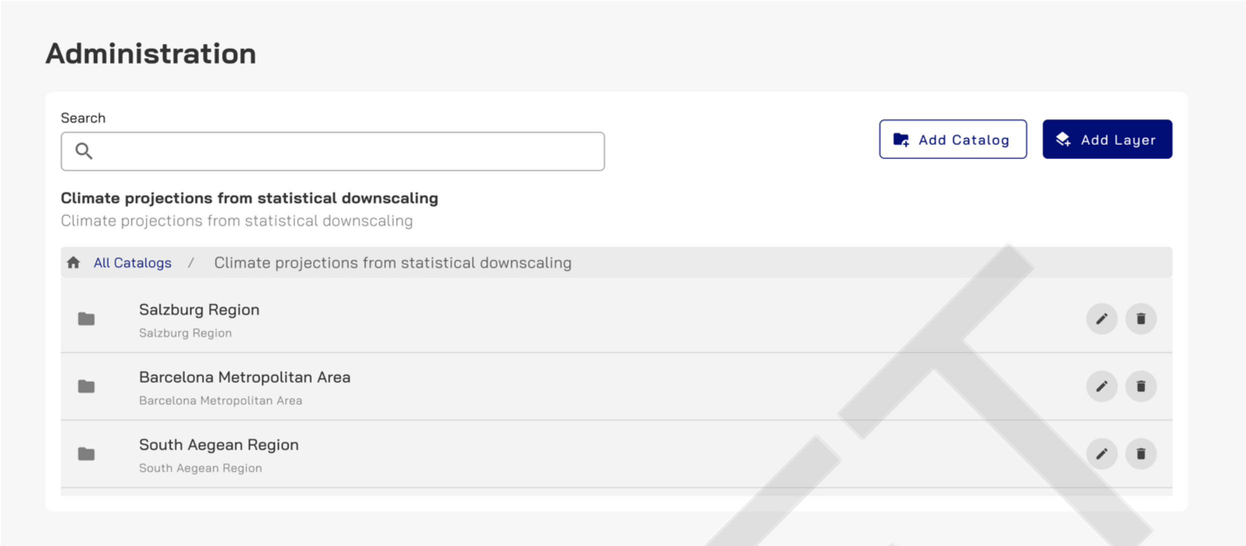

Figure 22: Map Viewer - Admin panel update (1).

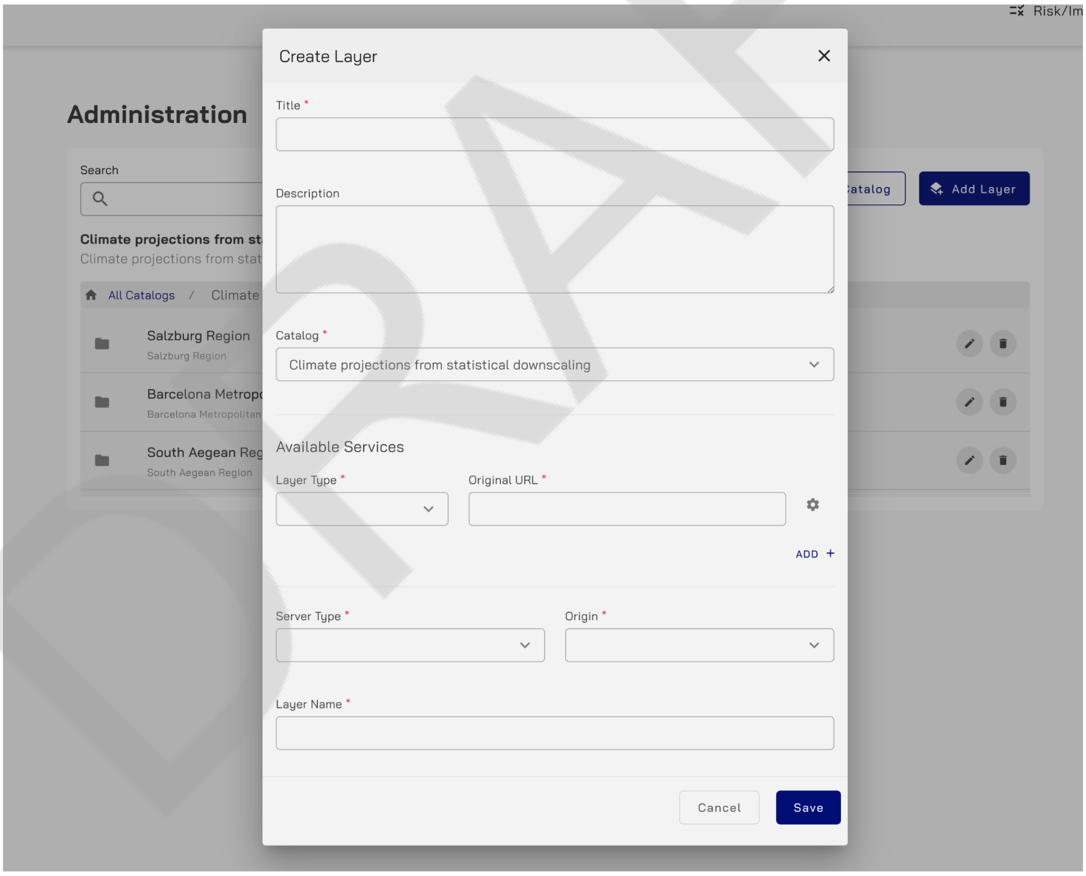

Figure 23: Map Viewer - Admin panel update (2).

In the Map Viewer itself, users can now display the legend explanation directly inside the map by selecting

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this button on the left panel , which is particularly beneficial when users require to have easy access to multiple legends at the same time, such as when using the split view configuration (Figure 24).

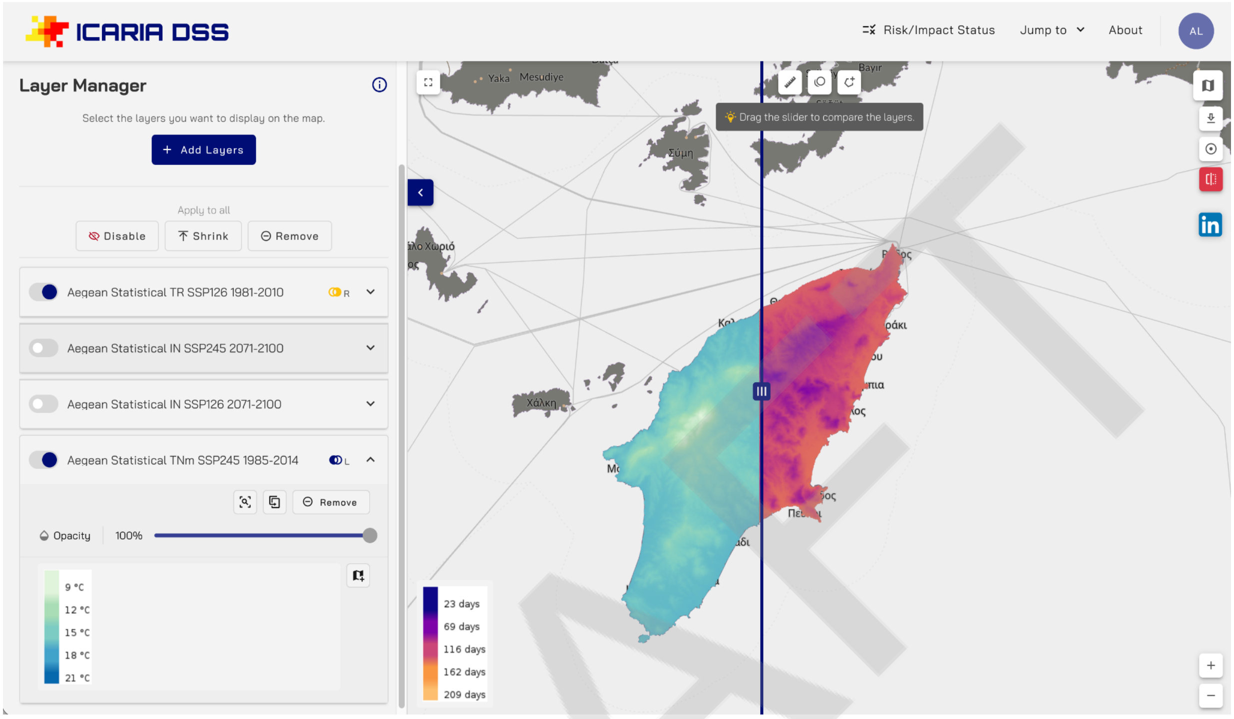

Figure 24: Map Viewer - Legend update.

In addition, the list of available climate projection layers has been reordered and now follows an alphabetical structure based on SSP and time period across all catalogues to allow users to browse through them more easily (Figure 25).

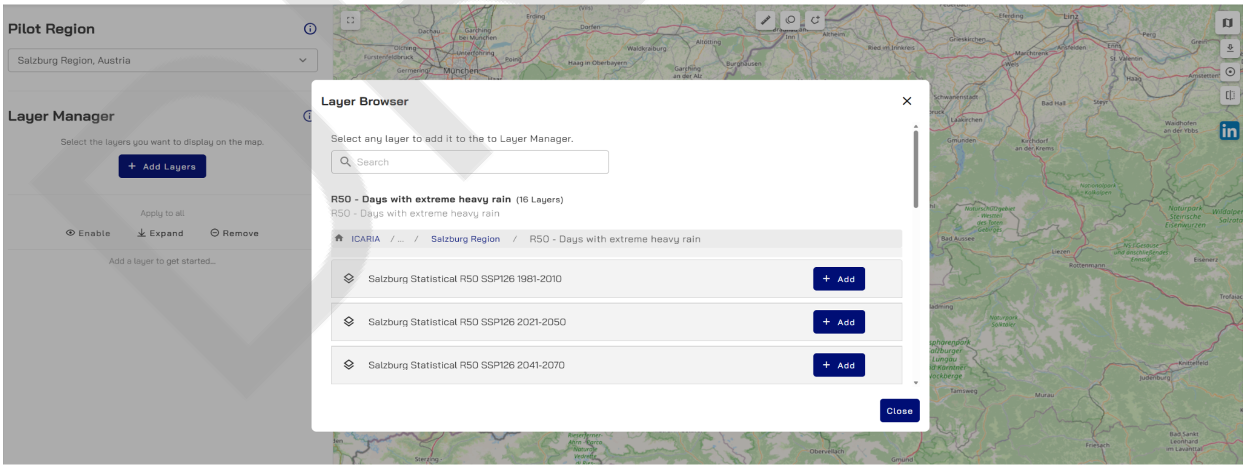

Figure 25: Map Viewer – Projection layers catalogue update.

Lastly, when a new layer is added in the Layer Manager, the Map Viewer automatically adjusts its view to

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the geographic area covered by that layer based on the layer's coordinates, ensuring that the relevant region is immediately visible to the user, no matter the location they might be viewing before loading the layer. Previously, this was only possible upon manually using the "Zoom to Layer" button in the layer toolbar.

4.2.6 Results/Report

The Results section and generation of the PDF report remain mostly unchanged compared to Version 1. Small updates were carried out to accommodate the Wildfire impact assessment workflow which returns 3 layers as outputs in contrast to the rest that only return only one. At the same time, the accompanying tables in the Results/Report now include the units of measurement of each field, the same as in the pop-up attribute tables in the Map Viewer (Figure 26).

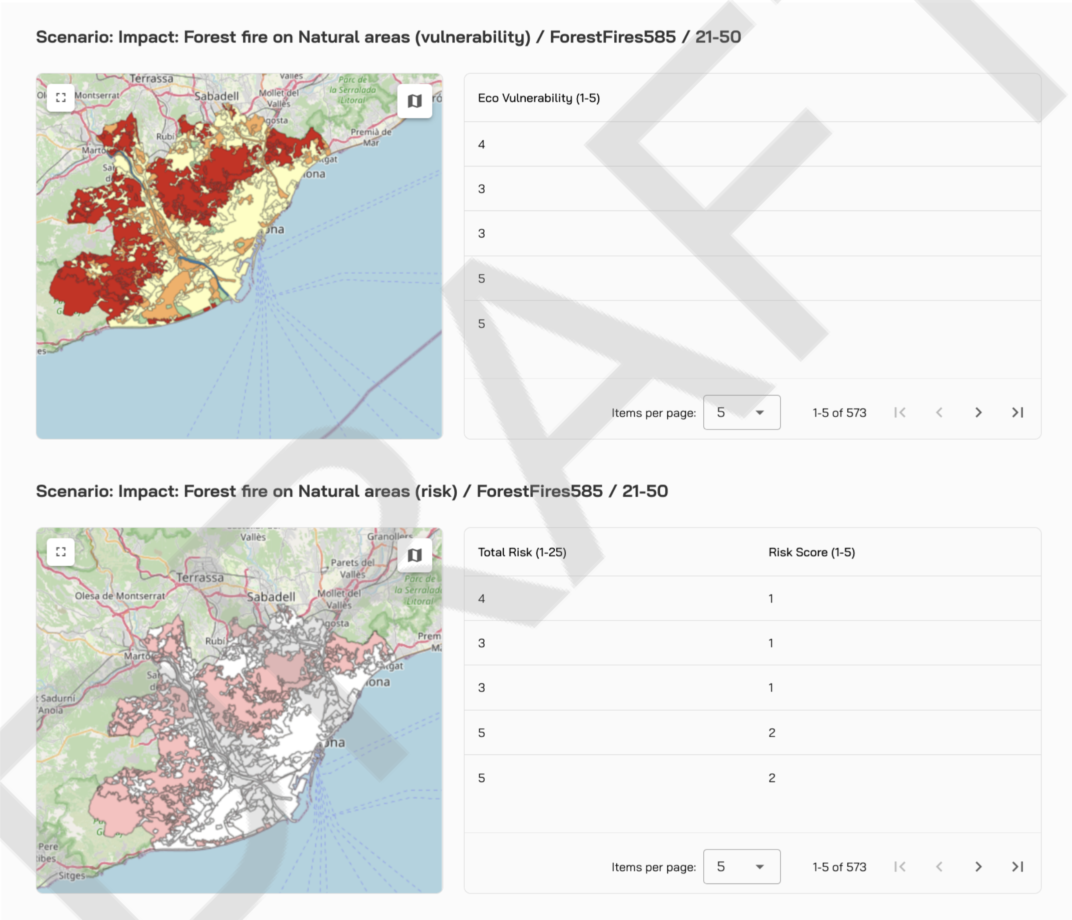

Figure 26: Units and multiple layers update.

4.2.7 Account

Within the Account, registered users can now view their current role in the platform (Stakeholder or Technician) and submit a role change request by contacting the DRAXIS team via the displayed email

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address (Figure 27). Technicians may request to be assigned the Stakeholder role, and stakeholders may request to be reassigned as Technicians.

