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D3.4 Decision Support System

Version 1

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D3.4 Decision support system – Version 1

Summary		
This deliverable introduces the first version of the ICARIA Decision Support System (DSS), a digital platform that integrates climate projections, impact assessment workflows, resilience scoring, and adaptation planning into a single user-friendly environment. By enabling stakeholders to evaluate risks, test adaptation measures, and compare scenarios, the DSS supports evidence-based decision-making for strengthening resilience across critical assets, infrastructure, and regions.		

Deliverable number	Work package	
D3.4	WP3	
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List of Acronyms and Abbreviations

AMB	Barcelona Metropolitan Area
AOI	Area of interest
API	Application Programming Interface
BAU	Business-As-Usual
CDS	Copernicus Climate Data Store
CLC	CORINE Land Cover Classes
CoP	Community of Practice
CORINE	Coordination of Information on the Environment Product
CRS	Coordinate Reference System
CRUD	Create, Read, Update, Delete
CSV	Comma-separated-values file format
D	Deliverable
DEM	Digital Elevation Model
DMP	Data Management Plan
DSS	Decision Support System
ECMWF	European Centre for Medium-Range Weather Forecasts
EPSG	European Petroleum Survey Group
EU	European Union
EU-DEM	European Digital Elevation Model
EURO-CORDEX	Coordinated Downscaling Experiment - European Domain
FWI	Fire Weather Index
GCM	Global Climate Model
GeoJSON	Geographic JavaScript Object Notation
GeoTIFF	Geographic Tagged Image File Format

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GIS	Geographic Information System
GPKG	Geopackage open format
JRC	Joint Research Centre
KPI	Key Performance Indicator
LUISA	Land Use-based Integrated Sustainability Assessment
ML	Machine Learning
OGC	Open Geospatial Consortium
OSM	OpenStreetMaps
PMT	Project Management Team
QA	Quality Assurance
RAF	Resilience Assessment Framework
RAT	Resilience Assessment Tool
SAR	South Aegean
SHP	Shapefile
SLZ	Salzburg
SSO	Strategic Sub Objective
T	Task
UI	User Interface
UX	User Experience
WP	Work Package

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Executive Summary

ICARIA is a HORIZON Research and Innovation Actions project funded by the European Union under grant agreement 101093806. The project aims to advance asset-level modelling in order to better capture the direct and indirect impacts of complex, cascading, and compound climate-related disasters, as well as the potential risk reduction achieved through sustainable and cost-effective adaptation measures.

This deliverable presents the first version of the ICARIA Decision Support System (DSS), developed under Task 3.4 in WP3. The DSS integrates climate projections, hazard and impact assessment workflows, resilience evaluation tools, and adaptation planning functionalities into a single, integrated platform. It provides stakeholders with a practical, user-friendly environment to analyse risks, explore resilience, and prioritise adaptation strategies across diverse case studies. By combining these capabilities, the DSS supports evidence-based climate adaptation. It enables stakeholders to translate complex data into actionable insights, compare scenarios, and prioritise measures that strengthen resilience of assets, infrastructure, and regions in the face of climate-related hazards.

As the central digital output of ICARIA, the DSS is pivotal to achieving the project's objectives. It consolidates key results from Work Packages (WP) 1–3 into an operational tool that will be validated through WP4 trials and disseminated via WP5 activities. The direct beneficiaries are case study facilitators and their communities, and technical partners who will use the DSS in testing and replication, but its value extends to critical infrastructure managers, technicians, and academic experts who can apply its outputs in resilience planning. By turning scientific methods into a practical decision-support tool, this deliverable ensures that ICARIA's research has tangible impact for both project stakeholders and external users.

This report presents the comprehensive work undertaken for the development of the first version of the DSS, encompassing the full lifecycle, from initial requirements elicitation and stakeholder consultations to iterative design refinements, technical implementation, and the successful deployment of the system's initial release. It provides an overview of the system's objectives, scientific foundations, core functionalities, navigational structure, architecture, and deployment setup, along with the timeline of action. The deliverable also provides access to a detailed User Guide to support users in navigating and operating the DSS effectively.

The final version (D3.5), due in M38, will update this initial release based on feedback from the case study implementation trials in WP4, ensuring the tool continues to evolve and meet stakeholder needs.

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1 Introduction

1.1 Project ICARIA

In recent decades, the frequency and intensity of climate-related disasters, such as floods, heatwaves, and droughts, have been steadily rising, with projections suggesting that this trend will continue or even worsen in the coming years. These events are becoming increasingly complex, often occurring in combination or triggering cascading impacts that affect communities, infrastructure, and economies on multiple levels.

In response to these growing challenges, the ICARIA project aims to support better climate adaptation planning through the development of an asset-level modelling framework. The goal is to improve our understanding of how climate-related risks affect critical infrastructure and to identify sustainable, cost-effective solutions that strengthen resilience. A key focus is on anticipating how future climate conditions might increase life-cycle costs - whether through damage, failure, or maintenance - and helping decision-makers take proactive steps to address them.

This approach is being piloted in three diverse regions across Europe: the Barcelona Metropolitan Area (Spain), the South Aegean Region (Greece), and the Salzburg Region (Austria). Each represents a different set of environmental, geographic, and socio-economic conditions, offering valuable insights into how climate resilience strategies can be adapted to local needs.

To achieve this aim, ICARIA has identified a number of Strategic Sub Objectives (SSO); among them, the DSS is directly linked with SSO6: “Better decision taking for cost-efficient adaptation solutions by developing a DSS to compare adaptation solutions”. In this context, two KPIs have been set for the completion of this subobjective:

- Satisfactory implementation of the DSS (75% satisfaction on Community of Practice - CoP poll results)
- Use of DSS in all the 3 ICARIA case studies for trials and mini-trials.

Developed as part of the project and validated through real-world case studies, the DSS integrates multiple scientific tools and modelling approaches into one cohesive digital environment. The DSS is positioned as a central tool of ICARIA, enabling stakeholders to translate climate projections, impact assessment metrics, resilience metrics, and adaptation measures into informed, evidence-based decisions.

1.2 Deliverable Structure

The deliverable is structured into eight (8) distinct chapters:

- Chapter 1: Introduces the project, DSS objectives, development timeline, and task dependencies.
- Chapter 2: Describes the scientific foundation and methodology informing the DSS.
- Chapter 3: Defines key user groups and outlines the system's core services.
- Chapter 4: Walks through the navigation structure and all major functionalities.
- Chapter 5: Explains the system’s architecture, technology stack, and data integration.
- Chapter 6: Describes the deployment setup, user permissions and how users can access the

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system.

- Chapter 7: Outlines future enhancements and the timeline for version 2.
- Chapter 8: Summarises key outcomes and insights from the initial DSS release.
- Appendices:
    - Appendix 1: User Scenarios: step-by-step narratives of how users interact with the DSS, developed during the design phase.
    - Appendix 2: User Stories/Requirements: short functional requirements from a user's perspective, provided by ICARIA partners during the design phase.
    - Appendix 3: Design mockups: sample visual mock-ups showing the DSS layout and navigation flow, developed during the design phase.
    - Appendix 4: User Testing Scripts: preliminary examples of instructions and tasks for testing the system, to be applied in WP4 trials and mini-trials.
    - Appendix 5: RAF Assessment Questions: includes the questions that were selected for the DSS RAF assessment.
    - Appendix 6: User Guide: manual explaining how to access and use the DSS.
    - Appendix 7: Full documentation of the ICARIA Processing API for Impact Assessment
    - Appendix 8: Data Management Statement

1.3 Objectives of the DSS

The primary objective of the ICARIA DSS is to support high-quality, evidence-based decision-making for climate adaptation by integrating various modelling, risk assessment, and resilience tools into a single, streamlined platform. Traditional geospatial and hazard modelling tools are often fragmented, highly technical, and inaccessible to non-experts. The ICARIA DSS bridges this gap by combining climate risk data, resilience metrics, and adaptation strategies within a simplified interface that reduces the reliance on Geographic Information System (GIS) or modelling expertise. The DSS is tailored to support a wide range of users, from technical experts generating hazard scenarios, to public authorities and stakeholders comparing the effectiveness of adaptation measures. Ultimately, the DSS delivers structured, transparent, and easily communicable outputs, empowering better climate adaptation decisions at both the asset and regional levels. Specifically, the DSS aims to:

- Deliver a harmonised system that standardises input/output flows between diverse models and datasets.
- Enable asset-level impact assessments that integrate hazard indicators, exposure data, and vulnerability functions, based on downscaled climate projections.
- Incorporate hazard information that reflects not only single events but also cascading and compound phenomena, as provided by ICARIA hazard models.
- Provide a structured approach for evaluating resilience, linking governance, infrastructure, and community perspectives.
- Support transparent and evidence-based decision-making by comparing scenarios and prioritising adaptation measures with a multi-criteria approach.
- Offer a user-friendly interface for geospatial visualisation, scenario comparison, and report generation.

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1.4 Action Plan of Version 1

The development of Version 1 of the DSS followed a structured process, moving from scoping and requirements to technical implementation and Quality Assurance (QA). Table 1 summarises the main steps.

Table 1: Action plan of version 1.

#	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)	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	Deliverable preparation and submission	M33

The action list for version 2 of the DSS is a continuation of the current one and is presented in chapter 7.

1.5 Interdependencies with Other Work Packages

Task 3.4 constitutes a pivotal component of WP3, serving as the development and integration axis for the ICARIA DSS. This task transforms the conceptual, modelling, and data foundations laid by earlier project activities into an operational platform tailored for real-world application.

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The development of the ICARIA DSS followed a blended approach, combining the integration of established tools with the creation of new, project-specific functionalities. Most of the components integrated into the system build on and extend methodologies and tools developed in previous project results. Dyring ICARIA, several tools were developed from scratch as individual components of the DSS, importantly the Map Viewer, the Risk/Impact Assessment functionality, the Project Manager concept which includes reporting, as well as the unification of all the above into a single web platform.

What makes the DSS novel is not only these new components, but the way in which existing tools and methods have been connected into a single, coherent decision-support environment. By harmonising input/output flows, and enabling seamless interaction across components, ICARIA advances beyond fragmented tools from past projects. The result is a unified, user-friendly platform that brings scientific methods into practical use for climate adaptation planning, demonstrating innovation in integration and usability rather than reinventing each tool in isolation.

<u>Requirements and conceptualisation</u>

Led by DRAXIS and the coordination team (AQUA), the conceptualisation process brings together multiple ICARIA results presented in Chapter 2 (risk and impact assessment, resilience assessment, adaptation measures) ensuring they function cohesively within the broader DSS platform. Input was provided by the case study facilitators (AQUA, AIT, and NCSR-D), who defined the data requirements and contextual needs for each region. Data for climate projections and impact assessment samples were also collected, with contributions from AIT and FIC. In parallel, ICARIA tool providers supported the integration process: LNEC for the Resilience Assessment Framework (RAF), NCSR-D for the Resilience Assessment Tool (RAT), and CETAQUA for the adaptation measures. Building on these specifications, CERTH documented and developed the three impact assessment workflows for the hazards defined by the case studies (floods by AQUA, wildfires by NCSR-D and windstorms by AIT).

During the conceptualisation and design of the DSS, all main outputs were presented to and validated by the Project Management Team (PMT) and ICARIA consortium, ensuring that development would proceed according to the needs and specifications defined by the project. Such outputs include the documentation of all DSS requirements and functionalities (Appendices 1, 2), the interactive mock-ups and design (Appendix 3), and the integration plans for all external components (impact assessment workflows, RAF-RAT tools, adaptation measures).

<u>Development of the DSS</u>

Task 3.4 (DSS development) is tightly interconnected with multiple WPs. It translates the concepts, methods, and data produced elsewhere in ICARIA into an operational platform:

- **WP1** supplies climate projection data and vulnerability functions that underpin the risk/impact assessment.
- **WP2** develops the multi-hazard framework and modelling approaches that shape DSS logic.
- **WP3** provides the core building blocks: the RAF, RAT, and adaptation measures portfolio.
- **WP4** validates the DSS in case studies, generating feedback for refinement.

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- **WP5** ensures dissemination and stakeholder engagement, supporting uptake.
- **WP6** guarantees consistency with the Data Management Plan (DMP), quality assurance, and project-wide standards.