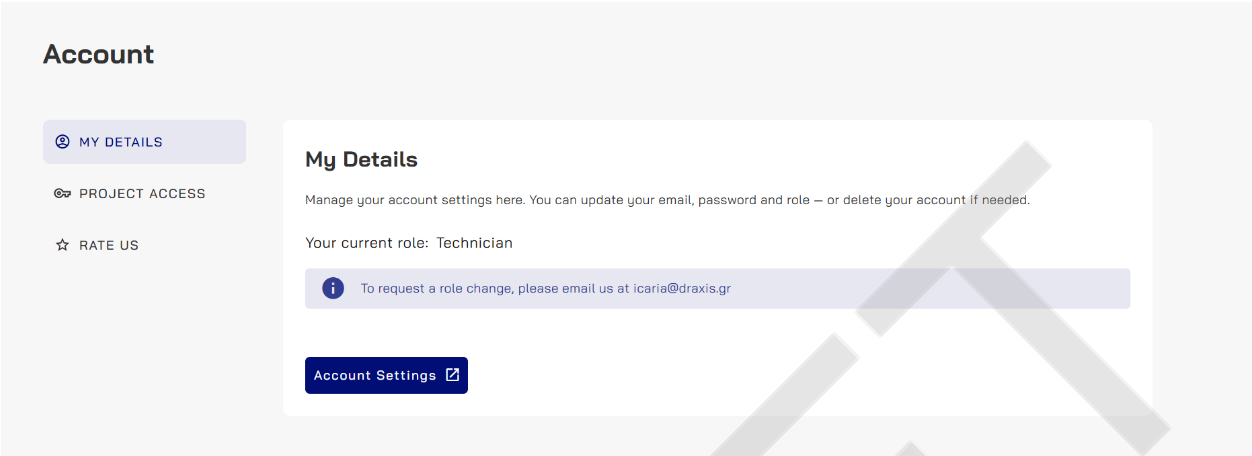

Figure 27: Account - Role change update.

4.2.8 Miscellaneous

Regarding the updates to the miscellaneous pages of the DSS, the first change is reflected in the About page, where the DSS User Guide is now attached at the top of the page, to increase discoverability. The user guide is accessible even to non-registered users and allows them to gain a comprehensive understanding of the platform's capabilities and functionalities (Figure 28). Upon clicking on the link, the users have access to the guide in a downloadable PDF.

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About the ICARIA Decision Support System

View ICARIA User Guide

ICARIA is a European Research and Innovation action focused on improving the resilience of critical assets and infrastructure to climate-related disasters. In response to the increasing frequency and severity of compound, cascading, and complex climate events - such as pluvial floods, heatwaves, droughts, and storm surges - the project promotes the development and application of an asset-level modelling framework for assessing risks and planning effective, sustainable adaptation strategies.

To ground its work in real-world conditions, ICARIA selected three case study regions with distinct environmental, geographical, and socio-economic contexts:

1. **Barcelona Metropolitan Area (Spain):** Coastal urban region facing extreme weather events such as storm surges, heatwaves, droughts, and pluvial flooding.
2. **South Aegean Region (Greece):** Island-based region highly vulnerable to similar events, with strong reliance on tourism infrastructure.
3. **Salzburg Region (Austria):** Mountainous inland region sensitive to glacier melt, heatwaves, and climate impacts on energy production and other critical sectors.

The ICARIA DSS is a major output of the project. It is a modular, web-based platform that integrates climate risk modeling, geospatial visualization, resilience assessment, and adaptation planning tools in one platform. It functions as a central hub for transforming complex climate and infrastructure data into actionable insights to support evidence-based decision-making for adaptation.

As a user-friendly digital environment, the DSS enables stakeholders to:

- **Access and integrate climate data**
  Import, visualize, and analyze both historical datasets and future climate projections derived from statistical and dynamical downscaled climate models, ensuring a clearer understanding of evolving hazards across timeframes and geographies.
- **Simulate risk impact scenarios**
  Model the potential impacts of climate-related hazards (e.g. forest fires, floods, windstorms) on critical assets and infrastructure using asset-level exposure, vulnerability curves, and hazard data tailored to each case study region.
- **Assess resilience across multiple dimensions**
  Evaluate how well areas or infrastructures can cope with climate events using two tools: the RAF and the RAT.
- **Explore and prioritize adaptation measures**
  Access a wide portfolio of adaptation solutions with expert-curated and user-generated options. Users can compare and score measures based on cost, co-benefits, effectiveness, feasibility, and alignment with site-specific conditions.
- **Visualize results on the map**
  Utilise the interactive Map Viewer to explore and interact with geospatial data, namely the results of the impact assessment including how adaptation measures can change the outcomes compared with baseline or business-as-usual scenarios. Visualise and compare climate projections in an intuitive way, download screenshots and video recordings of the visualised data layers and share results on social media.
- **Share insights and create reports**
  Export structured summaries and scenario results into easy-to-read PDF reports to support communication with colleagues, decision-makers, or local communities.

Designed to reduce reliance on expert-level GIS or technical expertise, the DSS simplifies workflows and lowers barriers to adoption, making it accessible to critical infrastructure managers, technicians, academic researchers, public authorities, asset and service planners among others.

To learn more about the ICARIA project and its mission to strengthen climate resilience across Europe, visit the official website: ICARIA Website.

Figure 28: About page - User guide update.

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Finally, the DSS now includes dedicated sections for Frequently Asked Questions (FAQ), Privacy Policy, and Cookies Policy (Figure 29). These additions enhance transparency and user support by providing clear information on system functionalities, data handling practices, user rights, and the overall terms governing the platform's use.

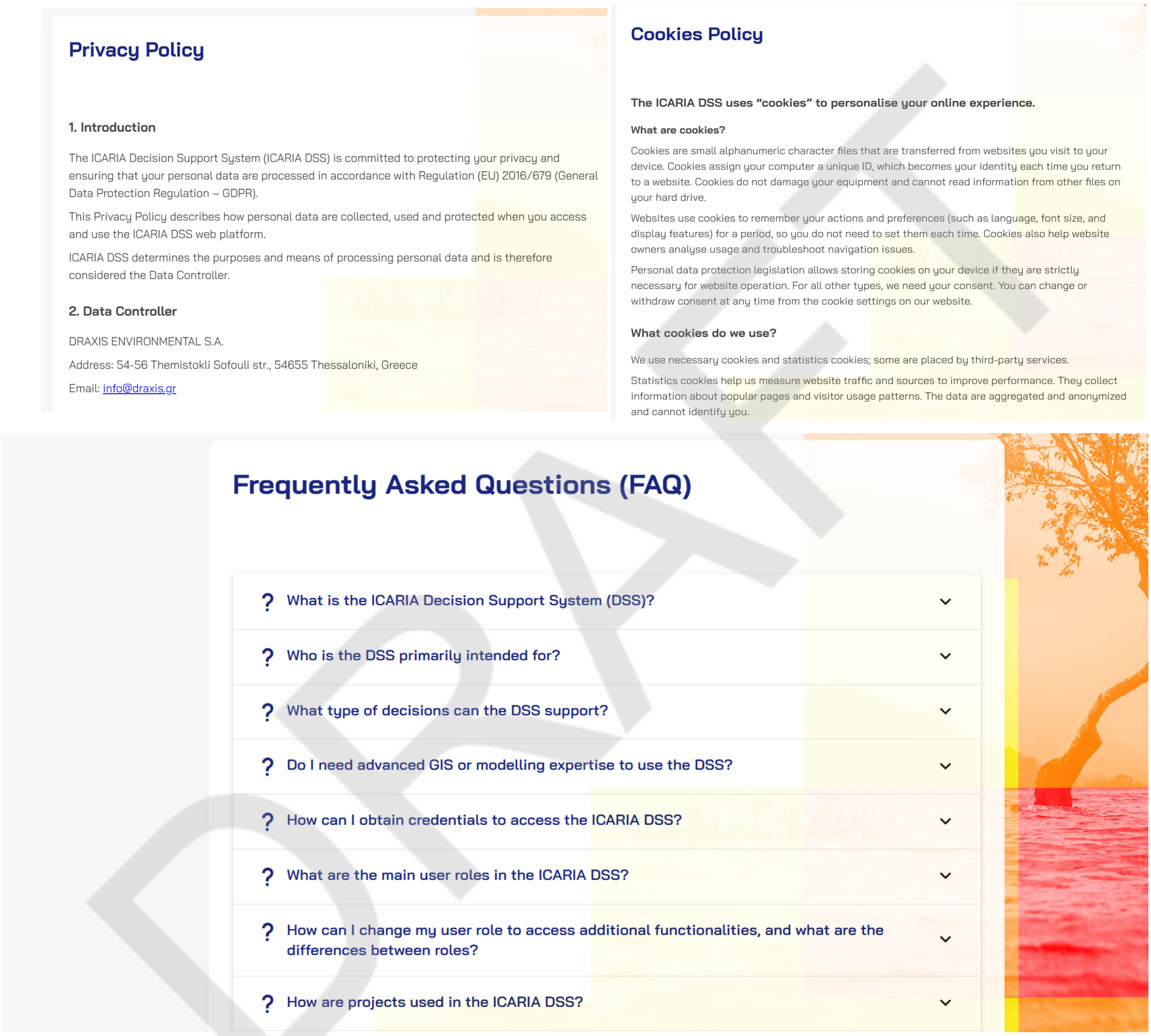

Figure 29: FAQ / Privacy Policy / Cookies Policy pages.

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4.2.9 Stakeholder and General Public Roles - Key Differences

With the introduction of the Stakeholder and General Public roles, the DSS navigation structure was adjusted to reflect role-based access restrictions, dynamically adapting visible menus, actions, and available functionalities according to each user's permissions.

4.2.9.1 Stakeholder user role

4.2.9.1.1 Jump to Navigation

The first difference is reflected in the navigation menu, where a dedicated notice is displayed at the bottom to inform stakeholders of their access restrictions. Moreover, the stakeholder cannot see the Risk/Impact status pop-up in the header as they cannot run impact assessments themselves (Figure 30).

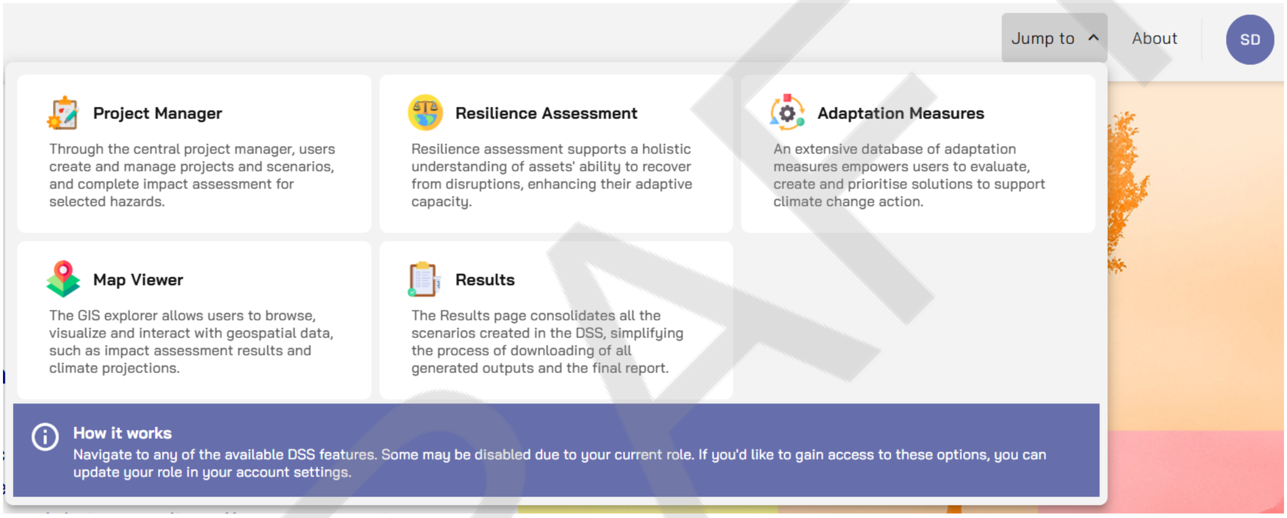

Figure 30: Jump to navigation - Stakeholder view.

4.2.9.1.2 Project Manager

Within the Project Manager, stakeholders can only access projects that have been shared with them, and the actions column is therefore not displayed (Figure 31).

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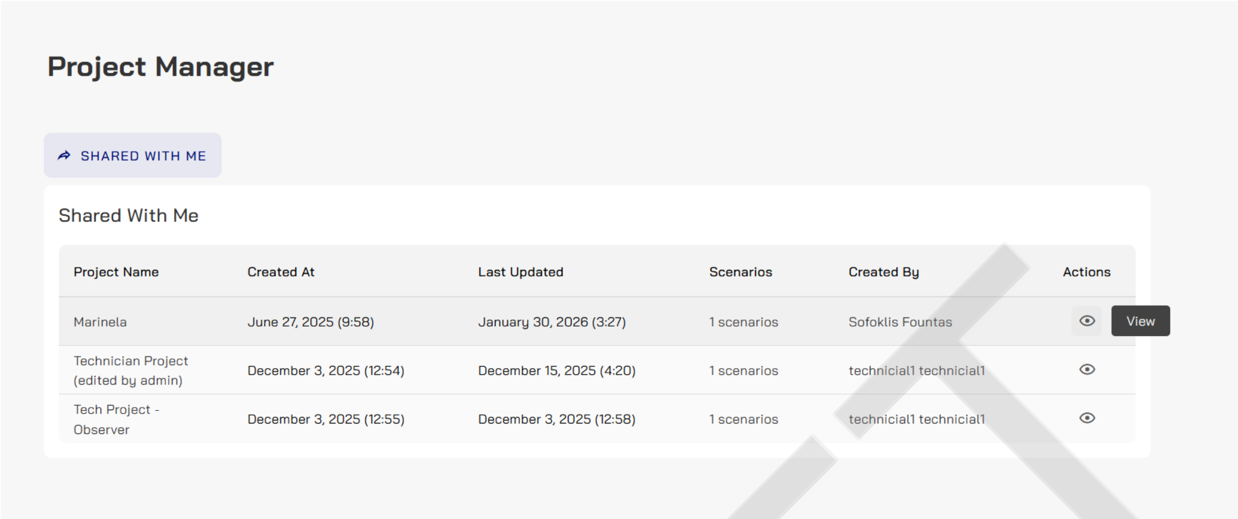

Figure 31: Project Manager - Stakeholder view.

When accessing a project, stakeholders are limited to viewing project details, the associated scenarios, and the final report (Figure 32). The option to download the report remains available to them.

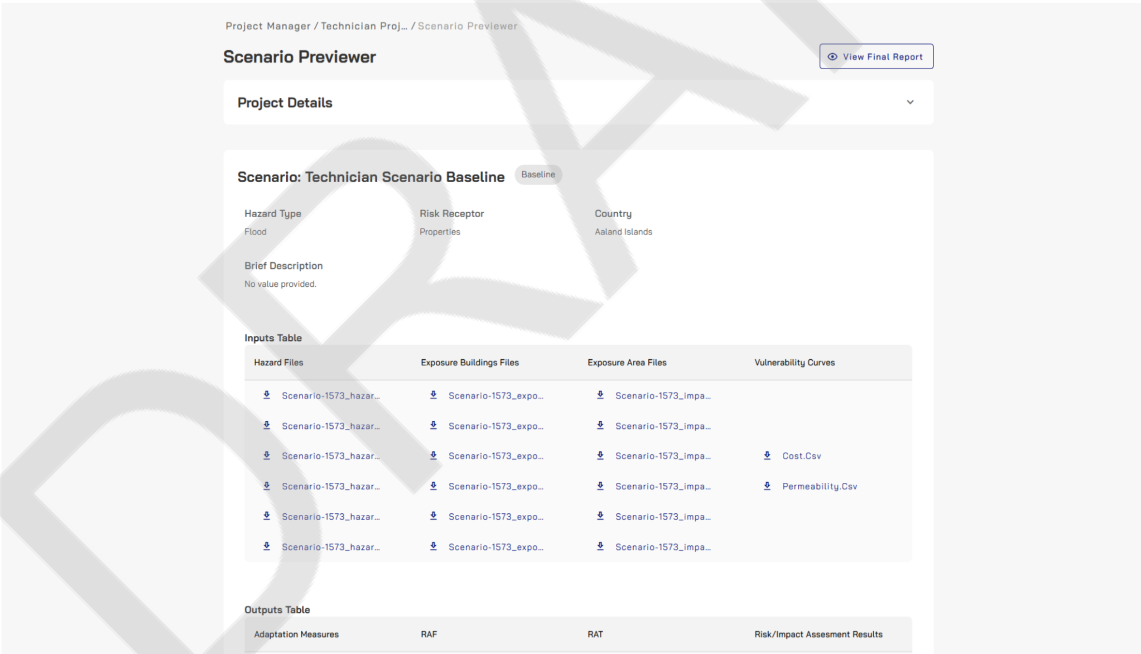

Figure 32: Scenario Previewer - Stakeholder view.

4.2.9.1.3 Resilience Assessment

Similarly to the Project Manager, the Resilience Assessment Framework allows stakeholders only to view and download the final results of completed assessments or, where applicable, compare two completed assessments prepared by technicians (Figure 33).

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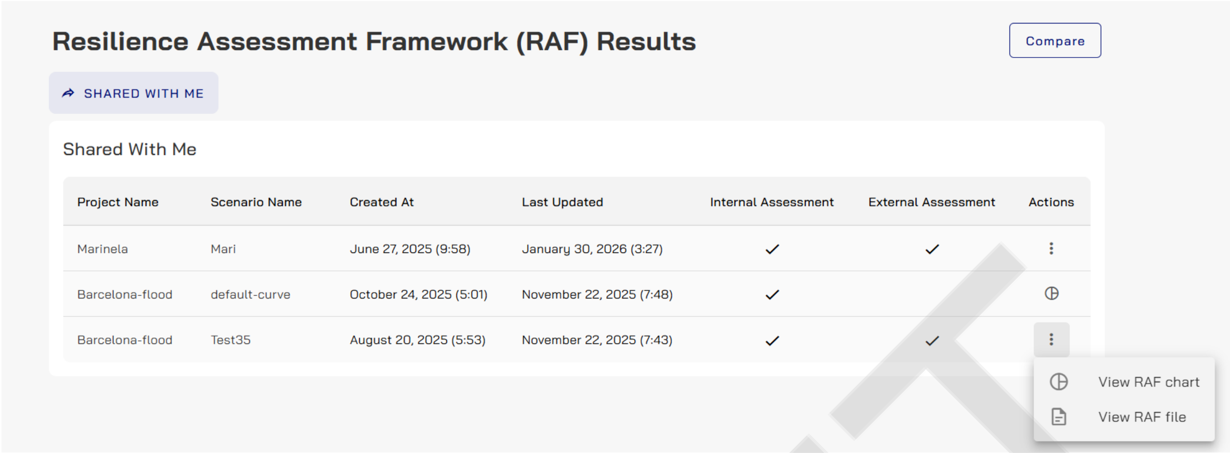

Figure 33: Resilience Assessment Framework - Stakeholder view.

The Resilience Assessment Tool follows the same access logic, displaying the radar chart and overall results to stakeholders without permitting modification of individual indicators or alteration of the calculated outcome The message in orange highlight “Shared project with view-only access” informs them of this fact (Figure 34).

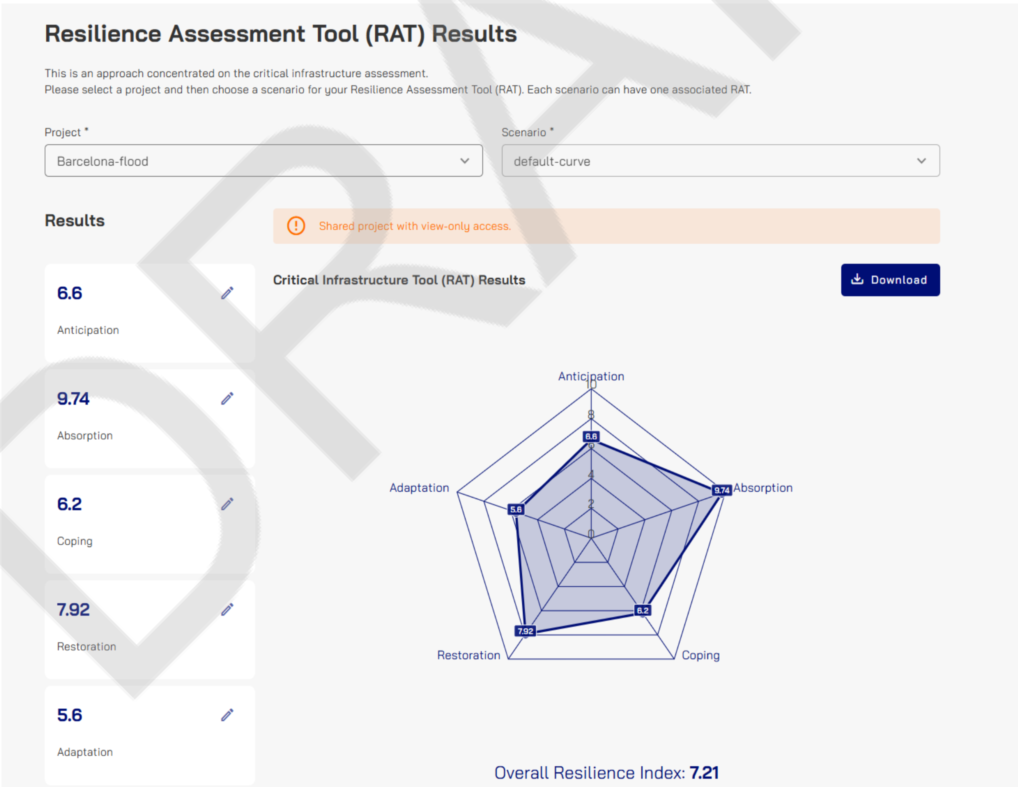

Figure 34: Resilience Assessment Tool - Stakeholder view.

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4.2.9.1.4 Adaptation Measures

In the Adaptation Measures, stakeholders can perform most of the actions available to technicians, including multi-criteria prioritisation and comparison of measures. However, they do not have the ability to create or manage new measures. Stakeholders can only interact with ICARIA's measures or those shared with them by technicians (Figure 35).

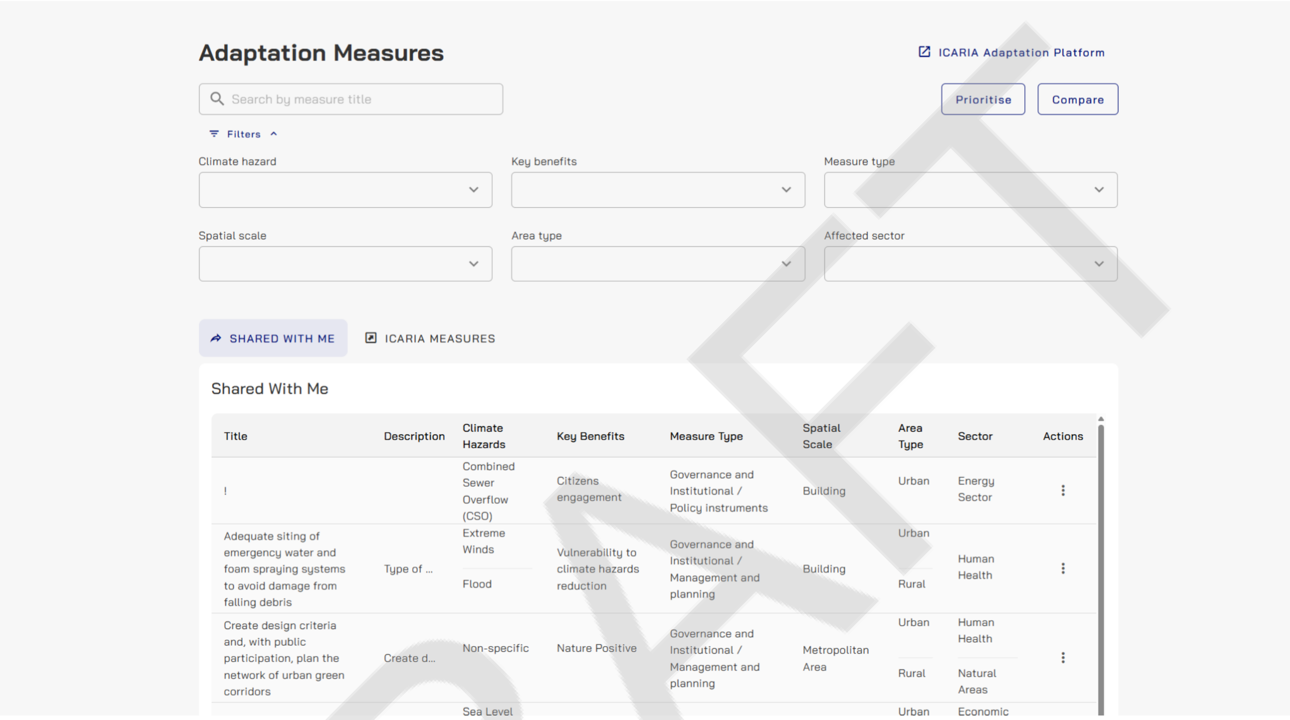

Figure 35: Adaptation Measures - Stakeholder view.

4.2.9.1.5 Map Viewer

The Map Viewer provides stakeholders with access to the full range of functionalities. The only difference is that stakeholders do not own or manage their own layers. They can only access layers that have been shared with them or those provided as part of the ICARIA project (Figure 36).

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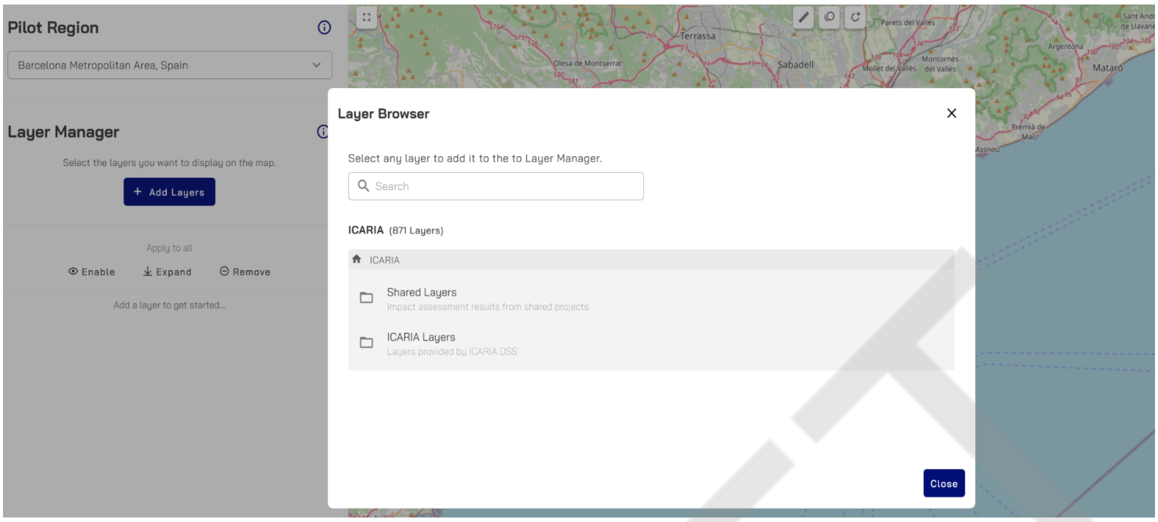

Figure 36: Map Viewer - Stakeholder view.

4.2.9.1.6 Results

Lastly, the Results section follows the same access logic, allowing stakeholders to view outcomes without any editing or modification permissions (Figure 37).

Results

SHARED WITH ME

Shared With Me

Project Name	Scenarios	Created At	Last Updated	Actions
Marinela	1 scenarios	June 27, 2025 (9:58)	January 30, 2026 (3:27)	👁
Technician Project (edited by admin)	1 scenarios	December 3, 2025 (12:54)	December 15, 2025 (4:20)	👁
Tech Project - Observer	1 scenarios	December 3, 2025 (12:55)	December 3, 2025 (12:58)	👁
Barcelona-flood	3 scenarios	August 20, 2025 (5:53)	November 22, 2025 (7:48)	👁

Figure 37: Results - Stakeholder view.

4.2.9.1.7 Account

Within the Account, the navigation remains the same as the one described for the technician role, with the exception being that stakeholders can only view the shared projects in the respective tab (Figure 38).

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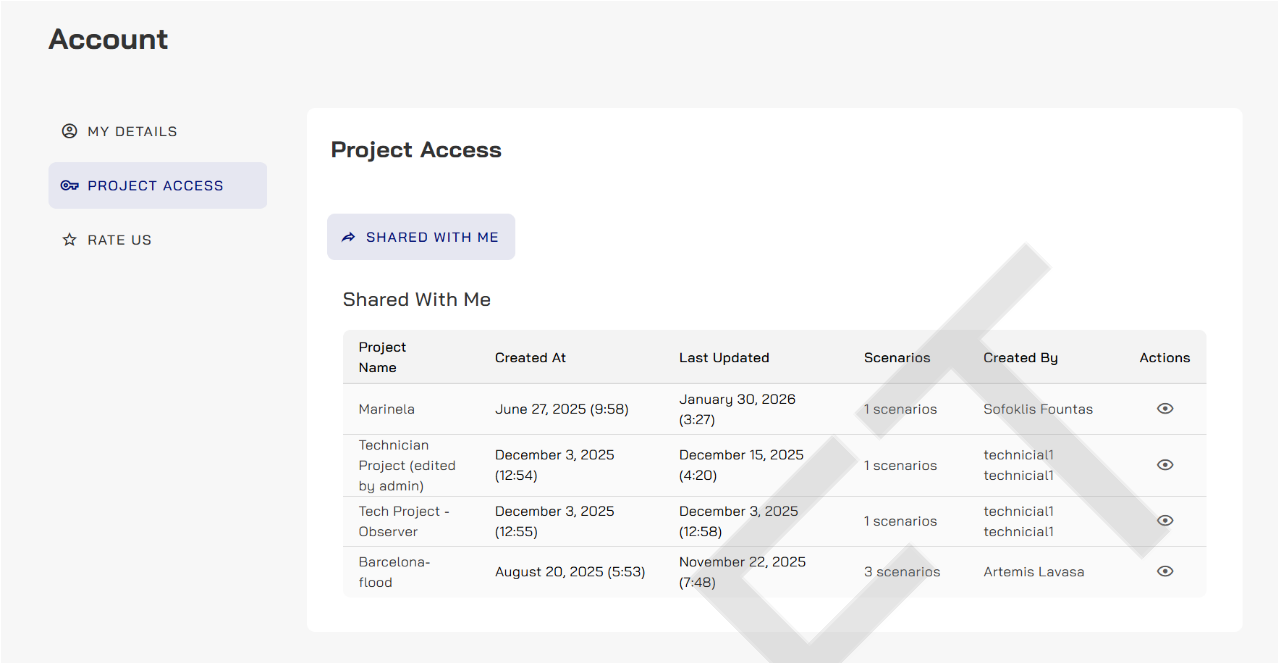

Figure 38: Account - Stakeholder view.