This web of dependencies highlights the DSS as both an integrator and enabler, drawing on ICARIA's scientific outputs while serving as their practical interface. WP1 and WP2 provide the climate data, hazard models, and impact functions that underpin the DSS. These include indicators and maps that account for cascading and compound phenomena, ensuring that hazard complexity is represented in the system. WP3 builds directly on these outputs, integrating them into the DSS to support both single- and multi-hazard analyses. WP4 then applies and validates the DSS in real case studies, testing its capacity to inform adaptation planning under diverse conditions. The main inputs to the DSS from other Tasks and Work Packages are summarised in Figure 1 below:

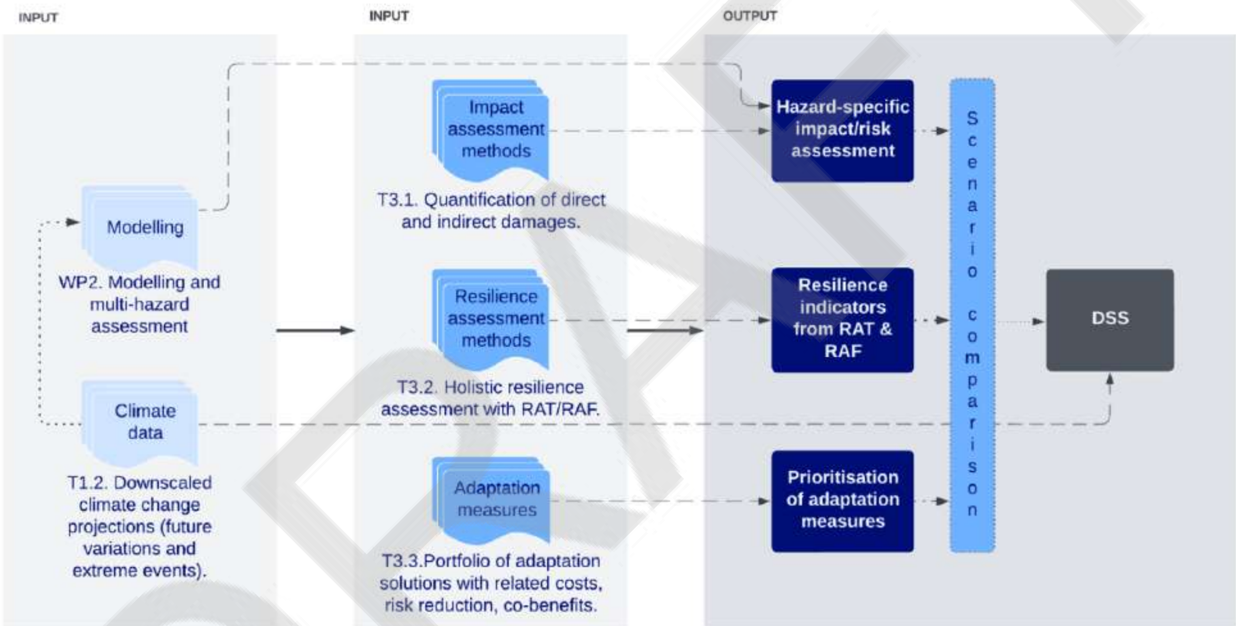

Figure 1: Main Inputs & Outputs of the DSS.

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2 Methodological Basis of the DSS

This section outlines the key tools and methodologies integrated into the ICARIA DSS from other ICARIA tasks. It outlines how selected methods, originally developed by expert partners in previous project WPs/Tasks, have been translated into the system's core functionalities. The DSS is built on four methodological pillars: Risk/Impact assessment, Resilience assessment, Adaptation measures, and Climate projections. Together, they form a coherent framework that supports holistic, evidence-based climate adaptation planning.

Importantly, the DSS applies indicators curated by the project to evaluate:

- **Adaptation**: considering co-benefits across economic, social, and environmental dimensions.
- **Impact**: including projected damage costs, service disruption, and other measurable consequences.
- **Resilience**: from both a holistic and a critical infrastructure perspectives.

These indicators are assessed under different scenario types:

- **Baseline**: current conditions without climate change or intervention.
- **Business-As-Usual (BAU)**: future conditions assuming no new adaptation actions.
- **Adaptation scenarios**: future conditions that include the implementation of selected measures.

By comparing performance across these indicators and scenario types, the ICARIA DSS enables a multi-dimensional evaluation of adaptation strategies. This helps decision-makers identify the most effective, and robust pathways for increasing resilience against climate-related disasters (Figure 2).

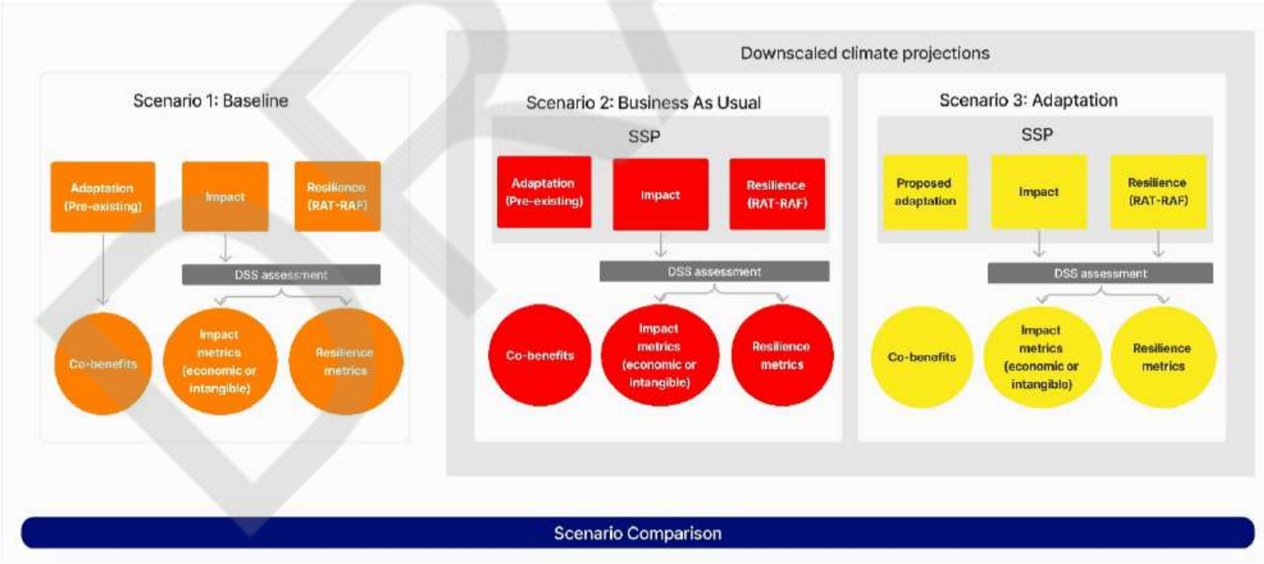

Figure 2: ICARIA DSS Methodology.

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2.1 Risk/Impact Assessment

This section documents the backend workflows implemented in the DSS, detailing the backend processes such as the data inputs, processing logic, and output structure used to compute exposure, vulnerability from single events across 3 different subregions (Barcelona (floods), Salzburg (windstorms), and Rhodes in South Aegean (wildfires)) (Leone et al., 2025; Turchi et al., 2024). It supports flexible user-defined inputs as guided via the User Interface (UI) and provides receptor-specific outputs enabling spatial decision support in hazard management.

The backend implementation of the impact assessment process supports 3 hazards and 6 risk receptors in the following pairings:

- Floods: Properties
- Windstorms: Electricity towers, Powerlines
- Wildfires: Natural areas, Population, Buildings

2.1.1 Workflow A: Pluvial Floods

2.1.1.1 Summary and objectives of Workflow A

This section describes the backend implementation for pluvial floods (Locatelli et. al., 2020; Martínez-Gomariz et. al., 2019; Martínez-Gomariz et. al., 2020; Baugh et. al., 2024) for assessing economic damage from inundation in urban areas. Two (2) workflow variants are implemented, namely:

- Path 1: Local parameter-based methodology (AMB model provided by AQUA).
- Path 2: Predefined parameter methodology (Global Default values).

In both variants, users must upload shapefiles describing hazard, exposure, and impact areas. In the first method, two additional CSV tables (permeability and cost values) are required, whereas in the second method, predefined categories are applied, reducing user input.

Table 2: General Structure of Workflow A.

Workflow A summary			
Hazard	Raster or vector polygon shapefile describing water depth and flow velocity across affected areas	**Exposure**	Shapefile of building/agricultural footprints with usage-specific floor area attributes
Vulnerability	Calculated using permeability and cost functions (Path 1) or inferred from predefined	**Input/Output**	Input: Three (3) shapefiles (exposure_buildings, hazard_map, impact_results) and two (2) CSVs (permeability_table, cost_table) for Path 1 only.

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	usage types (Path 2)		Output: One or more shapefiles (e.g., "*flood_damage.shp*", "*buildings_damage.shp*") containing flood damage values that can be visualised as thematic risk maps or integrated in GIS systems.

2.1.1.2 Pipeline Procedure

The flowchart for Path 1 & Path 2 for the pluvial flood is shown below.

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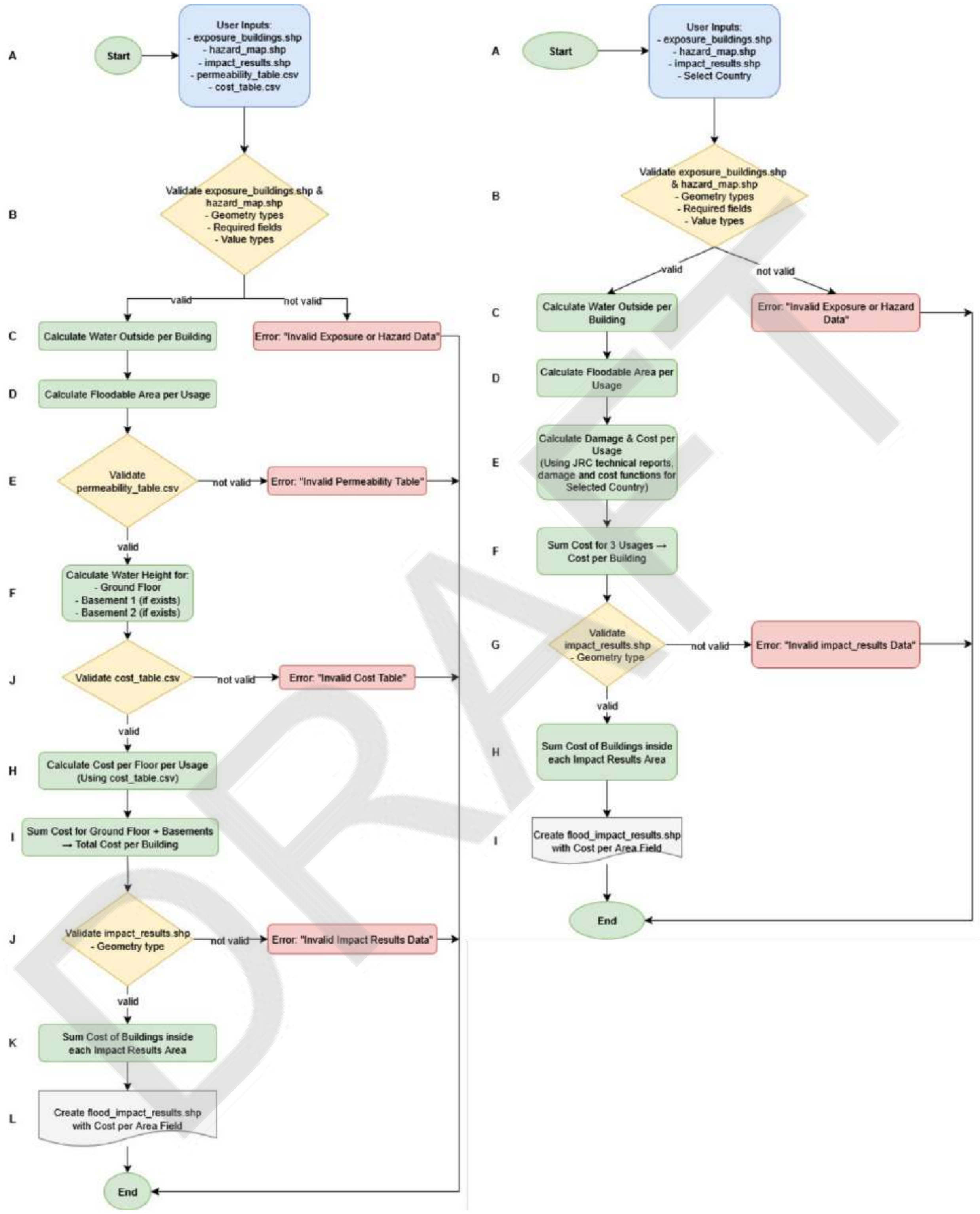

Figure 3: Flowchart for Paths 1 & 2 for the pluvial floods.
AMB Model (left) & Global Default values (right).

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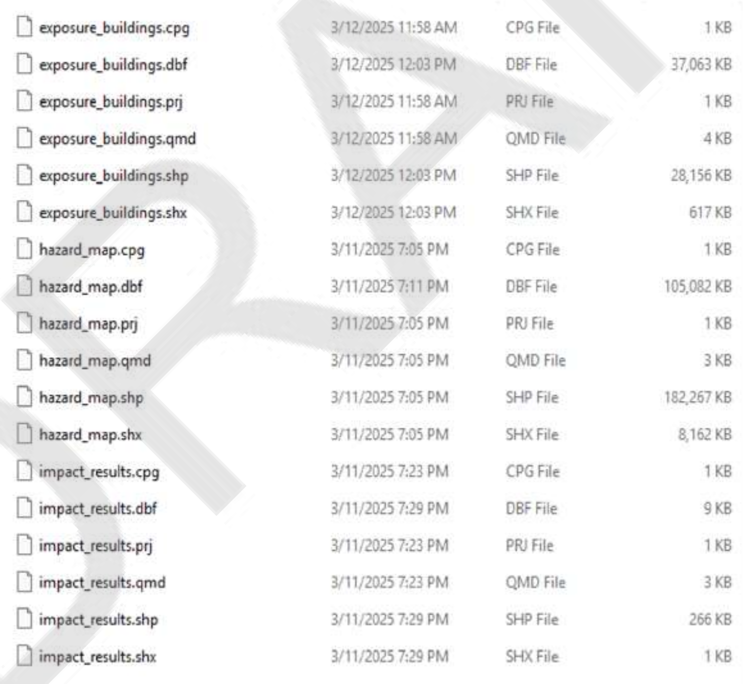
Both paths start with the same set of user inputs, including exposure, hazard, and impact data. In each case, the exposure and hazard files are validated before calculating water depth outside buildings and identifying the corresponding floodable areas. From this point, the first path continues by validating permeability and cost tables to compute water depth for different building levels and to derive floor-specific and total building costs, which are then linked to the impact results. The second path, in contrast, proceeds directly from floodable area calculations to applying country-specific damage and cost functions, after which costs are summed per building and validated against the impact results. In both paths, the final step aggregates buildings' costs within the impact zones and creates a shapefile reporting the cost per area.

2.1.1.3 Input Specification

<u>Description of the input</u>

In both paths, the user is required to upload three shapefiles (Steps A and B from both flowcharts in Figure 3):

- "*exposure_buildings.shp*": contains the footprints of individual buildings or agricultural parcels.
- "*hazard_map.shp*": contains flood hazard distribution, with required attributes.
- "*impact_results.shp*": defines the spatial units where flood impact is to be computed.



exposure_buildings.cpg	3/12/2025 11:58 AM	CPG File	1 KB
exposure_buildings.dbf	3/12/2025 12:03 PM	DBF File	37,063 KB
exposure_buildings.prj	3/12/2025 11:58 AM	PRJ File	1 KB
exposure_buildings.qmd	3/12/2025 11:58 AM	QMD File	4 KB
exposure_buildings.shp	3/12/2025 12:03 PM	SHP File	28,156 KB
exposure_buildings.shx	3/12/2025 12:03 PM	SHX File	617 KB
hazard_map.cpg	3/11/2025 7:05 PM	CPG File	1 KB
hazard_map.dbf	3/11/2025 7:11 PM	DBF File	105,082 KB
hazard_map.prj	3/11/2025 7:05 PM	PRJ File	1 KB
hazard_map.qmd	3/11/2025 7:05 PM	QMD File	3 KB
hazard_map.shp	3/11/2025 7:05 PM	SHP File	182,267 KB
hazard_map.shx	3/11/2025 7:05 PM	SHX File	8,162 KB
impact_results.cpg	3/11/2025 7:23 PM	CPG File	1 KB
impact_results.dbf	3/11/2025 7:29 PM	DBF File	9 KB
impact_results.prj	3/11/2025 7:23 PM	PRJ File	1 KB
impact_results.qmd	3/11/2025 7:23 PM	QMD File	3 KB
impact_results.shp	3/11/2025 7:29 PM	SHP File	266 KB
impact_results.shx	3/11/2025 7:29 PM	SHX File	1 KB

Figure 4: Example of an input .shp file.

Each shapefile must contain valid Polygon or MultiPolygon geometries. The files should include at least 5–10 features for exposure and 10–20 for hazard to be considered valid. Z-dimensions (heights) are optional; other geometry types will be ignored.

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In Path 1 (AMB method), the exposure shapefile must follow a structured column format to represent floor-level usage per building. Columns must include, for ground floor and basement: "*GF_01*", "*B1_01*", "*B2_01*", "*...*", "*GF_n+1*", "*B1_n+1*", "*B2_n+1*", and an *ID* column. All values must be numeric (*int*, *float*, or *NaN*) except the *ID*, which must be a string (*str*). The "*hazard_map.shp*" must include two numeric fields:

- "*DEPTH2D*": floodwater depth (*float*)
- "*SPEED2D*": floodwater velocity (*float*)

Other fields are ignored. The "*impact_results.shp*" is used solely for geometry; its attributes are not required.

In Path 1, users must also upload two (2) CSV files:

- "*permeability_table.csv*": defines flow intrusion from flooding into buildings by usage type; columns must match those in "*exposure_buildings.shp*" and include a "*x_axis*" (external water depth in cm).
- *"cost_table.csv":* defines cost per square meter by water depth and usage; must match the structure and column order of the permeability table (Step E, Figure 3, left side).

In Path 2, only the "*exposure_buildings.shp*" column requirements differ:

- Users must include three fields named "*COMMERCIAL*", "*RESIDENTIAL*", and "*INDUSTRIAL*", with numeric values. No CSVs are required in this case.
- Permeability and cost values per usage (commercial, residential, or industrial) are hardcoded, taken from JRC technical reports (Global flood depth-damage functions (Step E, Figure 3, right side): Moel et. al., 2016). The user must choose the country of the study from a dropdown menu to use the cost and damage functions regarding the specific country.

Table 3: Overview of input types, descriptions, and requirement status for Workflow A.

Input requirements				
Input field	**Risk receptor (all)**	**Input type**	**Input description**	**Necessary / Optional**
Path 1				
"*exposure_buildings.shp*"	Buildings	Shapefile (Polygon)	Must contain 3 × (n+1) + 1 columns named "*GF_01...n+1*", "*B1_01...n+1, B2_01...n+1*", and "*ID*"; values are area per use	Necessary
"*hazard_map.shp*"	Water extent	Shapefile (Polygon)	Must contain two fields: "*DEPTH2D*", "*SPEED2D*" with *float*/*int* values (or *NaN*); other fields are ignored	Necessary

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“*impact_results.shp*”	Analysis zones	Shapefile (Polygon)	Any polygonal area where flood impact should be computed; attribute table may contain any fields	Necessary
“*permeability_table.csv*”	All buildings	CSV	Must contain one “*x_axis*” column (depth outside) + (n+1) usage columns; values between 0.0 and 1.0	Necessary
“*cost_table.csv*”	All buildings	CSV	First column is depth; others are cost values per usage	Necessary
Path 2				
“*exposure_buildings.shp*”	Buildings	Shapefile (Polygon)	Must include three columns: “*COMMERCIAL*”, “*RESIDENTIAL*”, “*INDUSTRIAL*”, with *float* or *int* values	Necessary
“*hazard_map.shp*”	Water extent	Shapefile (Polygon)	Same requirements as Path 1: “*DEPTH2D*”, “*SPEED2D*” columns	Necessary
“*impact_results.shp*”	Analysis zones	Shapefile (Polygon)	Same geometry and validity conditions as Path 1	Necessary
“*permeability_table.csv*”	–	–	Not required	Not applicable
“*cost_table.csv*”	–	–	Not required	Not applicable

- All shapefiles must include a minimum number of valid geometries (5–10 for exposure, 10–20 for hazard) and must be of type Polygon or MultiPolygon.
- The *ID* column in “*exposure_buildings*” must be a string type; all other data must be float, int, or NaN.
- In Path 2, all required values for permeability and cost per usage type are embedded in the DSS backend. Users only need to correctly label usage columns and choose the country that the study refers to.

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	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	GF_01	GF_02	GF_03	GF_04	GF_05	GF_06	B1_01	B1_02	B1_03	B1_04	B1_05	B1_06	B2_01	B2_02	B2_03	B2_04	B2_05	B2_06	ID
2	0	68	0	0	0	136	0	0	0	0	0	0	0	0	0	0	0	0	9444315DF2894C
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8361840DF2886A
4	0	0	0	0	0	90	37	0	0	0	0	48	0	0	0	0	0	0	8361816DF2886A
5	0	0	0	0	0	112	0	0	0	0	0	0	0	0	0	0	0	0	7670931DF2877B
6	0	0	0	0	0	0	0	20067	0	0	0	0	0	0	0	0	0	0	08256W9DF3802F
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1720510DF3812B
8	0	0	0	0	0	0	0	21638	0	0	0	0	0	0	0	0	0	0	1724202DF3812D
9	0	1521	0	0	0	0	0	2697	0	0	0	0	0	0	0	0	0	0	80437X2DF2884C
10	0	0	0	0	0	0	0	16589	0	0	0	0	0	0	0	0	0	0	9107604DF2890G
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7638409DF2873H
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7738104DF2873H
13	0	0	0	0	0	35	0	0	0	0	0	0	0	0	0	0	0	0	14943A3DF3819C
14	0	0	0	0	0	69	0	0	0	0	0	0	0	0	0	0	0	0	14943A2DF3819C
15	0	0	0	1308	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8723108DF2882D
16	0	0	0	778	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8723107DF2882D
17	0	0	0	0	0	66	0	0	0	0	0	0	0	0	0	0	0	0	9803632DF2890D
18	0	0	0	68	0	20	7	60	0	0	0	0	0	0	0	0	0	0	2375412DF3827E
19	0	0	0	0	0	108	0	0	0	0	0	0	0	0	0	0	0	0	1898950DF3819H
20	12	0	0	0	0	45	0	0	0	0	0	0	0	0	0	0	0	0	1898915DF3819H
21	0	0	0	0	0	55	0	0	0	0	0	0	0	0	0	0	0	0	9803638DF2890D
22	0	0	0	43	0	583	56	469	0	37	0	0	89	526	0	0	0	0	7623209DF2872D
23	0	0	0	20	0	91	0	0	0	0	0	0	0	0	0	0	0	0	1288616DF3818G
24	0	0	0	122	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1288617DF3818G
25	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0956635DF3805F
26	180	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0655104DF3805F

Figure 5: Example of a "exposure_buildings.dbf" file structure

1	OBJECTID	element_nc	AREA2D	DEPTH2D	SPEED2D
2	1	25825	53.086303710937500	0.000000000000000	0.000000000000000
3	2	25828	57.689331054687500	0.000000000000000	0.000000000000000
4	3	25829	49.412475585937500	0.000000000000000	0.000000000000000
5	4	25830	67.385498046875000	0.000000000000000	0.000000000000000
6	5	25831	67.867919921875000	0.000000000000000	0.000000000000000
7	6	25832	52.487915039062500	0.000000000000000	0.000000000000000
8	7	25833	55.325317382812500	0.000000000000000	0.000000000000000
9	8	25834	71.946289062500000	0.000000000000000	0.000000000000000
10	9	25835	54.283203125000000	0.000000000000000	0.000000000000000
11	10	25836	60.275634765625000	0.000000000000000	0.000000000000000
12	11	25977	46.242919921875000	0.000000000000000	0.000000000000000
13	12	25978	50.012817382812500	0.000000000000000	0.000000000000000
14	13	25982	74.121459960937500	0.000000000000000	0.000000000000000
15	14	25983	66.135620117187500	0.000000000000000	0.000000000000000
16	15	26002	93.525634765625000	0.000000000000000	0.000000000000000
17	16	26003	55.831787109375000	0.000000000000000	0.000000000000000
18	17	26004	53.889892578125000	0.000000000000000	0.000000000000000
19	18	26005	46.348754882812500	0.000000000000000	0.000000000000000
20	19	26006	45.333496093750000	0.000000000000000	0.000000000000000
21	20	26007	88.867919921875000	0.000000000000000	0.000000000000000
22	21	26008	65.147094726562500	0.000000000000000	0.000000000000000
23	22	26009	82.747070312500000	0.000000000000000	0.000000000000000
24	23	26010	71.765502929687500	0.000000000000000	0.000000000000000

Figure 6: Example of a “hazard_map.dbf" attribute table”.