4.2.9.2 General Public user role (Unregistered)

The General Public role has full access only to the Map Viewer functionality without having to log in, while there is no access to the other features as the "Jump" to button is not accessible, as evident from the header in the below image. Access is limited to layers associated with the ICARIA project, while layers created or shared by other users are not visible (Figures 39 & 40). All other DSS functionalities remain inaccessible to this role.

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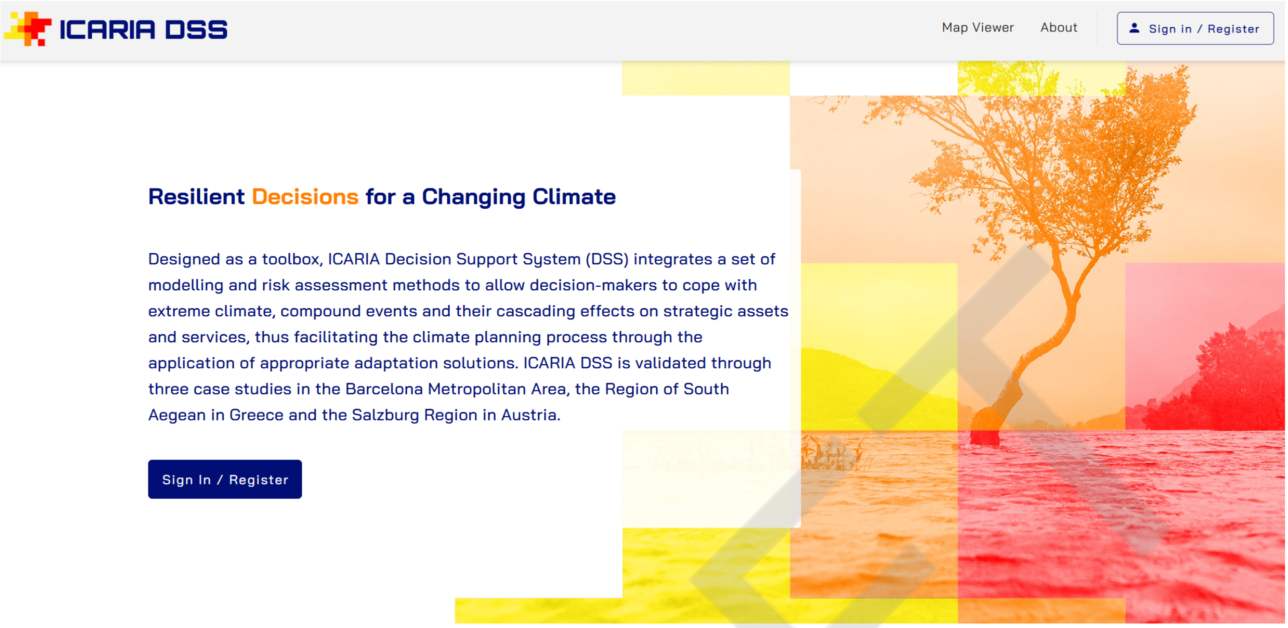

Figure 39: Home page – General Public view.

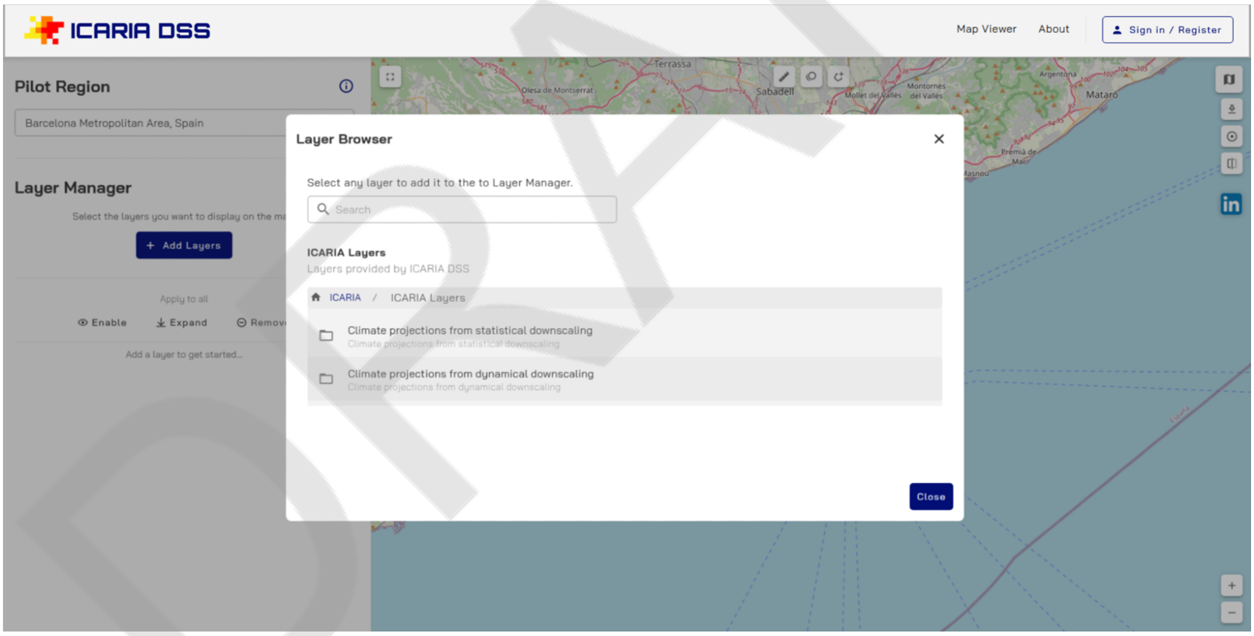

Figure 40: Map Viewer - Public view of Catalogue.

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5 System Architecture

As outlined in detail in Deliverable D3.4, chapter 5 describes the ICARIA DSS's architecture, which is implemented using a modular, service-oriented architecture. The overall architectural design, system components, and quality assurance approach remain unchanged in the current version and are therefore summarised here for completeness.

The DSS is composed of interoperable services organised into the following layers:

- **User Interaction Layer**: a Vue-based frontend using Vuetify for the graphical interface.
- **Business Logic Layer**: a Django backend exposing REST APIs.
- **Geospatial Services Layer**: PostgreSQL with PostGIS and GeoServer for spatial data storage and Open Geospatial Consortium (OGC)-compliant services.
- **Authentication Layer**: Keycloak implementing OAuth2-based role-based access control.
- **Integration Layer**: interfaces to external services such as the Resilience Assessment Tool (RAT) and risk/impact assessment APIs.
- **Orchestration Layer:** Docker containers enabling isolated and reproducible deployments.

Table 7: Technical stack components.

Component	Technology	Notes
Frontend	Vue 3 + Vuetify	Custom geospatial UI
Backend	Django	REST API & business logic
Database	PostgreSQL + PostGIS	Draxis/PostGIS Docker image
GIS Server	GeoServer	OGC services (WMS/WFS)
Authentication	Keycloak	OAuth2, RBAC
Reverse Proxy	NGINX	Optional
Containers	Docker	Per service

Data flow within the system follows a standard request–response pattern: user inputs are submitted via the frontend, processed by the backend, stored or retrieved from the database, and rendered back to the user based on authentication and role permissions. External integrations include REST-based communication with the RAT service, the risk/impact assessment APIs, and the adaptation measures implementation interface.

Finally, the quality assurance strategy combines manual functional testing, automated load and stress testing, and security testing to ensure reliability, performance, and robustness. Load and stress tests demonstrated stable system behaviour under concurrent usage, while security testing relied on built-in Django protections and Keycloak-based authentication mechanisms. Code quality is enforced through automated linting and formatting tools for both backend and frontend components.

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6 Deployment and Access

As outlined in detail in Deliverable D3.4, chapter 6 describes how the ICARIA DSS is deployed and accessed, with the aim of balancing operational control, security, and ease of use for both technical administrators and end-users. The system relies on containerisation and a dedicated hosting environment to ensure consistent performance, straightforward maintenance, and reliable operation. The deployment pipeline is designed to be repeatable and scalable, enabling updates and environment changes to be managed with minimal disruption.

Hosting environment: The DSS is deployed on a dedicated server to ensure full control over the hosting environment and system resources. The full stack is containerised using Docker, providing consistent and isolated environments for the frontend, backend, database, and authentication services. Deployment is orchestrated with Docker Compose (Laravel backend, PostgreSQL, Keycloak, Vue frontend), configuration is handled through environment files (.env), and routine maintenance/deployment is performed via SSH using Docker CLI. This setup supports flexibility, component isolation, and easier replication of environments for staging/testing.

Access: User access is provided through a secure web URL. Authentication is handled via Keycloak, which manages login, sessions, and role enforcement. The only feature accessible without authentication is the map viewer. Developer/administrator access is provided through SSH access to the dedicated server, allowing container management, log inspection, and updates. Environment-specific parameters (e.g., credentials and domain settings) are managed via .env files within the Docker setup

6.1 User Roles and Permissions

ICARIA DSS supports multiple user groups, each mapped to specific roles and access levels based on their responsibilities and technical background. Two more roles are available in version 2: a) Stakeholder and b) General Public (unregistered). The complete access permissions per role are as follows:

6.1.1. Administrator: DRAXIS

Access Level: Full
Permissions:

- **Project management:** Create, view, edit, and delete projects and scenarios.
- **Data management:** Import, edit, and delete all types of data (both preloaded and user-submitted).
- **User management:** Create, edit, and delete user accounts; assign roles; manage permissions.
- **Integrations:** Manage APIs, integrate external tools.
- **Documentation:** Upload and manage system documentation, user guides, and policies.

As system administrators, DRAXIS has access to all projects created within the DSS. This access is strictly limited to technical and maintenance purposes, ensuring that the development team can resolve issues, correct errors, and apply necessary updates to keep the platform functional and secure. Since the DSS is a web application, data are stored on servers, not locally on individual users' devices, which allows for

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consistent system performance and centralised monitoring of potential technical problems. No personal data is used beyond what is essential for user authentication, and project-related inputs remain strictly within the scope of ICARIA's research objectives. Administrative access is exercised when required for troubleshooting or ensuring the integrity of the system, such as usability and security.

6.1.2. Registered User: Technician

Access Level: High (but limited to own data and projects)
Permissions:

- **Project management:** Create, view, share and edit their projects and scenarios; upload, edit, delete their own data.
- **Risk/impact assessment:** Import hazard, exposure, vulnerability data and carry out calculations of impacts.
- **Adaptation measures:** View list of measures, filtering, comparison, prioritisation. Create new measures locally, edit and delete them.
- **Resilience assessment:** Complete RAF/RAT questionnaires, generate and compare results.
- **Map viewer:** Access to full functionality including visualisation of preloaded map layers and own impact assessment results.
- **Data:** View pre-loaded data and own data.
- **Account:** Manage account, manage access to all projects with registered users.
- **My results:** View list of results generated in all projects. View and compare impact assessment results from different scenarios. Download results and generate reports.
- **Feedback submission**: Submit short feedback (from Account) and more targeted feedback (from Footer).

6.1.3. Registered User: Stakeholder

Access Level: Medium
Permissions:

- **Project management, Risk/impact assessment:** View projects shared by a technician without editing permissions. Cannot upload or manage data on the platform.
- **Adaptation measures**: View list of measures, filtering, comparison, prioritisation. Cannot create new measures.
- **Resilience assessment**: View results from RAF/RAT questionnaires completed by a technician and shared.
- **Map viewer**: Access to full functionality including visualisation of preloaded map layers and impact assessment results upon being shared by a technician.
- **Data**: View pre-loaded data and data shared by a technician.
- **Account**: Manage account, view shared projects, request role change to technician.
- **My results**: View list of results for specific projects or scenarios made available by the technician. View and compare results different from scenarios upon sharing by a technician. Download results and reports generated by technicians.

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- **Feedback submission**: Submit short feedback (from Account) and more targeted feedback (from Footer).

6.1.4. Unregistered User: General Public

Access Level: Limited
Permissions:

- **Map viewer**: Access to full functionality for visualisation of preloaded map layers.
- **Data**: View pre-loaded data only.

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7 DSS application in ICARIA case studies

ICARIA DSS is a web-based tool to support a better decision-making process in terms of climate resilience and adaptation for regional authorities and critical infrastructure operators across Europe. With this objective, the DSS has been developed according to the following principles:

- **Methodological coherence:** the nomenclature and structure of the various components of the DSS (e.g. risk assessment workflows, RAF and RAT questionnaires) are coherent with the ICARIA holistic modelling framework (WP1) and assessment methodology applied across the different case studies.
- **Holistic perspective of climate resilience**: resilience is a multi-perspective topic; for this reason, the DSS includes different methodologies and data collection functionalities that converge this diversity. Importantly, the results of these methods are complementary when assessing the natural risks that are faced in a region.
- **Modularity:** despite the diversity of tools and workflows in the DSS, the tool is designed to create "projects" to address particular risks or resilience aspects of the area of study using a subset of the available tools.
- **Replicability:** although the DSS development has been based on the scientific work developed on the three ICARIA case studies, all its functionalities are designed to be fully replicable in other European regions.

As reflected in Figure 2 in Chapter 2, a key feature of the DSS is its capacity to perform parallel assessments of different climate scenarios for one specific area of study, including baseline (BAS), business as usual (BAU) and Adaptation scenarios. This allows the assessment of the consequences of different extreme weather events, the risk reduction capacity of specific adaptation measures, or the increase in resilience associated with resilience improvement policies.

The objective of this chapter is to provide evidence of the implementation of the DSS on the three ICARIA case studies in Task 4.2 (ICARIA Trials). Importantly, these experiences with potential end-users provided the necessary feedback to implement part of the improvements on the second version of the DSS.

Within ICARIA, full risk assessments considering a large set of hazard and multi-hazard drivers and risk receptors have been performed, as fully described in D4.2 and D4.3 (Turchi et al., 2026). The methodologies enabling these comprehensive assessments are grounded in the deep sectoral expertise of the project partners. A significant part of this knowledge has been translated into the DSS. Although the DSS has not been used to reproduce the same level of exhaustive, fully offline risk assessments conducted for the three case studies, it has nevertheless enabled the evaluation of damages in case studies without requiring the same level of prior expert knowledge or detailed off-line analysis.