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x_axis	warehous	car_park	restaurant	general_ti	dwelling	homeown	sport	education	hotels	industries
0	0	0	0.45	0	0	0	0	0	0	0
1	0.006	0.009	0.455	0.003	0.003	0.003	0.009	0.003	0.003	0.009
2	0.011	0.018	0.46	0.006	0.006	0.006	0.018	0.006	0.006	0.018
3	0.017	0.027	0.465	0.009	0.009	0.009	0.027	0.009	0.009	0.027
4	0.022	0.036	0.47	0.012	0.012	0.012	0.036	0.012	0.012	0.036
5	0.028	0.045	0.475	0.015	0.015	0.015	0.045	0.015	0.015	0.045
6	0.034	0.054	0.48	0.017	0.017	0.017	0.054	0.017	0.017	0.054
7	0.039	0.063	0.485	0.02	0.02	0.02	0.063	0.02	0.02	0.063
8	0.045	0.072	0.49	0.023	0.023	0.023	0.072	0.023	0.023	0.072
9	0.05	0.081	0.495	0.026	0.026	0.026	0.081	0.026	0.026	0.081
10	0.056	0.09	0.5	0.029	0.029	0.029	0.09	0.029	0.029	0.09
11	0.062	0.099	0.505	0.032	0.032	0.032	0.099	0.032	0.032	0.099
12	0.069	0.109	0.51	0.041	0.041	0.041	0.109	0.041	0.041	0.109
13	0.075	0.118	0.515	0.05	0.05	0.05	0.118	0.05	0.05	0.118
14	0.082	0.127	0.52	0.059	0.059	0.059	0.127	0.059	0.059	0.127
15	0.088	0.136	0.525	0.068	0.068	0.068	0.136	0.068	0.068	0.136
16	0.094	0.146	0.53	0.076	0.076	0.076	0.146	0.076	0.076	0.146
17	0.101	0.155	0.535	0.085	0.085	0.085	0.155	0.085	0.085	0.155
18	0.107	0.163	0.54	0.094	0.094	0.094	0.163	0.094	0.094	0.163
19	0.113	0.172	0.545	0.103	0.103	0.103	0.172	0.103	0.103	0.172
20	0.12	0.18	0.55	0.112	0.112	0.112	0.18	0.112	0.112	0.18
21	0.126	0.188	0.555	0.121	0.121	0.121	0.188	0.121	0.121	0.188
22	0.133	0.197	0.56	0.13	0.13	0.13	0.197	0.13	0.13	0.197
23	0.139	0.205	0.565	0.139	0.139	0.139	0.205	0.139	0.139	0.205
24	0.147	0.214	0.57	0.148	0.148	0.148	0.214	0.148	0.148	0.214
25	0.154	0.222	0.575	0.157	0.157	0.157	0.222	0.157	0.157	0.222
26	0.162	0.23	0.58	0.165	0.165	0.165	0.23	0.165	0.165	0.23
27	0.169	0.237	0.585	0.174	0.174	0.174	0.237	0.174	0.174	0.237
28	0.177	0.247	0.59	0.183	0.183	0.183	0.247	0.183	0.183	0.247
29	0.184	0.255	0.595	0.192	0.192	0.192	0.255	0.192	0.192	0.255
30	0.192	0.263	0.6	0.201	0.201	0.201	0.263	0.201	0.201	0.263
31	0.2	0.27	0.605	0.21	0.21	0.21	0.27	0.21	0.21	0.27
32	0.207	0.278	0.61	0.219	0.219	0.219	0.278	0.219	0.219	0.278
33	0.214	0.286	0.615	0.228	0.228	0.228	0.286	0.228	0.228	0.286

Figure 7: Permeability CSV file structure example.

Area detection and preprocessing

The spatial extent of the flood impact analysis is determined automatically based on the geometric intersection and union of the uploaded "*hazard_map.shp*" and "*exposure_buildings.shp*" layers. This ensures that calculations are performed only within the common spatial domain covered by both hazard and exposure data. To maintain consistency in spatial computations, all input shapefiles must use the same Coordinate Reference System (CRS). Files with mismatched CRSs will either be reprojected automatically (if enabled in the backend) or flagged as invalid during preprocessing.

Only features with valid Polygon or MultiPolygon geometries are accepted. During validation, all features are checked for geometry type conformity, and any features with unsupported geometries or corrupt topology are excluded from the workflow and logged for user feedback. Additional preprocessing includes:

- Attribute field verification (e.g., presence *of "DEPTH2D"*, "*COMMERCIAL*", etc.).
- Geometry repair, if enabled, for minor topological issues.
- Extent cropping, if requested, to reduce the analysis to a defined bounding area.

2.1.1.4 Core Process

Exposure estimation

In Path 1, the system calculates total floor area per building and usage type using the columns "*GF_*", "*B1_*", and "*B2_*". Each triple of columns corresponds to a specific use, and an additional set of columns (with index n+1) represents non-usable areas. In Path 2, the total floor area is derived from the three usage-specific columns directly ("*COMMERCIAL*", "*RESIDENTIAL*", "*INDUSTRIAL*").

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Vulnerability Assessment

In Path 1, the vulnerability component is determined using a user-provided CSV file named "*permeability_table.csv*". This file defines the proportion of floodwater (flow intrusion) that penetrates each building's interior (related to a sealing coefficient) based on two variables (see Steps C, D, E, and F in Figure 3, left side):

1. The external flood depth (measured in centimeters), and
2. The building usage type, as defined in the exposure shapefile.

The CSV structure must adhere to the following format:

- The first column, typically named "*x_axis*", contains integer values representing external flood depth in centimeters.
- Each subsequent column corresponds to a specific usage type, such as "*warehouse*", "*car_park*", "*restaurant*", "*dwelling*", etc.

The *.dbf* file of "*exposure_buildings.shp*" includes usage-specific floor area attributes for ground floor (GF), first basement (B1), and second basement (B2) levels, plus an *ID* column. Each cell in the CSV should contain a float value between 0.0 and 1.0, indicating the proportion of the exterior water level that enters the building for that usage type at that specific water depth. These values are used to model internal flooding per building.

The ordering of the columns in the CSV must match the ordering of the usage types defined in the *.dbf* of the *exposure_buildings* shapefile. For example, if "*GF_01*", "*B1_01*", and "*B2_01*" refer to the *warehouse*, then the second column in the CSV (after "*x_axis*") must correspond to the *warehouse*. This correspondence is not automatically validated and must be managed by the user.

In Path 2, the user is not required to provide a "*permeability_table.csv*". Instead, default permeability functions are internally defined for the three accepted usage types ("*COMMERCIAL*", "*RESIDENTIAL*", and "*INDUSTRIAL*") and are applied automatically.

Risk Calculation

The flood calculation process integrates the hazard data, the exposure attributes, and the vulnerability functions to estimate the expected damage for each spatial unit defined in the *impact_results* shapefile. For each building or parcel identified in the *exposure_buildings* shapefile layer, the water depth values from the *hazard_map* shapefile are intersected, and the corresponding internal flood depth is calculated. In Path 1, the depths are determined by applying ratios from the *permebility_table* shapefile, specific to each building type. In Path 2, predefined penetration coefficients are used instead. These internal depths are then multiplied by the corresponding cost per square meter, as specified in the *cost_table* shapefile (Path 1; see Steps I, J, and K in Figure 3, left side) or embedded system defaults (Path 2; see Steps F, G, and H in Figure 3, right side), to produce an estimate of monetary damage. The total risk is then aggregated for each area of interest defined in the *impact_results* layer, generating a spatially explicit impact assessment (for Path 1 see Step L in Figure 3, left side; for Path 2 see Step I in Figure 3, right side).

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2.1.1.5 Output Description

The main output of the flood risk backend is a vector shapefile that mirrors the geometry of the "*impact_results.shp*" input layer. Each polygon in this output is enriched with new attribute fields indicating:

- the estimated internal flood depth,
- the calculated economic cost per area, and
- any other derived impact metrics (e.g., damage index, building usage-specific summaries).

These outputs are produced for all valid polygons present in the *impact_results* shapefile, provided that the hazard and exposure layers intersect within the polygon boundaries. The outputs can be visualised in the DSS platform or exported for external GIS analysis. Both paths generate similarly structured outputs, although the underlying cost and vulnerability computations differ.

Table 4: Summary of the output data for Workflow A.

Output Description			
Output File	**Format**	**Content**	**Availability Condition**
"*flood_impact_results.shp*"	Shapefile	Per impact area: total cost, average flood depth, average water velocity, usage-based summaries	Generated only if all three shapefiles are valid and at least one overlap exists
"*summary_stats.csv*" (optional)	CSV	Aggregated risk/cost statistics per building type or zone	Only generated in Path 1 if internal summary export is enabled

<u>Data availability</u>

Data availability is a critical factor for the successful execution of the flood risk backend. All shapefiles must be uploaded with valid geometry, and the attribute tables must conform to expected structures. In Path 1, both CSV files ("*permeability_table.csv*" and "*cost_table.csv*") are required and must be properly formatted to match the corresponding fields in the exposure dataset. If these files are missing, lack the correct formation, or are inconsistent with the exposure data, the path will fail validation and halt execution. In Path 2, only the three (3) shapefiles are necessary, provided that the exposure layer includes the mandatory usage type. Missing or incompatible columns will render the dataset invalid.

<u>Specifications to consider</u>

Several technical and operational specification must be observed to ensure workflow validity:

- All spatial data must use a consistent CRS to allow accurate spatial overlay (Wechsler et. al., 2019).
- Geometries must be of type Polygon or MultiPolygon; any features with point, line, or invalid geometries will be excluded.
- The exposure shapefile must include the correct usage-type fields:

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- In Path 1: custom usage types like "*GF_01*", "*B1_01*", etc., matching those in the CSV files.
- In Path 2: only the fields "*COMMERCIAL*", *RESIDENTIAL*, and "*INDUSTRIAL*" are accepted.

- CSV files (Path 1) must have one row per water depth value, and columns in the same order as in the exposure attributes.
- All numeric fields must fall within acceptable ranges:
  - Permeability: Floats in the range [0.0 – 1.0] representing the penetration ratio of outside water into each building type.
  - Cost: > 0 (no negative values) In the *cost_table* shapefile, the values must be positive floats or integers, representing monetary loss per square meter at each water level.
- The *impact_results* shapefile must contain at least one valid polygon; otherwise, the workflow cannot compute results.
- The expected number of usage types (and thus CSV columns) is inferred from the *.dbf* file of the *exposure_buildings* shapefile.

Validation of all inputs occurs prior to processing. If validation fails, the user is informed of the issue, and no outputs are generated.

Example output

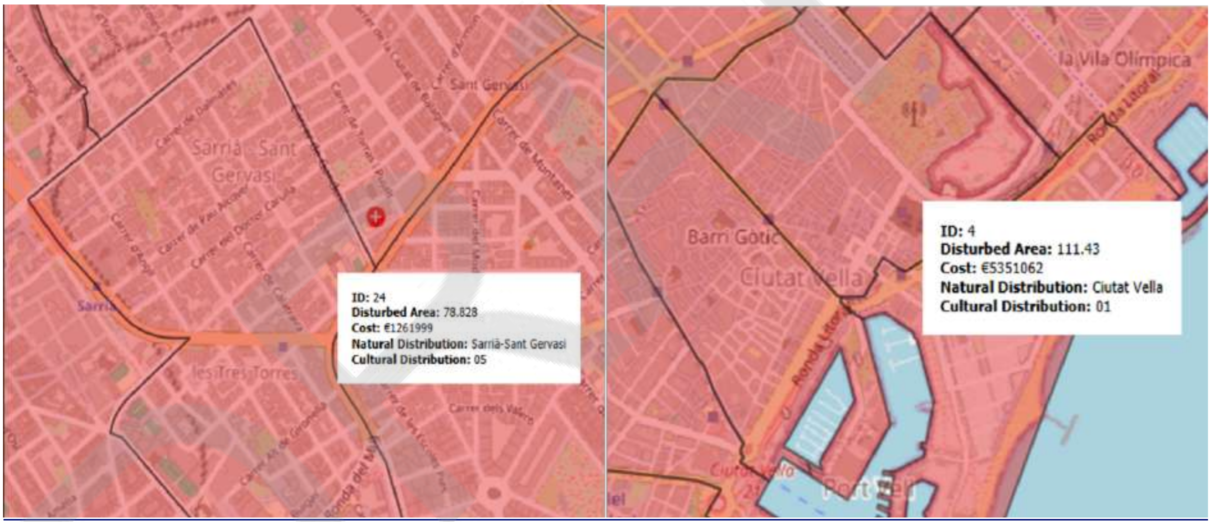

Figure 8: Example output for two areas in Barcelona.
Values for cost are displayed along with the name of the area, the cultural distribution[1], and ID codes.

2.1.2 Workflow B: Windstorms

2.1.2.1 Summary and objectives of Workflow A

This section describes the backend workflow for assessing windstorm-related risks to electric power infrastructure (Panteli & Mancarella, 2017) in the DSS. The workflow supports two infrastructure types (risk receptors): (i) towers, and (ii) powerlines. Based on the raster wind hazard data and the vector infrastructure

[1] The cultural distribution refers to a value given for each region in the original data.

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shapefiles, the backend implementation calculates the damage probability and assigns a risk class to each element. Outputs are generated focused on the infrastructure types provided by the user. The workflow includes preprocessing (e.g., line segmentation), gust speed mapping, risk scoring, and classification. The implementation scheme is designed to support modular features, extensibility, and straightforward connection with the UI.

Table 5: General structure of Workflow B.

Workflow B summary		
Raster map ("*vmax_gust_event.tif*") of maximum gust wind speed per pixel	**Exposure**	Vector shapefiles of towers (points) and powerlines (lines)
Currently uniform per asset type (may vary by infrastructure type in future versions)	**Input/Output**	The input section includes raster and vector shapefiles while the output section includes shapefiles with gust speed, damage probability, and risk class

2.1.2.2 Pipeline Procedure

An example of a flowchart of assets is listed below, for the towers, and powerlines respectively.

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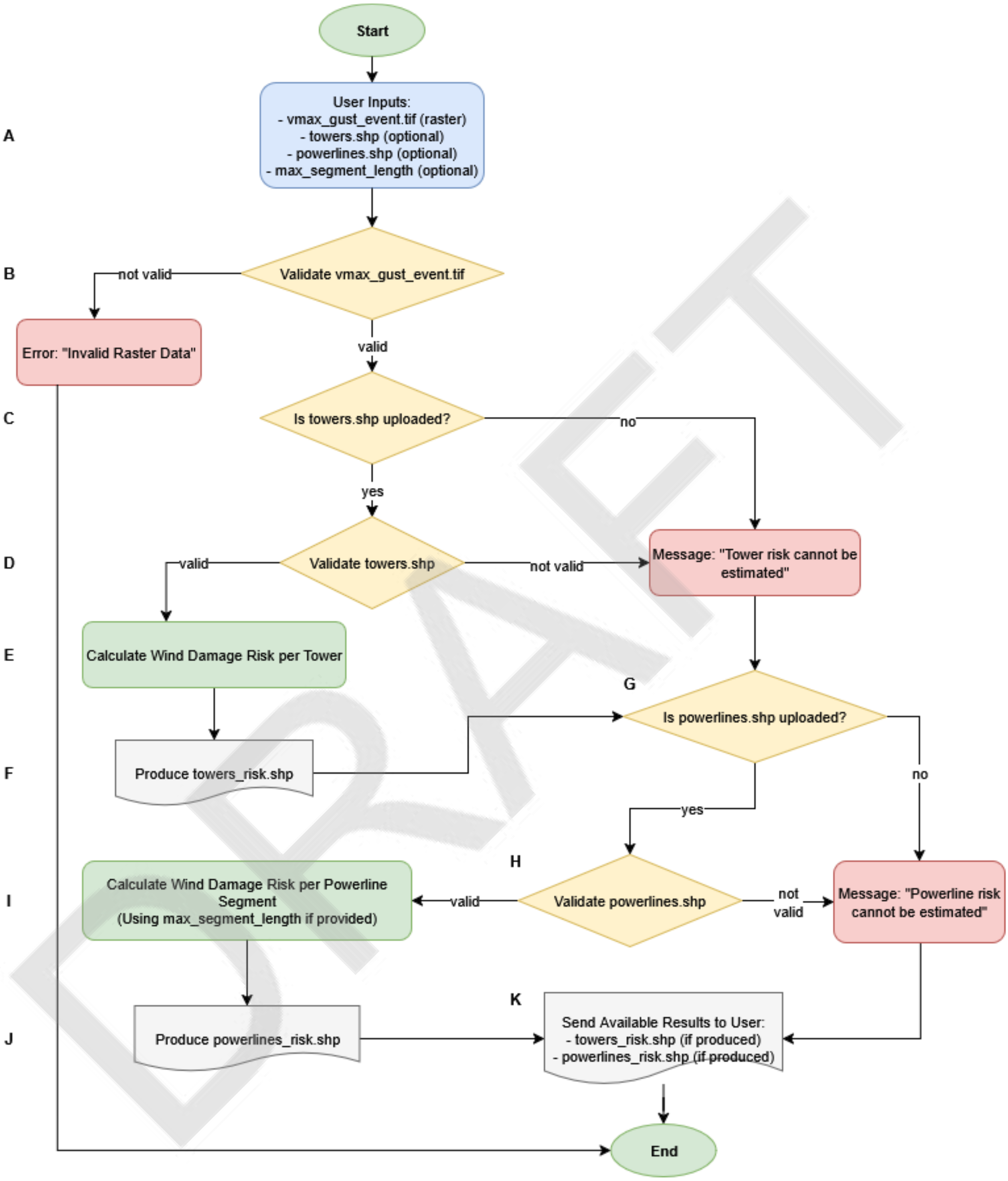

Figure 9: Example flowchart for the windstorm case in Workflow B.

The workflow begins by validating a user-imported raster file containing maximum wind gust values ("*vmax_gust_event.tif*"), before any further processing. If the raster is invalid, the procedure stops with an error message. When valid, the workflow branches depending on the availability of optional vector inputs.

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If tower data ("*towers.shp*") is provided, they are validated, and in the case of successful validation, wind damage risk is calculated for each tower and exported as a dedicated risk layer ("*towers_risk.shp*"). If tower data are missing or are invalid, the workflow issues a message indicating that tower risk cannot be estimated. Similarly, if powerline data ("*powerlines.shp*") is uploaded, they are validated, and wind damage risk is then calculated for each powerline segment, making use of the optional maximum segment length parameter when available, and the results are exported as a shapefile ("*powerlines_risk.shp*"). If powerline data are not provided or fail validation, a message is returned noting that powerline risk cannot be estimated. At the conclusion of the process, all successfully generated outputs, tower and/or powerline risk shapefiles are returned to the user.

2.1.2.3 Input Specification

The windstorm workflow's input depends on the risk receptor the user has chosen. Currently, two (2) risk receptors are supported, towers, and powerlines. The description of the input selection (see also Steps A-D in Figure 9) and characteristics is described below:

Hazard input

- The wind hazard input must be provided in the form of a GeoTIFF raster named (or mapped as) "*vmax_gust_event.tif*".
- Each pixel value must represent the maximum gust speed (in m/s or km/h) for the selected scenario(s).
- Data type: *float* or *int*.
- Spatial coverage must fully encompass the exposure layers.
- CRS: must match the exposure layers (e.g., EPSG:3005 or EPSG:4326).

A list of the alternative accepted filenames may be introduced to remove the current strict dependency on the "*vmax_gust_event.tif*" file.

Exposure input

The exposure component consists of two optional vector shapefiles representing electricity infrastructure (towers, and powerlines). The system automatically detects whether each has been provided based on the filename given as input.

a) "*towers.shp*" – Electricity towers
   - Geometry: a point.
   - Description: each point represents the position of the transmission tower or the pole.
   - Optional attributes:
     - "*id*", "*ID*", "*tower_id*", "*full_id*": unique identifier (*str* or *int*) for referencing the tower in external systems.
     - "*type*", "*power*": describes the structural type (e.g., "*tower*", "*pole*", "*portal*"), such as either a wooden pole or a metallic pylon.

In the current implementation all towers use the same risk function regardless of type.

b) "*powerlines.shp*" – Transmission lines

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- Geometry: linestring.
- Description: each line represents an electrical cable or a transmission line.
- Optional attributes:
  - "*id*", "*ID*", "*tower_id*", "*full_id*": unique identifier (*str* or *int*) for each line segment.
  - "*type*", "*power*": describes the infrastructure class (e.g., "*line*", "*powerline*", etc.).

Line segmentation parameters

Transmission lines in the "*powerlines.shp*" may extend across a wide area and experience varying wind speeds. To address this, each line can be automatically split into smaller segments before the risk evaluation. The characteristics can include:

- Input variable: "*max_segment_length*".
- Type: *float* or *int*.
- Accepted range: 50-1000 meters.
- Default value: 400 meters (arbitrary choice that can vary depending on the powerline and electricity network).

These characteristics can provide the necessary information for estimating gust speed locally avoiding overgeneralisation over long line geometries and wide areas.

Specific input requirements for this workflow can be found summed up in the table below:

Table 6: Overview of input types, descriptions, and requirement status for Workflow B.

Input requirements				
Input field	**Risk receptor (all)**	**Input type**	**Input description**	**Necessary / Optional**
"*vmax_gust_event_tif*"	All	Raster (GeoTIFF)	Raster file containing maximum gust wind speed per pixel (*float* or *int*)	Necessary
"*towers.shp*"	Towers	Shapefile (Point)	Point geometries representing transmission towers or poles; may include *id* and *type* fields	Optional
"*powerlines.shp*"	Powerlines	Shapefile (LineString)	Line geometries representing electric cables; may include *id* and *type* fields	Optional

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"*max_segment_length*"	Powerlines	*Float/ Int*	User-defined maximum segment length for splitting long lines; default value is provided if invalid input is provided	Optional

Area detection and preprocessing

The spatial extent of the analysis is derived from the given boundary box based on the uploaded infrastructure shapefiles. Agnostically if whether the user provides the shapefile for the towers or the powerlines, the backend implementation uses the combined spatial coverage of the given layers as the area of interest. In the case of powerlines, where the unavoidably long linear geometries may span several kilometres, the system segments each line into smaller subcomponents of approximately equal length. The maximum length of each of these segments is determined by a specified hard coded variable, which must be provided by the user. These preprocessing steps aims to result in evaluating each segment with sufficient granularity relative to the wind hazard raster.

2.1.2.4 Core Process

Exposure estimation

The system estimated the wind exposure for each infrastructure element. Gust speed values from the raster file(s) are interpolated and assigned to each tower point and powerline segment. The selection of the interpolation method is performed internally, depending on the available resolution of the input raster and the density of the infrastructure data. For each element, a localised estimate of the wind speed is assigned, which is used in subsequent risk calculations. This approach allows the windstorm workflow to account for special variability in wind speed across complex terrain.

Vulnerability Assessment

The vulnerability component of the windstorm workflow is implemented using uniform functions per asset type. All towers are assigned the same vulnerability model, and all powerlines follow a shared model as well. However, the backend implementation is designed to recognise the subtype of each assert (e.g., a tower, a pole, etc.). These attributes offer the flexibility to be used either from the current version of the DSS to differentiate vulnerability scores, or to be preserved in the processing pipeline for potential integration into upgraded versions of the DSS. Such upgrades may include for example differentiated vulnerability curves based on infrastructure materials, design standards, or any other dedicated characteristics.

Risk Calculation

Once exposure and vulnerability components (values) are defined, the system calculates a risk score for each element using a predefined function that relates wind speed to the probability of damage. The exact form of this function is currently based on empirical data and applies uniformly across each asset class. In addition, each infrastructure element is assigned a risk class, represented as an integer between 1 and

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5. Classification may be based either on percentile rankings (e.g., the bottom 20% of assets in terms of risk fall into class 1, the top 20% into class 5), or on fixed damage probability or gust speed thresholds. The exact method of classification may evolve depending on stakeholder requirements or regulatory thresholds (see also Steps E-J in Figure 9).