Some short examples of these implementations are reported as follows.

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7.1 DSS Implementation in the Barcelona Metropolitan Area (AMB) Case Study

7.1.1 DSS "impact assessment" implementation in the AMB CS

The implementation of the DSS in the Barcelona Metropolitan Area was focused on the assessment of the climate resilience of this region against pluvial floods. For operational reasons, the scope of the assessment through the DSS was limited to the municipality of Barcelona.

The risk assessment workflow tested in the AMB was "impact of floods on buildings", where pluvial floods are the hazard driver and all buildings in the area of study are the risk receptor. Impact is expressed in monetary terms. Figure 41 summarises the data inputs provided for the three scenarios compared.

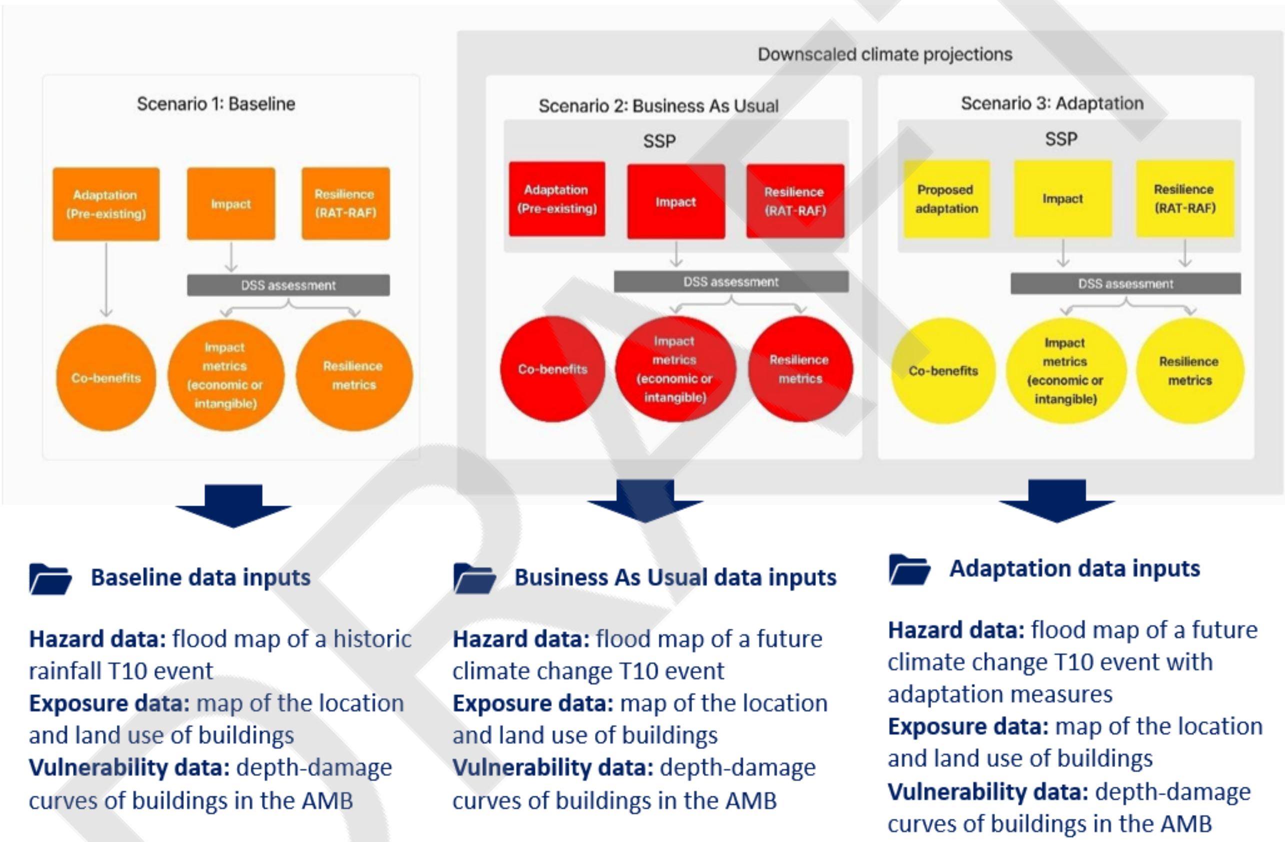

Figure 41: Data inputs for the DSS impact assessment implementation in the AMB CS.

The datasets provided were very similar for all three scenarios. The reason for this is that, for this example, the changes were concentrated on the hazard maps, although the DSS allows different kinds of updates in terms of exposure and vulnerability (for example updating flood-depth damage curves or land use for the future). In the baseline scenario, the design storm was a T10 rainfall event based on the historic precipitation patterns of Barcelona. The business-as-usual scenario considered the effect of climate change on the baseline T10 design storm, resulting in a higher intensity rainfall event producing more critical pluvial floods. The adaptation case used the design storm of the BAU scenario and included several

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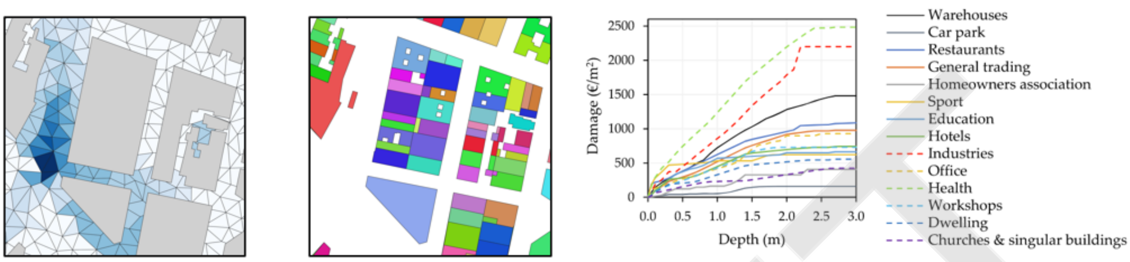
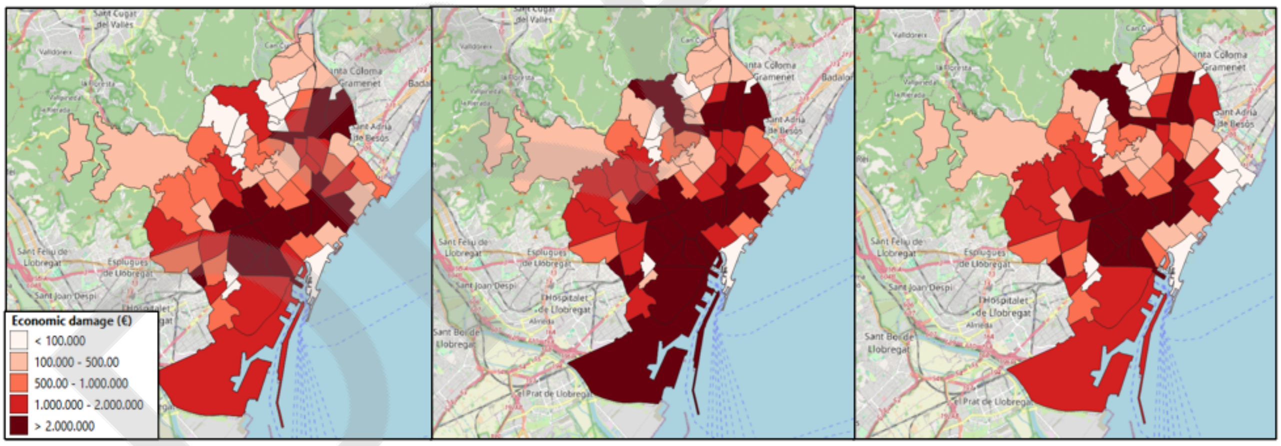
adaptation measures (fully outlined in D4.2) in the hazard model to reflect a resilience improvement policy. Figure 44 shows a scheme of the layers mentioned in Figure 42, for the following cases: (a) flood hazard map, (b) building exposure map indicating land uses, and (c) tailored vulnerability depth-damage curves specific to each land use type.



(a) (b) (c)

Figure 42: Representation of data inputs for the DSS impact assessment implementation AMB CS.

The DSS outputs reflected the economic damage of floods on buildings aggregated per neighbourhood. In the map attributes, it could be observed that the damages associated with the BAU scenario were higher than the Baseline (due to the increase in rainfall intensity) and the Adaptation (due to the effect of adaptation measures). When styled, the DSS outputs clearly reflect the evolution of economic damages across Barcelona for the different scenarios considered (a) Baseline, (b) Business As Usual, and (c) Adaptation), as Figure 43 shows. Importantly, results can be aggregated in different areas of interest. This example considered the neighbourhoods of Barcelona.



(a) (b) (c)

Figure 43: DSS outputs of flood economic impact on buildings for the considered scenarios.

7.1.2 DSS "resilience assessment tools" implementation in the AMB CS

The ICARIA DSS offers two tools to assess climate resilience. The RAF is focused on resilience policy assessment, and the RAT is oriented to infrastructure operators. Both tools are based on expert surveys addressed to one or multiple stakeholders with the specific knowledge to answer them. Figures 44 and 45

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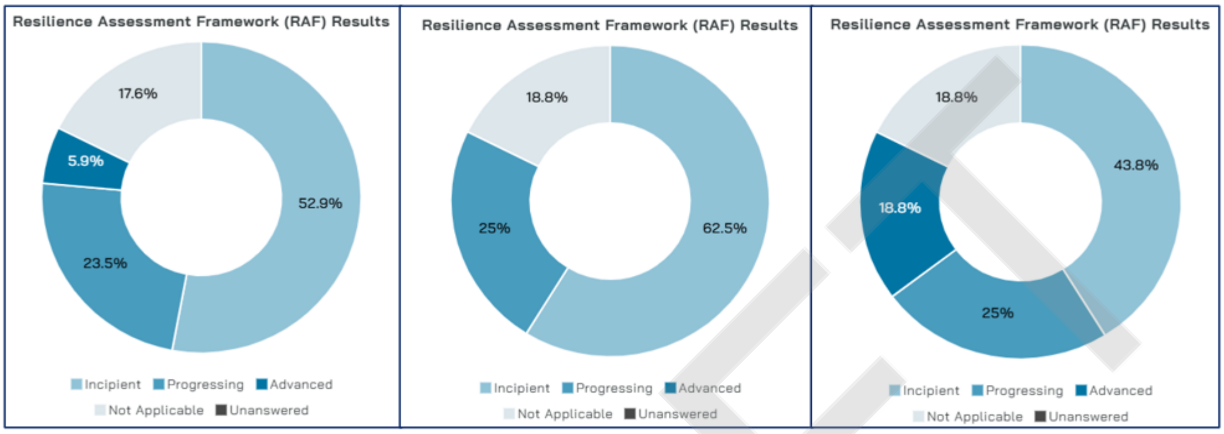
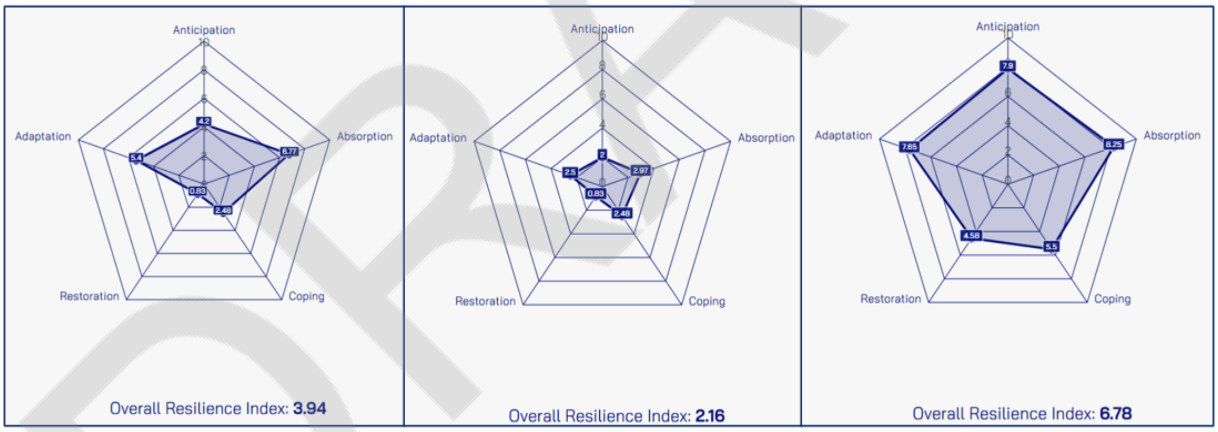
show the resilience assessment answers gathered from stakeholders in the AMB CS for the scenarios: (a) Baseline, (b) Business As Usual, and (c) Adaptation. It can be observed that resilience decreases both in RAF and RAT when comparing Baseline and Business as Usual scenarios, while the Adaptation case shows an increase in metrics.



(a) (b) (c)

Figure 44: DSS outputs of the RAF resilience assessment tool.



(a) (b) (c)

Figure 45: DSS outputs of the RAT resilience assessment tool.

In summary, the results in Figures 43 to 45 allow the multi-criteria analysis when comparing the impacts of natural hazards across different scenarios: Baseline showing moderate impacts, Business as usual with higher results due to climate change effects, and Adaptation offering risk reduction thanks to the implemented adaptation measures. These changes are visible at multiple levels: direct damage (Figure 43), the region's holistic resilience (Figure 44), and infrastructure resilience (Figure 45). In addition, the portfolio of adaptation measures allows identifying the main co-benefits of the adaptation measures considered in

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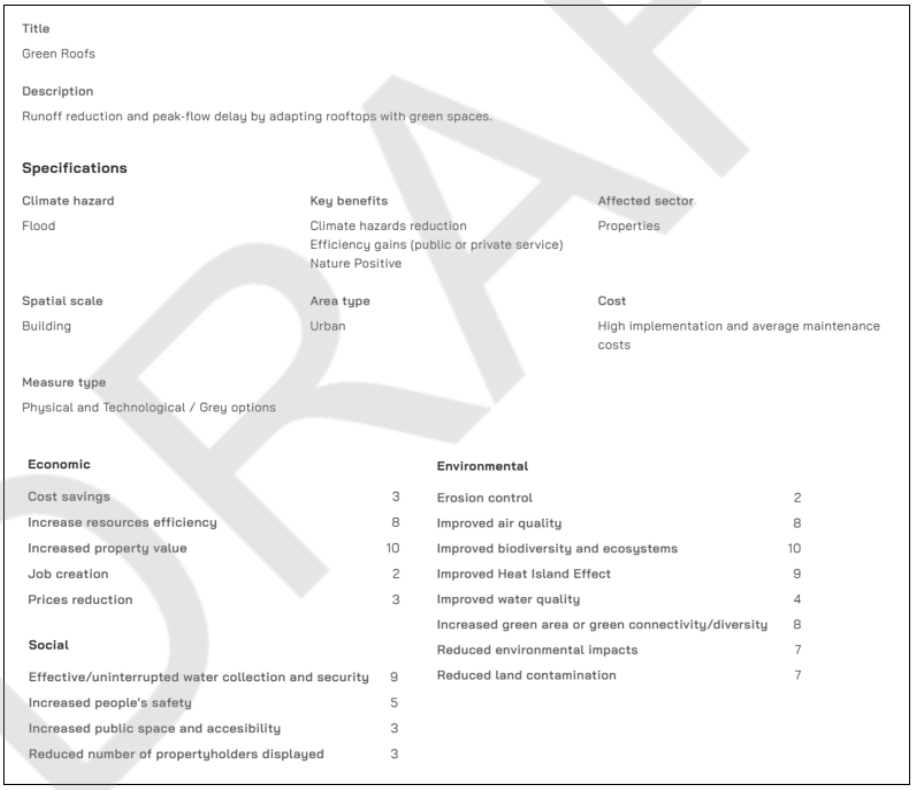
the adaptation scenario. In this case, the measures adopted where porous pavements, green roofs, and bioretention areas—implemented in a distributed manner to reduce flood risk while delivering broad co-benefits. Hydrologically, they reduce runoff and delay peak flows. Beyond flood mitigation, these measures improve thermal comfort and heatwave resilience by lowering surface and indoor temperatures and mitigating the urban heat island effect. They also enhance public health and urban liveability through better air quality, pollutant removal, and the creation of multifunctional green spaces. Environmentally, the strategy improves stormwater quality, supports groundwater recharge, and strengthens urban biodiversity and ecological connectivity.

7.1.3 DSS "portfolio of adaptation" implementation in the AMB CS

The ICARIA DSS incorporates a portfolio of adaptation measures that comprises a wide range of risk reduction measures that can constitute parts of a regional adaptation strategy. Beyond the measure itself, the portfolio indicates co-benefits and other characteristics that can support the selection of particular actions. Furthermore, the DSS allows adding adaptation measures according to the user's knowledge. Figure 46 shows an adaptation measure developed by stakeholders during the DSS testing.



Title
Green Roofs

Description
Runoff reduction and peak-flow delay by adapting rooftops with green spaces.

Specifications

Climate hazard	Key benefits	Affected sector
Flood	Climate hazards reduction Efficiency gains (public or private service) Nature Positive	Properties
Spatial scale	**Area type**	**Cost**
Building	Urban	High implementation and average maintenance costs

Measure type
Physical and Technological / Grey options

Economic	
Cost savings	3
Increase resources efficiency	8
Increased property value	10
Job creation	2
Prices reduction	3

Social	
Effective/uninterrupted water collection and security	9
Increased people's safety	5
Increased public space and accesibility	3
Reduced number of propertyholders displayed	3

Environmental	
Erosion control	2
Improved air quality	8
Improved biodiversity and ecosystems	10
Improved Heat Island Effect	9
Improved water quality	4
Increased green area or green connectivity/diversity	8
Reduced environmental impacts	7
Reduced land contamination	7

Figure 46: Example of the adaptation measure "green roofs" developed by DSS users.

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7.2 South Aegean (SAR) Case Study

7.2.1 DSS "impact assessment" implementation in the SAR CS

The risk-assessment workflow implemented within the DMKTS framework for the ICARIA project focuses on wildfire risk to critical assets on Rhodes Island, where forest fire is the hazard driver with the primary risk receptors being the natural areas. Impact is expressed in monetary and functional-performance terms, integrating asset-level modelling of exposure, vulnerability, and adaptation measures under different climate scenarios.

The impact assessment methodology is briefly presented in Figure 47, below. The baseline scenario is based on the historical climate data, used for the calculation of FWI for the CS area. The business as usual is based on the future projected climatic conditions, and finally the adaptation is based on FWI data from future projected climatic conditions, when the land use is changed in specific areas of the island, mainly due to vegetation type/coverage.

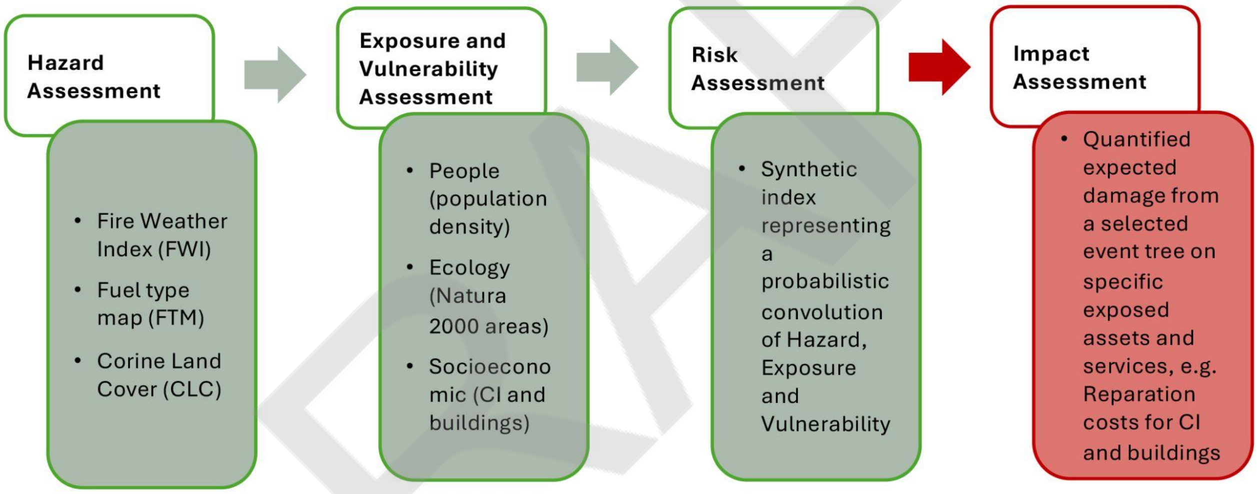

Figure 47: Wildfire risk assessment methodology.

The users were provided the main 2 datasets they needed to use the DSS. The first dataset was the gridded data of FWI in 5x5 km grid cells (Hazard). The second dataset was the CLC (from Copernicus), clipped on the Rhodes extent. The DSS, based on the CLC code, assigns a Vulnerability score according to the link-up table embedded in Figure 48, which shows the results for the following 3 cases. It may be noted that the output seen in (b) has since been renamed "Hazard" instead of "Exposure", per Figure 17.

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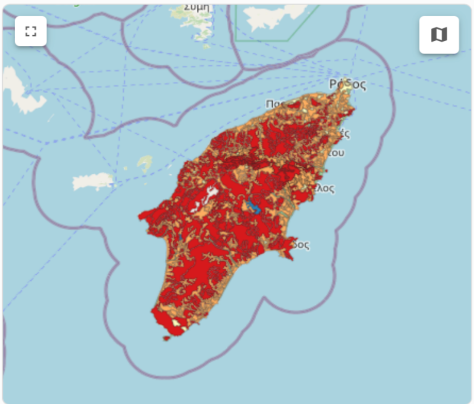
Scenario: Impact: Forest fire on Natural areas (vulnerability) / CoP Rhodes / Wildfire risk assessment

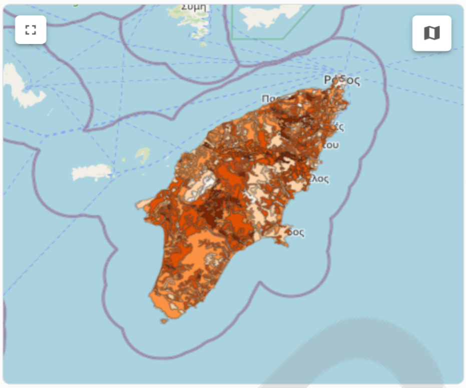


Eco Vulnerability (1-5)
3
3
4
5
4

Items per page: 5   1-5 of 807

(a)

Scenario: Impact: Forest fire on Natural areas (exposure) / CoP Rhodes / Wildfire risk assessment

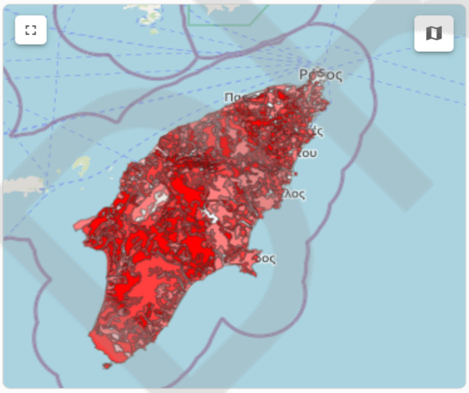


Exposure (1-5)	Fwi (1-5)	Fuel (1-10)
1	5	1
1	5	1
4	5	7
3	5	5
3	5	5

Items per page: 5   1-5 of 807

(b)

Scenario: Impact: Forest fire on Natural areas (risk) / CoP Rhodes / Wildfire risk assessment



Total Risk (1-25)	Risk Score (1-5)
3	1
3	1
16	4
15	4
12	3

Items per page: 5   1-5 of 807

(c)

Figure 48: DSS outputs of Wildfire risk assessment. (a)Vulnerability, (b) Hazard, and (c) Risk maps.

The DSS results indicated, as expected, the increased risk for the natural areas of Rhodes islands. The southern and central part of the island show the highest risk. This is based on the fact that this part

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remains unaffected by the urbanisation, which takes place in the northern and eastern part of the island, where the natural areas are not altered and the main agricultural activities take place.

7.2.2 DSS "resilience assessment tools" implementation in the SAR CS

The ICARIA DSS offers two tools to assess climate resilience. The RAF is focused on resilience policy assessment, and the RAT is oriented to infrastructure operators. Both tools are based on expert surveys addressed to one or multiple stakeholders with the specific knowledge to answer them. Figures 49 and 50 show the resilience assessment answers gathered from stakeholders in the SAR CS for the physical areas (with adaptation scenario), when comparing Baseline and the Adaptation scenarios in SAR Trial.

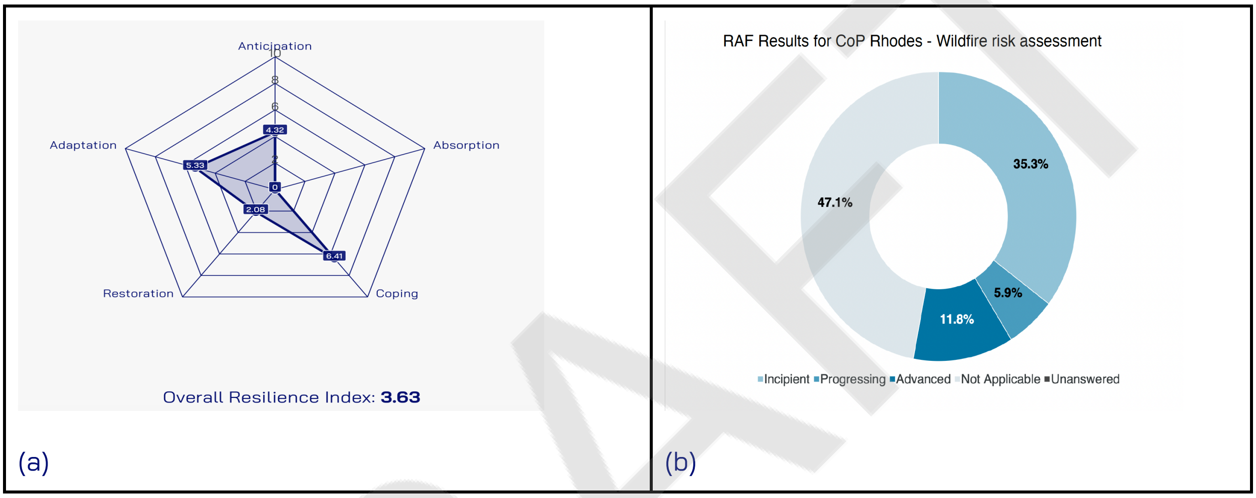

Figure 49: RAT (a) and RAF (b) results for Wildfire resilience assessment.

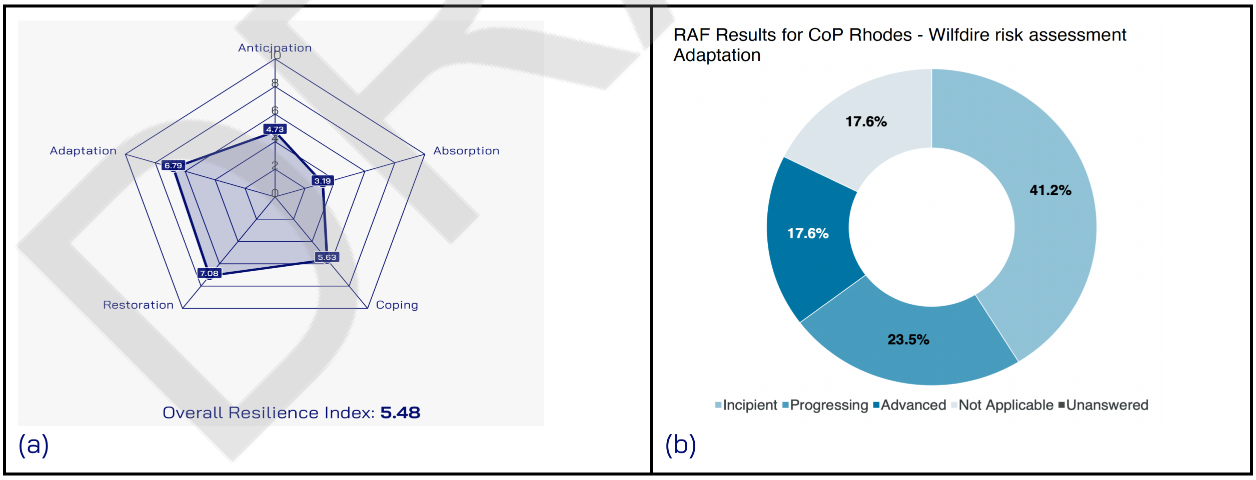

Figure 50: RAT (a) and RAF (b) results for Wildfire resilience assessment.

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7.2.3 DSS "portfolio of adaptation" implementation in the SAR CS

The adaptation solution selected and tested for the island of Rhodes, for increasing resilience against wildfires, from the portfolio of solutions, was Reforestation and forest conversion with fire resisting endemic species (Figure 51). As shown above, this solution shows increase is resilience based on the outputs or RAF and RAT tools.