2.1.2.5 Output Description

The outputs of the windstorm workflow consist of shapefiles that retain the original geometry of the input infrastructure and are enriched with risk-related attributes. When towers are included, the output shapefile contains point geometries with fields for unique identifier, interpolated gust speed, estimated probability of damage, and assigned risk class. Similarly, for powerlines, the output includes line-string geometries representing the segmented parts of the electricity network, with analogous fields describing local wind speed, damage probability, and categorical risk level. These outputs are designed to support both expert analysis and integration into the DSS UI for visualisation and filtering (see also Step K in Figure 9).

Table 7: Summary of the output data for Workflow B.

Output Description			
Output File	**Format**	**Content**	**Availability Condition**
"*towers_risk.shp*"	Shapefile (Point)	Includes tower *id*, interpolated gust speed, damage probability, risk class	Generated only if the "*towers.shp*" is provided and valid
"*powerlines_risk.shp*"	Shapefile (LineString)	Includes segment *id*, interpolated gust speed, damage probability, risk class	Generated only if the "*powerlines.shp*" is provided and valid

<u>Data availability</u>

The backend implementation does not source any data autonomously. All required inputs, namely the wind hazard raster, and the infrastructure 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 workflow does not execute any computation for a receptor type if the corresponding input shapefile is not present.

<u>Specifications to consider:</u>

- All raster and vector inputs must be provided in the same CRS to ensure spatial alignment.
- The gust speed raster must have sufficient resolution to allow for meaningful interpolation to point and line features.
- The user-defined variable for maximum segment length must fail within the accepted range of 50 to 1000 meters, otherwise, the system will revert to the default value.

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- 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.

<u>Example output</u>

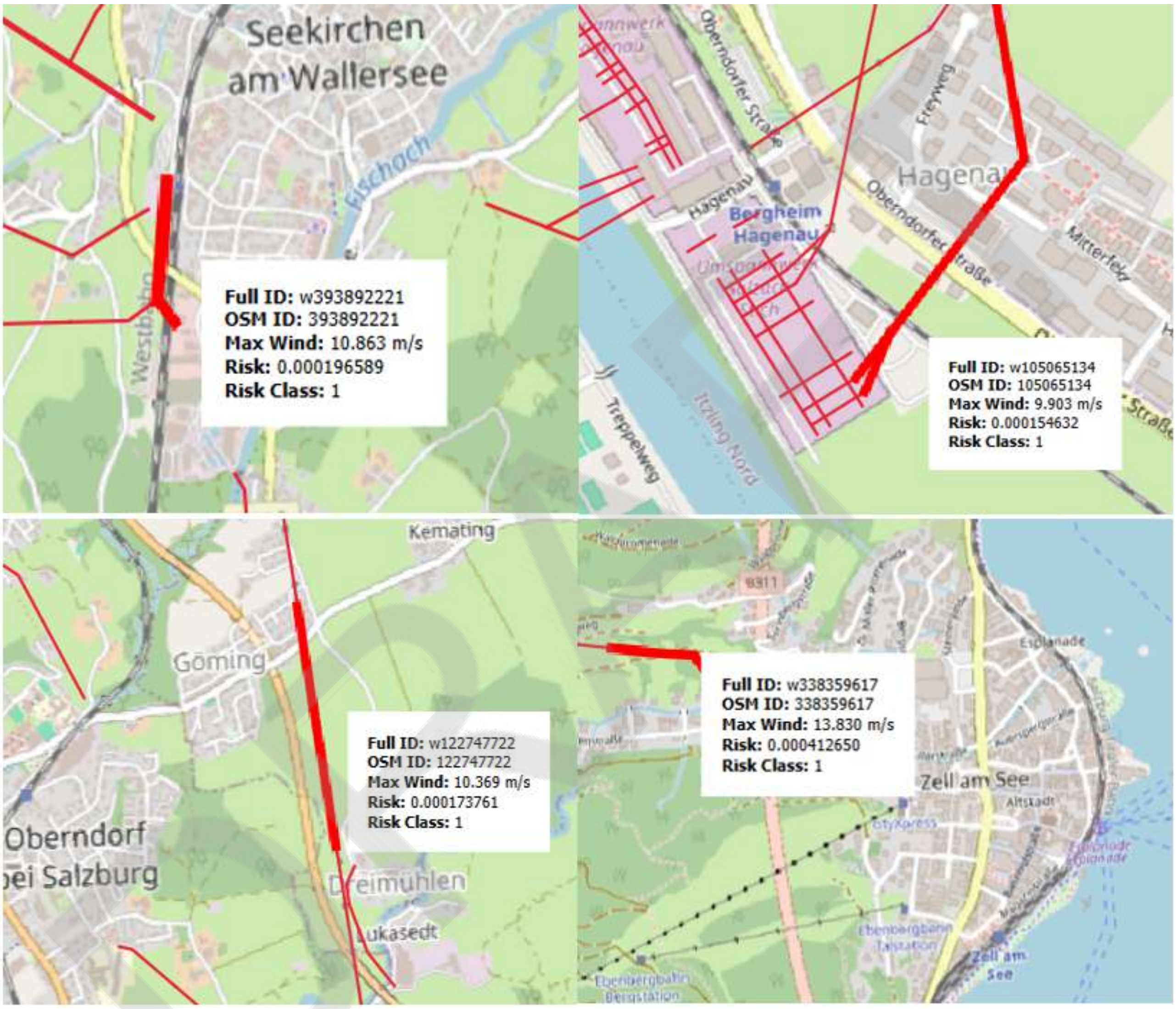

Figure 10: Example output for the powerlines.

In Figure 10, the max wind value is displayed measured in m/s along with the risk class of the selected area. Risk is defined as the probability that a given element will be damaged or destroyed. Its quantification and categorisation can be performed in various ways. For example, a 10% probability might be assigned a risk level of 5, or a 20% probability might correspond to a higher level, depending on the available risk value thresholds. The Risk Class (*risk_class)* indicates how much a specific element is at risk relative to

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others (e.g., other infrastructures). It is divided into intervals, though alternative classifications can be applied based on the underlying distribution of risk values.

2.1.3 Workflow C: Wildfires

2.1.3.1 Summary and objectives of Workflow C

This section focuses on the backend workflow of the wildfire hazard implemented in the DSS, detailing the data inputs, the processing steps, and the output structure used to compute exposure, vulnerability, and composite risk across the example case study of Rhodes Island in the South Aegean region in Greece. It supports user-defined input(s), and provides specified outputs for natural areas, population, and properties, allowing for spatial decision support in wildfire risk management.

Table 8: General structure of Workflow C.

Workflow C summary			
Hazard	Represents the fire weather risk for each chosen region, based on the number of days with a value of Fire Weather Index (FWI) higher than 50, from the uploaded *.shp* input file.	**Exposure**	Quantifies the likelihood of a wildfire affecting a specific receptor (e.g., natural areas, population, etc.), using hazard intensity and user-defined input data.
Vulnerability	Assesses the susceptibility of each CORINE Land Cover Class (CLC) area to wildfire damage, based on land use/fuel type inferred from the CLC codes.	**Input/Output**	Inputs include shapefiles for hazard (FWI), exposure data (population, buildings), and areas as given by using the CORINE Land cover areas (either bounding box or "*corine_areas.shp*"). Outputs are receptor-specific shapefiles for fire likelihood (exposure as defined by the experts conducting wildfire assessments for the given area), risk receptor damage score (vulnerability likewise as defined by the experts conducting wildfire assessments for the given area), and composite, per CORINE area.

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2.1.3.2 Pipeline Procedure

Three (3) flowcharts with examples of assets are presented below, one for buildings, ecology, and population respectively.

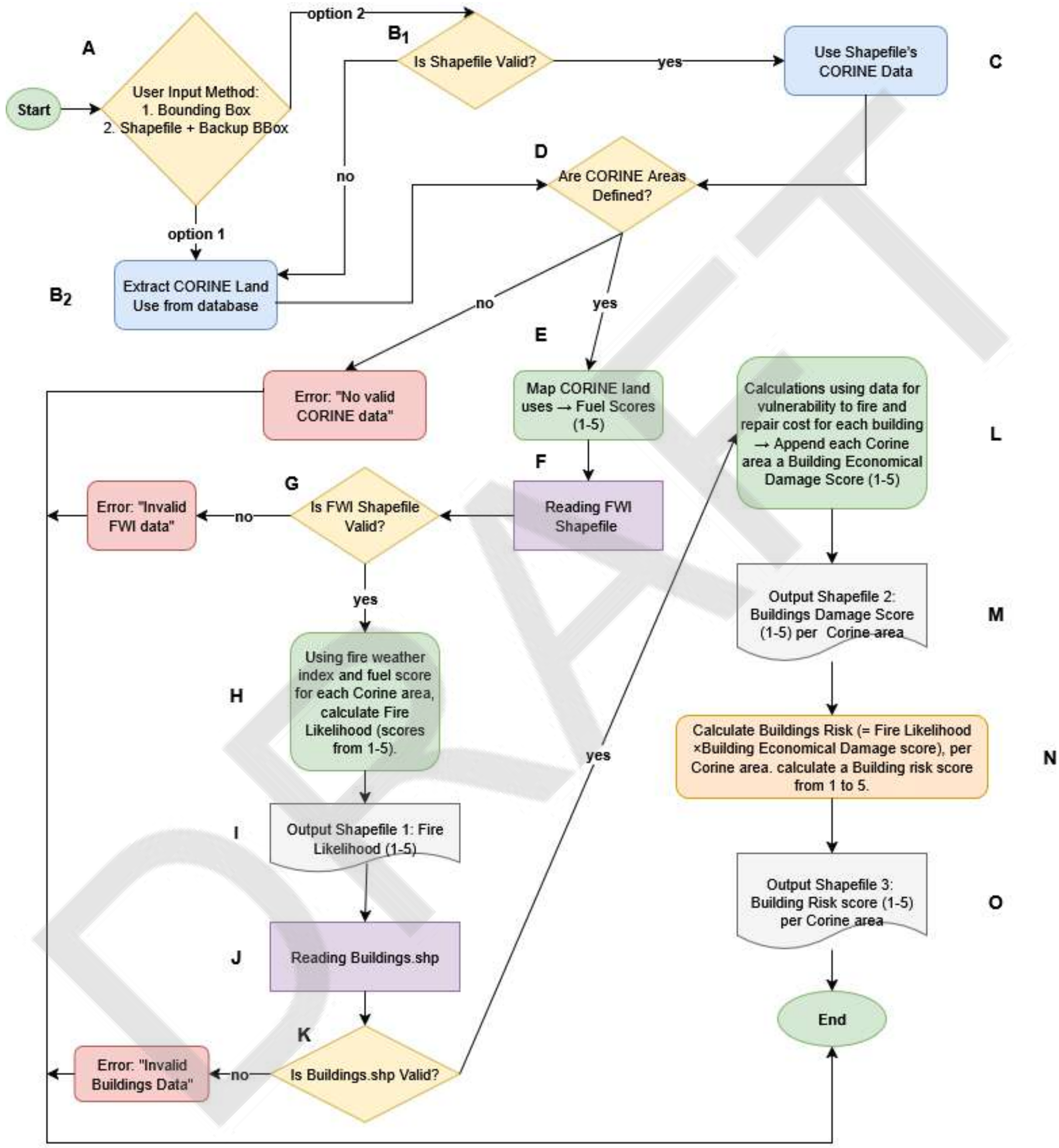

Figure 11: Example flowchart for buildings for the wildfires case for Workflow C.

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In Figure 11, the wildfires' flowchart for buildings begins with the user providing input either through a bounding box or a shapefile. If a shapefile is used, its validity is checked. Valid shapefiles supply CORINE land-use data directly, while invalid shapefiles trigger the extraction of CORINE data from the database. If no valid CORINE data can be established, the process terminates with an error. Once valid CORINE areas are established, they are mapped to fuel scores on a scale from 1 to 5. In parallel, an FWI shapefile is read and validated. If valid, the FWI is combined with the fuel scores to calculate fire likelihood values, which are stored as the first output shapefile. The workflow then proceeds with building data. A building shapefile is read and validated; invalid data result in termination. For valid data, calculations are performed using information on vulnerability to fire and repair costs to derive an economic damage score of buildings (1–5) for each CORINE area. The fire likelihood scores, and the building economical damage scores are subsequently combined to calculate a composite building risk score, also ranging from 1 to 5. The results are stored in three (3) outputs: shapefile 1 contains fire likelihood scores, shapefile 2 contains building economic damage scores per CORINE area, and shapefile 3 provides the final building risk scores per CORINE area.