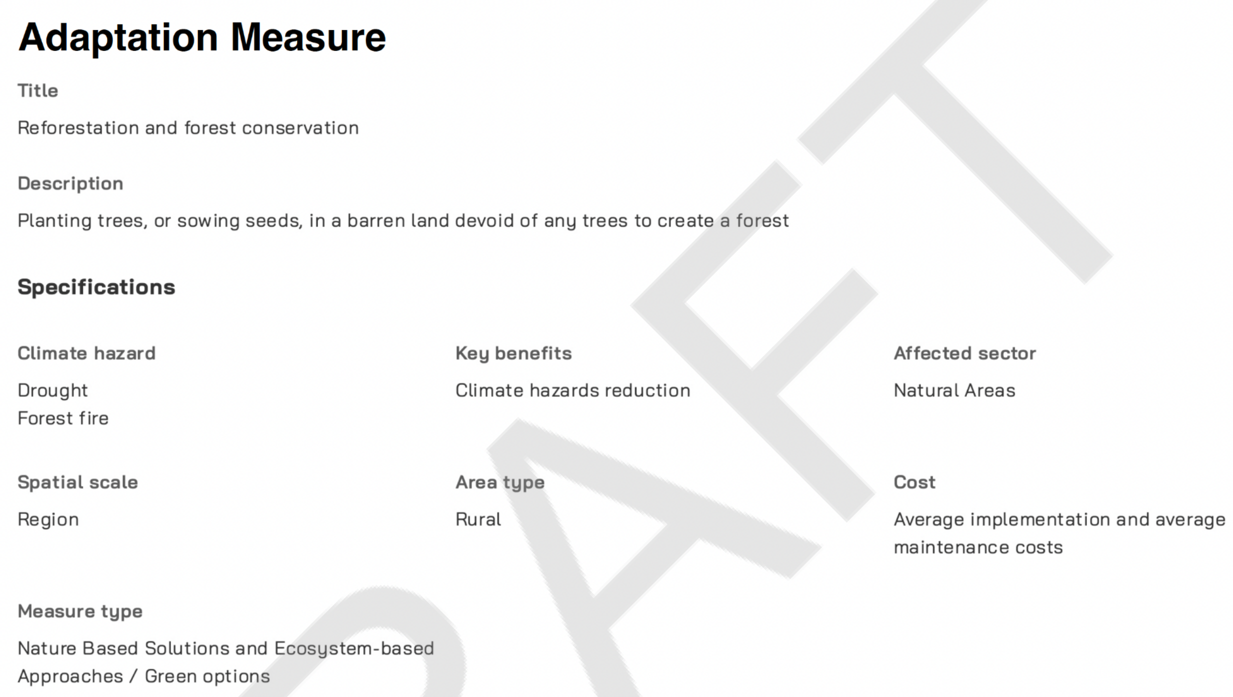

Figure 51: Example of the adaptation measure "Reforestation and forest conversion".

The increase in resilience, as translated in risk reduction, can be seen in the Ecology risk marks before and after adaptation solutions took place by the DSS users during the Community of Practice event. Figure 52 shows on the left the Risk assessment of the Ecology baseline scenario for the historical period without the adaptation solution while on the right side after the implementation of the adaptation solution.

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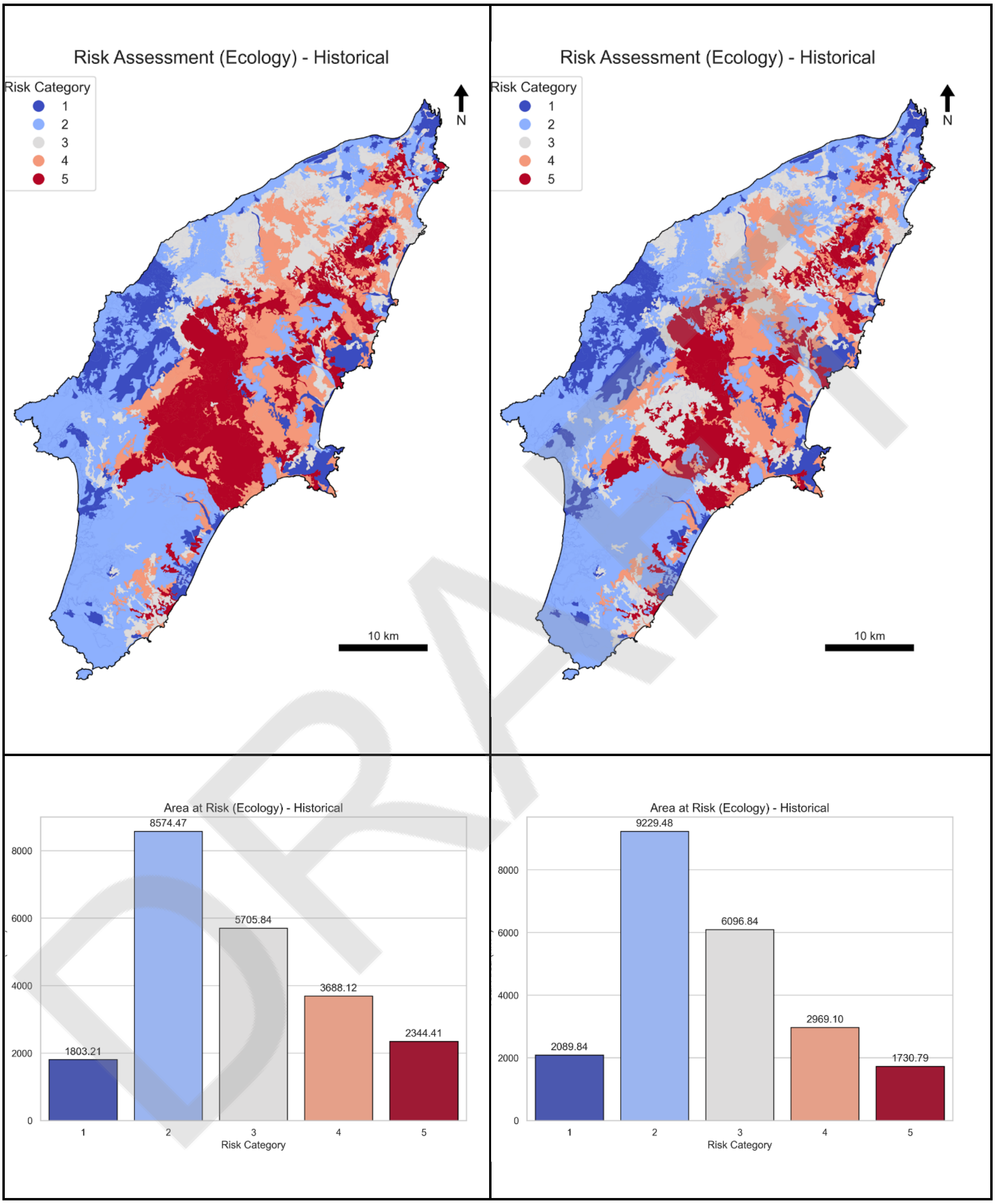

Figure 52: Risk assessment of the Ecology baseline scenario (with and without adaptation).

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7.3 Salzburg (SLZ) Case Study

7.3.1 DSS "impact assessment" implementation in the SLZ CS

The risk assessment workflow tested in the SLZ CS focused on flooding events, and their impacts (expressed in monetary terms) on the residential buildings. The second workflow addressed windstorm events and their potential impacts on electricity distribution, with particular emphasis on electricity infrastructure such as distribution networks and power poles. The table below depicts the data inputs used for the three scenarios.

Table 8: Data inputs for the SLZ scenarios.

Input data	Scenario 1: Baseline	Scenario 2: Business-as-usual	Scenario 3: Adaptation
Hazard data	Flood map of 2yr return period event (SSP5-8.5)	Flood map of 2y/30yr/100yr return period event (SSP5-8.5)	Flood map of 2y/30yr/100yr return period event (SSP5-8.5)
Exposure data	Location of buildings	Location of buildings	Location of buildings (relocating buildings in industrial area)
Vulnerability data	Default vulnerability curve (Huizinga et al., 2017)	Default vulnerability curve (Huizinga et al., 2017)	Default vulnerability curve (Huizinga et al., 2017)

Figure 53 below shows the data inputs for the DSS impact assessment for the following cases as per Huizinga et al. (2017): a) Flood hazard map ssp1-2.6 30y rp (b) buildings exposure map including height information (c) vulnerability curve for residential buildings.

(a) (b) (c)

Figure 53: Data inputs for the DSS impact assessment implementation in the SLZ CS.

The DSS outputs reflect the economic damage of floods on buildings aggregated per neighbourhood, in CS SLZ census regions were used as there are no smaller administrative units available. Nevertheless, the results can be aggregated to different polygons if available.

Figure 54 below shows the DSS outputs of flood economic impact on buildings for the scenarios: (a) 2yr return period (b) 30yr return period (c) 100yr return period

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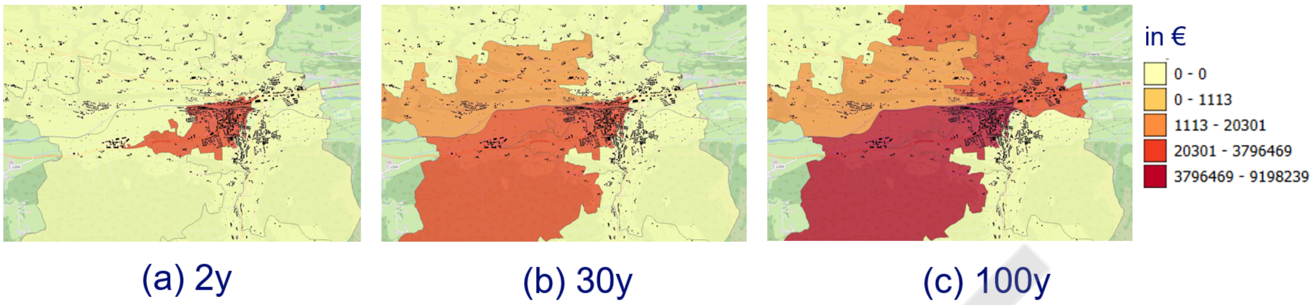

Figure 54: DSS outputs of flood economic impact on buildings.

The results for adaptation are depicted in the following figure (Figure 55). The adaptation scenario incorporates the relocation of industrial sites, a strategy proposed by stakeholders in response to the severe flood hazards indicated by the calculated hazard maps.

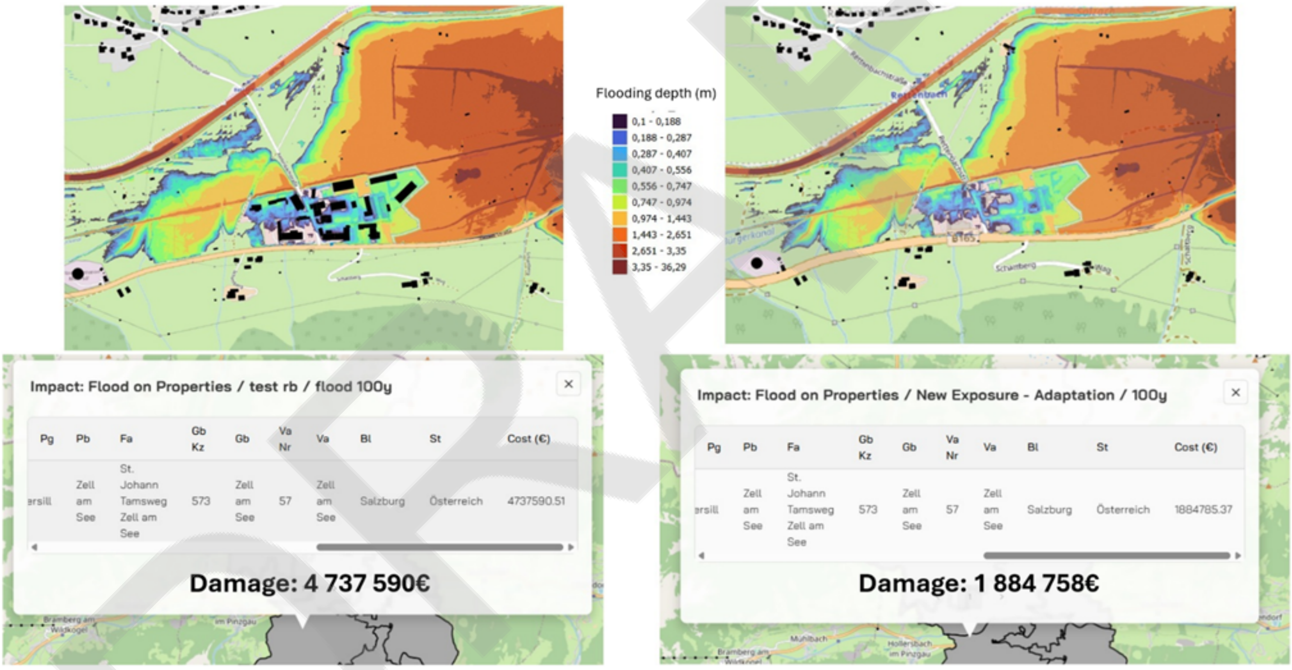

Figure 55: DSS results BAU (left) and adaptation (right) reallocating the industrial area.

7.3.2 DSS "resilience assessment tools" implementation in the SLZ CS

Both resilience assessment tools, the RAF and the RAT were tested by the stakeholders of the CS. The RAF, focussing on resilience policy assessment, was tested by a climate adaptation expert from the federal State of Salzburg and the manager of the Climate Change Adaptation Model Region. The RAT, oriented to infrastructure operators, was tested by a representative of the hydropower infrastructure of the region (Figure 56).

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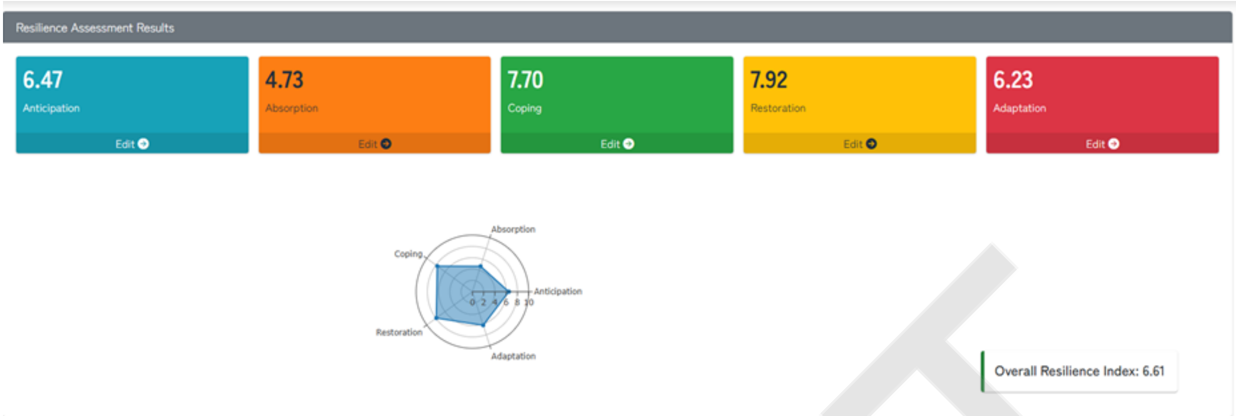

Figure 56: RAT results from the infrastructure operator for hydropower.

7.3.3 DSS “portfolio of adaptation” implementation in the SLZ CS

During the trial session with Community of Practice participants, the ICARIA DSS and its "portfolio of adaptation" were presented to showcase the system's practical application in regional resilience planning. To demonstrate the flexibility of the tool, the "Implement multi-hazard early warning systems" measure was specifically addressed in the assessment of traffic-related flood risks (Figure 57). This inclusion was based on the premise that proactive alerts allow for timely traffic diversion and vehicle relocation, thereby significantly reducing the number of cars exposed to flood damage. This exercise successfully illustrated how stakeholder-driven inputs can refine risk projections within the DSS framework.

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Title

Implement multi-hazard early warning systems

Description

The implementation of an impact-based multi-sectorial warning system during an emergency case.

Specifications

Climate hazard	Key benefits	Affected sector
Non-specific	Vulnerability to climate hazards reduction	Information / Management Sector
Spatial scale	**Area type**	**Cost**
City	Urban Rural	Average implementation and low maintenance costs
Measure type		
Governance and Institutional / Policy instruments		

Co-benefits

Climate actions are usually linked to co-benefits. In the report 'Co-benefits of urban climate action : A framework for cities', the C40 Cities Climate Leadership Group (C40) aims to support cities to 'understand value and then make the case for individual climate actions based on the environmental, economic and social costs and benefits' of those actions. Based on this report, a variety of co-benefits is provided here for each adaptation measure. A weight of 10 indicates that this co-benefit is highly relevant, while a 0 indicates that this co-benefit is not expected to occur.

Economic		Social	
Cost savings	5	Increased public space and accesibility	5
Increase resources efficiency	5	Reduced health impacts/mortality	3
Job creation	6		

Environmental

No Environmental Co-benefits

Figure 57: Multi-hazard early warning systems measure included in the portfolio.

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8 Way Forward

Having reached its final version through iterative development and testing, the ICARIA DSS moves beyond a phase of core functionality development and towards continued use, reuse, and value generation. The emphasis going forward is on making effective use of what has been developed and validated within the project for real world cases.

Consolidation and Knowledge Reuse

A central pathway for the DSS lies in its role as a knowledge resource. The methodologies, workflows, and system architecture developed in ICARIA form a reusable foundation that can support:

- Further research on climate risk, multi-hazard impacts, and resilience assessment
- Application of the ICARIA approach in different geographical contexts, sectors, or hazard settings
- Incorporation of the DSS, or parts of it, into future research and innovation projects as a reference framework

Through this reuse, the DSS is expected to contribute to cumulative learning, allowing results, methods, and experience gained in ICARIA to inform new activities.

Operational and Institutional Use

In addition to its research value, the DSS has shown clear potential to support practical decision-making related to climate adaptation. Its integrated design allows users to:

- Analyse climate risk and impact scenarios in a consistent and transparent way
- Assess resilience levels and compare adaptation options using shared metrics
- Produce results that can be traced back to assumptions, data inputs, and methodological choices

Such use supports structured discussions around planning priorities, investment options, and adaptation strategies, particularly in settings where decisions need to be supported by clear evidence and comparable results.

Sustainability and Long-Term Impact

The sustainability of the DSS is closely linked to its modular and flexible design, which allows individual components, methods, or workflows to be reused independently or combined in different ways. By enabling continued research use, practical application, and gradual uptake beyond the project, the ICARIA DSS is well positioned to retain relevance after the project's conclusion and to contribute to future efforts aimed at improving climate resilience.

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9 Conclusions

The final phase of ICARIA DSS development involved both consolidation and targeted extension of the system. Building on the foundation established in Deliverable D3.4, additional functionalities, refinements, and confirmations were implemented to address practical requirements identified during validation activities and to complete developments foreseen in the project design.

An important insight from this phase is that the DSS reached a stage where further development was driven less by changes to the core system architecture and more by the completion, extension, and alignment of planned and complementary functionalities. The extensions introduced in Version 2, including additional impact assessment workflows, enhancements to scenario handling, and expanded management and visualisation capabilities, were implemented in a manner consistent with existing system components and workflows.

The WP4 trial and mini-trial activities confirmed the overall logic and usefulness of the DSS, while providing focused input on areas where improvements were required to support clearer interaction and interpretation during practical use. During this phase, feedback derived from realistic usage scenarios proved most effective when it was translated into narrowly scoped, well-defined changes rather than broad redesign efforts. This approach reduced implementation risk, preserved backward compatibility with existing documentation and workflows, and ensured a stable transition from prototype to final system version.

Importantly, the trials provided empirical confirmation of design assumptions concerning differentiated interaction with the DSS. While all participant groups were able to explore the full range of system functionalities during validation, modelling-oriented tasks - such as input data preparation, parameter selection, and interpretation of impact calculation logic - were shown to require a higher level of technical expertise. The introduction and formalisation of additional user roles in Version 2, including the Stakeholder and General Public roles, address this observation by structuring access to functionalities in line with typical usage patterns, while maintaining access to results, visualisations, comparisons, and reports.

It was further demonstrated that usability improvements in advanced decision support systems can be achieved without altering analytical workflows or methodologies. The adjustments introduced in Version 2 illustrate that interface-level refinements - such as clearer feedback mechanisms, improved result presentation, and more consistent navigation cues - can significantly enhance interpretability and user confidence while preserving methodological continuity.

A further insight concerns the importance of transparency and traceability in complex analytical environments. Enhancements related to layer naming conventions, result styling, legends, and unit presentation underscore that users' ability to interpret outputs depends not only on the correctness of calculations, but also on the clarity with which assumptions, scales, and outputs are communicated. These aspects are particularly critical in systems intended to support discussion, comparison, and justification of adaptation decisions.

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In conclusion, the ICARIA DSS is delivered as a coherent outcome of the project, characterised by methodological continuity, extended functional coverage, improved usability, and clearer presentation of results. The final version confirms and operationalises the system design established earlier in the project and provides a stable reference implementation that can support future reuse, replication, and extension in both research and applied contexts.

In ICARIA, comprehensive multi-hazard risk assessments were carried out drawing on the strong sectoral expertise of the project partners. This knowledge has been largely integrated into the DSS. While the tool does not reproduce the fully exhaustive off-line analyses performed in the three case studies, it effectively supports damage assessment without requiring the same level of prior specialised expertise. In this framework, this deliverable has presented illustrative examples demonstrating the applicability of the DSS across different case studies, confirming its value as a practical, ready-to-use decision-support tool that can be deployed and adapted by other regions.

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Appendix 1: User Guide

This appendix provides a link to the updated DSS User Guide. The guide explains the use of the DSS, outlines its main components, and offers step-by-step navigation instructions to support accessibility and wider adoption. Given its length, the document is not reproduced here; instead, it is integrated into the DSS "About" page, where it is openly accessible to all users, including unregistered visitors, during platform use. Specifically, it can be accessed via the "View ICARIA User Guide" button at the top of the About page as indicated in Figure 28.

https://icaria.draxis.gr/about

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Appendix 2: ICARIA Processing API for Impact Assessment

This appendix presents the ICARIA Processing API, as initiated and described in detail in D3.4, which enables asynchronous geospatial processing for natural hazard impact assessments through (Hypertext Transfer Protocol) HTTP endpoints. The API facilitates background execution of extended analyses, supporting job submission, status monitoring, and result retrieval within a unified workflow. The online documentation for the API is available at https://m4d.services.iti.gr/api/api-docs/.

Summary of endpoints (D3.4)

In D3.4, operational services focused on **flood** and **wildfire** processing and the generation of GIS-ready outputs for subsequent analysis. Status information is available via both streaming and polling methods. Specifically, in the previous deliverable (see D3.4 Decision Support System, Appendix 7: ICARIA Processing API for Impact Assessment) the following endpoints were introduced for the Processing API: (i) Pluvial Flood (AMB model method, Path 1), (ii) Pluvial Flood (Global default values (EU Standard) method, Path 2), and (iii) Wildfires (EU Standard Method). In D3.5, the endpoints are extended by adding two (2) additional paths: (i) Pluvial Flood (Substations), and (ii) Windstorm assessment (Power Infrastructure). The first endpoint extends the previously included Pluvial Floods scenario, this time for Substations, and introduces a way to capture the cascade effects. The second endpoint aims to address the wind hazard by examining the Power infrastructure. Both follow the exact methodological approach and template introduced in D3.4, in terms of addition and presentation in this current deliverable.

New endpoints

This deliverable also introduces two (2) additional endpoints, to support the **windstorm** impact assessment, as well as the **flood substation** assessment designed to handle inputs from cascade events. The service is implemented in Python, using FastAPI for the HTTP interface and Pydantic for request validation and response serialization. Long-running geospatial computations are managed as Celery tasks, with Redis serving as both the message broker and state backend. The API is deployed as an Asynchronous Server Gateway Interface (ASGI) application on Uvicorn and is typically distributed using Docker. Inputs are received as multipart form data, and processing results are provided as temporary ZIP archives. An optional callback mechanism enables external systems to receive notifications upon job completion. The API is exposed via a base service URL and provides a built-in Swagger UI available at a dedicated endpoint for interactive exploration. Job submission returns a job identifier and task identifier immediately, while processing continues asynchronously in the background. Job status can be monitored through a Server-Sent Events stream or by polling a status endpoint that reports defined execution states and error conditions. Upon successful completion, results are retrieved from a download endpoint as a ZIP archive containing GIS-ready outputs, which are retained temporarily before scheduled cleanup. The API exposes dedicated endpoints for the Flood (custom) and Flood (EU standard) workflows as well as for the Wildfire workflow, each for specific input requirements, and output semantics. These processing endpoints are complemented by dedicated endpoints for job status monitoring and result download within the same service interface. Despite differences in hazard logic and input structure, all workflows adhere to a unified execution model, ensuring consistent interaction patterns across hazard types, from submission and

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background processing to status tracking and the retrieval of GIS ready outputs. The overall architecture provides reliable asynchronous execution, transparent state reporting, and structures error handling, consequently facilitating embedding into external systems and decision-support environments.

Pluvial Flood (Substations)

This endpoint identifies critical infrastructure (electrical substations) located within flooded areas. It performs a geometric intersection between substation points and flood hazard polygons to determine which assets are compromised.

Table 9: Endpoint Critical Infrastructure Flood Substation Impact Overview.

Flood Substations endpoint	
URL	http://[HOST]:8050/floods_substations/
Description	Runs the Critical Infrastructure Flood Substations workflow by intersecting substation points with flood hazard polygons. Returns a job identifier and Celery task ID.
Format	• **Request**: multipart/form-data • **Response**: application/json
HTTP METHOD	POST

Users must upload a single ZIP file containing both required shapefiles. The service automatically detects which file is the point layer (substations) and which is the polygon layer (flood hazard) based on their geometry type, so strict naming conventions are not enforced.

Table 10: Form-data fields of Flood Substations endpoint.

Flood Substations request form data field			
Name	**Type**	**Required**	**Description**
files	File	Yes	A single **.zip** archive containing two shapefiles: • **Substations** (Point geometry), • **Flood hazard** (Polygon geometry). Sidecar files (.dbf, .shx, .prj) must be included.
callback_url	String (URL)	No	Optional webhook to receive/upload the result upon completion.

Table 11: Response of Flood substations endpoint.

```
{
"job_id": "<uuid>",
```


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```
"task_id": "<celery_task_id>",
"callback_url": "<echoed or null>"
}
```

Errors

- **422** Unprocessable Entity if the ZIP file does not contain exactly one point layer and one polygon layer.
- **500** Internal Server Error for corrupt archives or processing exceptions.

Missing required files return 422. If a long-running job fails, the status feed will switch to FAILURE.

Windstorm assessment (Power Infrastructure)

This endpoint assesses the physical failure probability of power transmission assets (towers and lines) due to extreme wind gusts. It utilizes a raster hazard map and vector asset layers to calculate local impact probabilities.

Table 12: Endpoint Windstorm Assessment Overview

Flood Substations endpoint	
URL	http://[HOST]:8050/wind/
Description	Runs the Windstorm workflow for power infrastructure. Accepts a ZIP file with a wind gust raster and asset shapefiles (towers or powerlines). Returns a job identifier and Celery task ID.
Format	• **Request**: multipart/form-data • **Response**: application/json
HTTP METHOD	POST

The input ZIP file must contain the hazard raster (specially named *vmax_gust_event.tif*) and at least one asset layer (*towers.shp* and *powerlines.shp*). For powerlines, the algorithm segments long lines into smaller sections (default 400m) to capture spatial variations in wind speed.

Table 13: Form-data fields of the Windstorm endpoint.

Windstorm (Power Infrastructure) request form data field			
Name	**Type**	**Required**	**Description**

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archive	File	Yes	A **.zip** containing: • *vmax_gust_event.tif* (Wind gust raster in m/s), • ***towers.shp*** (Points) AND/OR ***powelines.shp*** (Lines).
receptor	String	Yes	Target asset type: "**Towers**' or "**Powerlines**".
max_segment_length	Float	No	Maximum length (in meters) to split powerlines for accurate sampling (default :**400**).
callback_url	String (URL)	No	Optional webhook to receive/upload the result upon completion.

Table 14: Response of Windstorm endpoint.

```
{
"job_id": "<uuid>",
"task_id": "<celery_task_id>",
"callback_url": "<echoed or null>"
}
```

Errors

- **400** Bad request if the uploaded archive is not valid ZIP or missing the specific *vmax_gust_event.tif* file.
- **422** Unprocessable Entity for invalid parameters (e.g., negative segment length).

Invalid ZIP files or missing specific raster names return an immediate 400. If a long-running job fails, the status feed will switch to FAILURE.

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Appendix 3: Data Management Statement

Table 15: Data used in preparation of ICARIA DSS (version 2).

Dataset name	Format	Size	Owner and re-use conditions	Potential Utility within and outside ICARIA	Unique ID
Hazard maps, exposure data, vulnerability curves (dynamically generated by the DSS)	Several (shp, tif, csv, json)	N/A	ICARIA Consortium	Modelling of impact assessment workflows	-
Spatially downscaled climate projections (T1.2)	tif	560 MB	FICLIMA	Use inside the DSS	doi.org/10.5281/ zenodo.12930101
Spatially downscaled climate projections (T1.2)	tif	14 MB	AIT	Use inside the DSS	TIF files generated based on https://doi.org/10.5281 /zenodo.14937418
Adaptation measures (T3.3)	API	N/A	ICARIA Consortium	Use inside the DSS	www.icariastrategies.eu /measures

Table 16: Data produced in preparation of ICARIA DSS (version 2).

Dataset name	Format	Size	Owner and re-use conditions	Potential Utility within and outside ICARIA	Unique ID
Impact assessment results	shp	Varies but usually in the order of MB	Results are available to authorised users with appropriate permissions to each generated result. There is	Downloadable geospatial files generated by users inside the DSS to be used as they see fit	Internal system id

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			currently no limitation for reuse.		
Reports	pdf	Depends on the amount of scenarios /results in a project, usually in the order of MB	Reports are available to authorised users with appropriate permissions to the respective project or scenario. There is currently no limitation for reuse.	Downloadable summary documents consolidating impact, resilience, and adaptation results for communication, documentation, and decision-support purposes.	Internal system id
Resilience results	pdf or image formats	In the order of MB	Results are available to authorised users with appropriate permissions to the respective assessment. There is currently no limitation for reuse.	Structured assessment outputs generated within the DSS to support resilience evaluation, comparison across scenarios, and strategic planning activities.	Internal system id
Adaptation measures	pdf	In the order of KB	Predefined measures are provided through the ICARIA portfolio. User-created measures are available only to authorised users with appropriate permissions. There is currently no limitation for reuse of downloaded content.	Structured adaptation measure records supporting filtering, comparison, multi-criteria prioritisation, and integration into climate adaptation planning workflows.	Internal system id

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More info: **www.icaria-project.eu**

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