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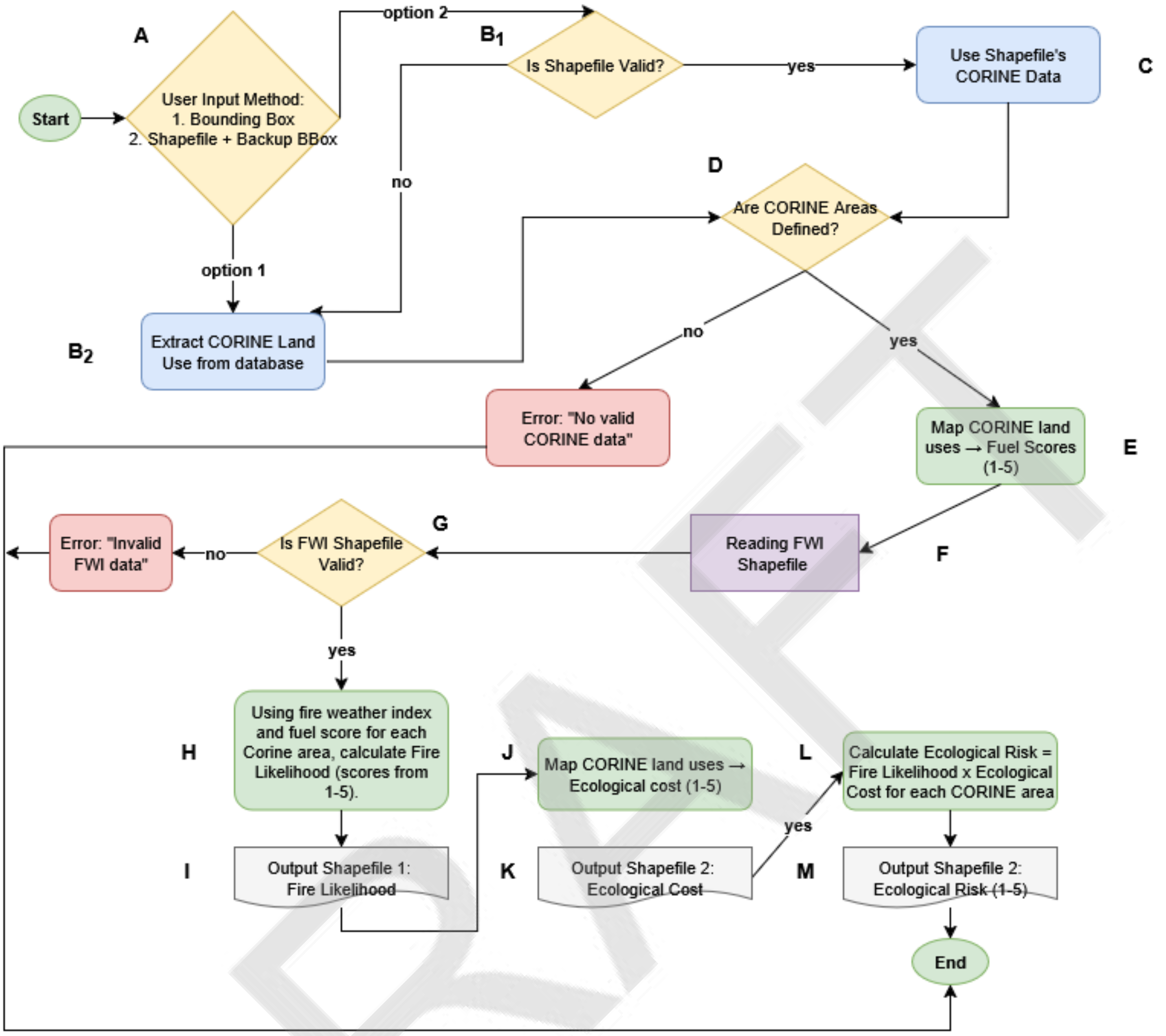

Figure 12: Example flowchart for ecology for the wildfires case for Workflow C.

In Figure 12, the wildfires' flowchart for ecology begins with the user providing input either as a bounding box or as a shapefile. If a shapefile is supplied, its validity is first verified. Valid shapefiles directly provide CORINE land-use data, while invalid shapefiles prompt the extraction of CORINE data from the database. If no valid CORINE data are available, the process terminates. Once CORINE areas have been confirmed, they are assigned fuel scores on a scale from 1 to 5. In parallel, an FWI shapefile is read and validated; if invalid, the flowchart stops. When valid, the FWI data are combined with the fuel scores to calculate fire likelihood values, also expressed on a scale from 1 to 5, and saved as the first output shapefile. Each CORINE area is further assigned an ecological cost value of 1–5, which is stored as the second output shapefile. In the final step, the fire likelihood values are integrated with the ecological cost scores to derive an overall ecological risk score for each CORINE area, producing the final output shapefile with results ranging from 1 to 5.

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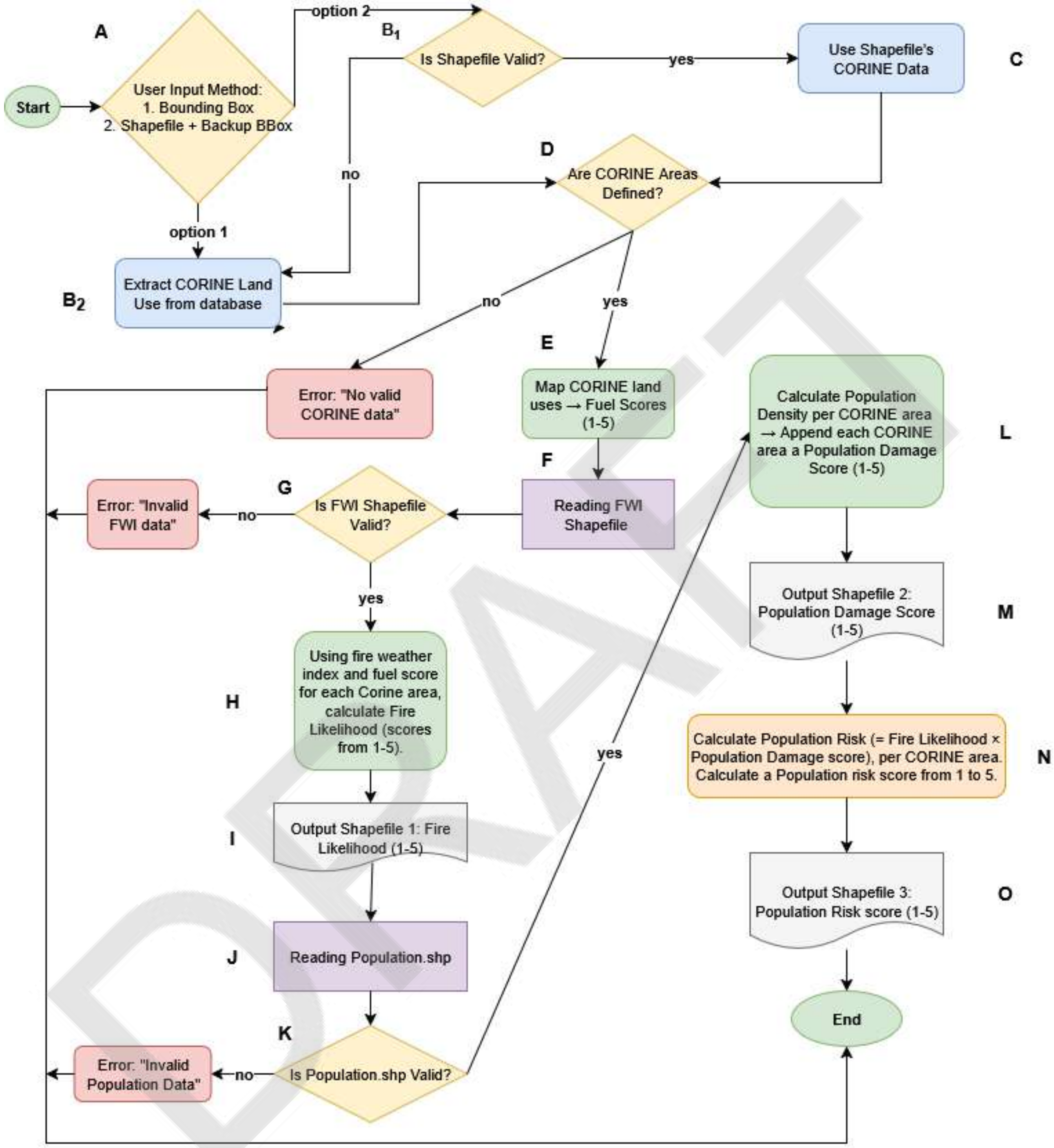

Figure 13: Example flowchart for population for the wildfires case for Workflow C.

In Figure 13, the wildfires' flowchart for population begins with the user selecting either a bounding box or a shapefile. If a shapefile is used, its validity is checked; valid shapefiles directly provide CORINE land-use data, while invalid shapefiles trigger the extraction of CORINE data from the database. If no valid CORINE data are available, the process terminates. Once CORINE areas are established, they are assigned fuel

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scores on a scale from 1 to 5. In parallel, an FWI shapefile is read and validated. If valid, the FWI data are combined with the fuel scores to calculate fire likelihood values, also expressed on a scale from 1 to 5, which are exported as the first output shapefile. The flowchart then incorporates the population asset layer, where a population shapefile is read and validated; invalid data leads to termination. When valid, population density values are processed to derive a population exposure and damage score 1–5 for each CORINE area, which is stored as the second output shapefile. In the final step, the fire likelihood scores are combined with the population damage scores to calculate an integrated population risk score of 1–5 for each CORINE area, which is saved in the third output shapefile.

2.1.3.3 Input Specification

The wildfire workflow's input depends on the risk receptor the user has chosen. Currently, three (3) risk receptors are supported; ecology, properties and population (Leyk et. al., 2019).

Input common for the three different receptors:

a) Input regarding the definition of the CORINE areas the user intend to study (see also Steps A-D in Figures 9-11 in the three flowcharts for the receptors). The wildfire workflow supports two (2) user-defined modes for specifying the geographic area of interest:
   - Mode A – Bounding box selection: The user submits a bounding box using minimum and maximum latitude and longitude values. The system recognises and uses these values to extract the corresponding CORINE polygons from the Copernicus Land Cover database. Below an example of a bounding box in JSON format:

     {"bounding_box": {"min_lon": 27.6, "min_lat": 35.8, "max_lon": 28.3, "max_lat": 36.5}}

   - Mode B – Custom shapefile (*.shp*): Alternatively, the user is given the option to upload a shapefile file named "*corine areas*", which must contain data that the user has extracted from the CORINE database, containing the land use codes of the CLC codes, regarding the area the user intends to study. Even in Mode B, the bounding box must still be submitted, so the system can fall back if the shapefile fails validation. The system will continue the process and issue a warning if the shapefile cannot be read properly.

b) Input regarding the weather's conduciveness to wildfires, in the areas of interest: A shapefile named "*FWI.shp*" that contains geometries that correspond to areas that intersect with the CORINE areas under study, and data regarding how many days per year the FWI value is larger than 50 (FWI > 50).

Input specific per risk receptor:

a) For the properties risk, a shapefile named "*Buildings.shp*" that contains all derived geometries that correspond to buildings, and data regarding their resistance to fire. There are two (2) available options for the user: either (i) the shapefile will contain extra data regarding the reparation cost of a building in case of fire, or (ii) a single numerical value will be given by the user that describes the mean reparation cost per square meter for the area of interest. In the flowchart (see Steps E-N, Figure 11), the validated buildings shapefile is used to calculate a building economic damage score

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(1–5) for each CORINE polygon, which is then combined with fire likelihood to produce the final building risk score.

b) For the ecological risk no further input is required. The ecological impact that a fire would cause in a selected area is derived from a mapping that appends to each land use code an ecological damage score. In the corresponding flowchart (see Steps E-L, Figure 12), the CORINE polygons are directly assigned ecological cost values (1–5), which are later combined with fire likelihood to calculate ecological risk.

c) For the population risk, a shapefile named "*Population.shp*" that contains all derived geometries that correspond to areas that intersect with the CORINE areas under study and incorporates data regarding the population residing within those areas. As illustrated in Figure 13 (see also Steps E-M), after the validation of the population shapefile, density values are used to derive a population damage score (1–5) per CORINE polygon, which is then combined with fire likelihood to produce a population risk score.

Specific input requirements for this workflow can be found summed up in the table below:

Table 9: Overview of input types, descriptions, and requirement status for Workflow C.

Input requirements				
Input field	**Risk receptor (all)**	**Input type**	**Input description**	**Necessary / Optional**
Vulnerability	All	Four (4) float values	The coordinates of the bounding box that defines the area of interest.	Necessary
Vulnerability	All	*"corine_areas.shp"*	A shapefile with polygon geometries and a column of int or string values with the land use codes.	Optional
Hazard	All	*"FWI.shp"*	A shapefile with polygon geometries and a column named '*FWI50*', with *int* or *float* values.	Necessary
Exposure	Population	*"Population.shp"*	A shapefile with polygon geometries and a column named "*population*" or "POPULATION" with *int* or *float* values.	Necessary for the population risk receptor
Exposure	Properties	*"Buildings.shp"*	A shapefile with polygon geometries and a column	Necessary for the properties

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			named *"category"* or "CATEGORY" with *int* values. Optional: a column named "rep_cost", "REP_COST", "cost" or "COST" with *int* or *float* values.	risk receptor
Exposure	Properties	A numerical value (*int* or *float*)	Optional: the numeric value must be given if the "optional cost" or *"rep_cost"* column **is not** included in the *"Buildings.shp"* file.	Optional for properties risk receptor.

Area detection and preprocessing

Based on the input mode, the system either extracts CORINE regions from the Copernicus database using the bounding box or reads them directly from the uploaded shapefile. Each polygon is mapped to a CORINE code, which defines the fuel type and risk receptor context. This step is common to all three workflows (ecological, population, buildings; Step E in all flowcharts).

2.1.3.4 Core Process

Exposure estimation

Exposure output is calculated for each CORINE polygon in the chosen area. The term "exposure" in this case describes the likelihood of a CORINE area being affected by a wildfire which differs from the general referencing in the DSS description (see also Steps F-I in all flowcharts).

Vulnerability Assessment

Each CORINE polygon is assigned a vulnerability value based on its land use code, which acts as a proxy for fire susceptibility (e.g., vegetation vs. urban). Although labeled "vulnerability" in this workflow, this measure may not align precisely with the DSS-wide vulnerability definition and may require harmonisation. In practice, this step diverges depending on the risk receptor: (i) ecological cost scores for the ecological workflow, (ii) population damage scores for the population workflow, and (iii) building economic damage scores for the building's workflow (In the ecological workflow this corresponds to steps J–K (ecological cost), in the population workflow to steps L–M (population damage), and in the buildings workflow to steps L–M (building economic damage)).

Risk Calculation

When both exposure and vulnerability values are available, the risk per CORINE unit is computed as:

$$\text{Risk} = \text{Exposure} \times \text{Vulnerability}$$

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2.1.3.5 Output Description

Three (3) shapefiles are generated per receptor: (i*) "exposure.shp"*, *" vulnerability.shp"*, and (iii) *" risk.shp"* (if all components are available to be sourced; see also Steps O in Figure 11, M in Figure 12, and O in Figure 13).

Table 10: Summary of the output data for the Workflow C.

Output Description			
Output File	**Format**	**Content**	**Availability Condition**
"exposure.shp"	Shapefile	Exposure scores per CORINE polygon	Always, if the *"FWI.shp"* file is valid
"vulnerability.shp"	Shapefile	Vulnerability scores per CORINE polygon	Always, if CORINE units are available
"risk.shp"	Shapefile	Composite risk = Exposure × Vulnerability	Only if both exposure and vulnerability exist

Data availability

The wildfire workflow operates using a mix of open European datasets and user-uploaded shapefiles:

- CLC: Available at 100 m resolution via Copernicus Land Monitoring Service.
- FWI: Provided by the user; must include a FWI50 column.
- Population: Can be extracted from Copernicus Emergency Management Service/Population Grid.
- Buildings: May be user-generated or derived from cadastral or open sources (e.g., OpenStreetMap) (Zhou et. al., 2022; Törnros et. al., 2015; Herfort et. al., 2023).

Fallback mechanisms are built into the workflow to tolerate missing or incomplete inputs where feasible.

Specifications to consider:

- The semantic use of "exposure" and "vulnerability" in this workflow may warrant further discussion in V2.
- Risk estimates depend on the quality of user inputs, particularly population and building datasets which can be a key factor for local or regional results or for a broader area of study.
- Time-dependence and seasonal dynamics are not currently modelled. Any capturing of any supporting characteristics might be able to be reached indirectly by the user after running dedicated tests.

Despite any limitations of the current version, the workflow provides a transparent and reproducible method for wildfire risk estimation aligned with European land classification practices and can be applied by the user for tests and for the purposes of trials and mini trials when and if needed.

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Example output

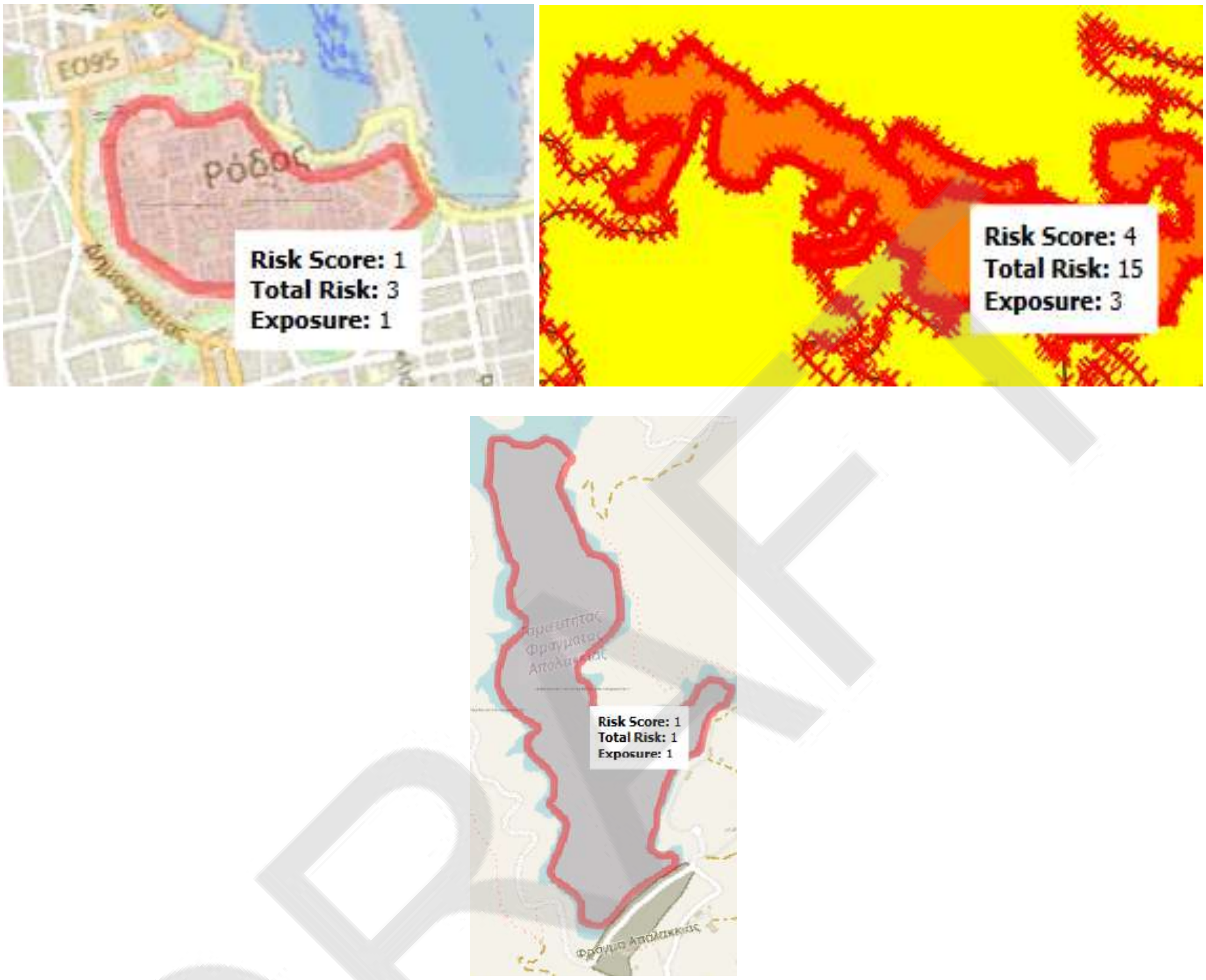

Figure 14: Example output for the wildfires on the island of Rhodes.

Within Figure 14, in the top left figure, the downtown area is selected, maintaining low risk and exposure scores respectively. In the top right figure, the selected area encompasses forest ecosystems, tree-dominated regions, and additional vegetated surfaces, with total risk values elevated and exposure values higher than those experienced for the downtown area of Rhodes city. In the bottom figure, an area where a water reservoir is selected presents the lowest values for the total risk and exposure, as expected.

2.2 Resilience Assessment

The ICARIA DSS provides users with tools to evaluate how well regions or infrastructure assets can absorb, adapt to, and recover from climate-related disruptions. Through the Resilience Assessment functionality, users can carry out structured evaluations tailored to either urban/regional systems or critical infrastructure, aligning with key European and international resilience frameworks.

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Two complementary tools are integrated into the platform:

- Resilience Assessment Framework – Focused on a holistic assessment of resilience at the urban and regional scale.
- Resilience Assessment Tool – Dedicated to evaluating critical infrastructure resilience.

These tools are based on the methodologies developed in D3.2 (Brito et al., 2024) which offer a structured, multi-dimensional approach to resilience grounded in system-level thinking and real-world service vulnerabilities.

2.2.1 Resilience Assessment Framework

The RAF helps users assess regional or service-level resilience through a simplified version of the official RAF tool, developed by LNEC[2]. Since the full RAF application includes hundreds of metrics, covering seven urban services, only a targeted subset was selected for integration into the DSS. This selection was made by LNEC in collaboration with DRAXIS, focusing on 17 core questions that best capture the four main resilience dimensions: organisational, spatial, functional, and physical. The questions are available in Appendix 5.

The rationale for this simplification is twofold: to reduce complexity for DSS users while still preserving comparability with the full RAF and captivating them to access the RAF App, and to ensure the results are practical and directly useful for the DSS's adaptation planning process.

The results of the assessment are presented in a donut chart distributed in 4 distinct categories based on the metric scores of each selection:

- Not Applicable (not scored)
- Incipient (0–1)
- Progressing (1–2)
- Advanced (2–3)

2.2.2 Resilience Assessment Tool

The RAT is integrated via Application Programming Interface (API) integration with NCSR D's official RAT application[3], providing users with access to the complete tool for evaluating critical infrastructure assets. Unlike the RAF tool questionnaire, which is only partially integrated, the RAT is included in its entirety without disrupting the user experience, thanks to its more compact and streamlined questionnaire. The RAT assesses five core resilience capacities: Anticipatory, Absorptive, Coping, Restorative, and Adaptive, each composed of specific indicators scored on a qualitative scale. The tool calculates an Overall Resilience Index and produces a radar chart to visualise performance across capacities.

Results of the RAT assessment provide a clear picture of critical infrastructure robustness under climate-related stress and help guide future adaptation planning.

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[2] https://icaria.lnec.pt/

[3] http://143.233.159.10:8003/icaria/questionnaire/

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2.3 Adaptation Measures

The ICARIA DSS integrates via API a curated portfolio of 320 adaptation measures from the ICARIA Adaptation Measures Portfolio[4] provided by CETAQUA, covering a wide spectrum of responses to climate-related hazards. These measures constitute the backbone of the Adaptation Measures functionality and are designed to support planning at both the regional and asset-level.

Adaptation Measures address a broad range of climate-related hazards and assets, aligning with case study priorities. Each measure is characterised through a structured, multi-attribute system that describes:

- Its primary benefit (e.g. reducing exposure, vulnerability, or improving governance).
- The main sectors it affects.
- Applicable area types (urban, rural, natural).
- Spatial scale, from building to regional level.
- Measure type, aligned with the EU's adaptation classification (governance, economic, technological, nature-based, knowledge-driven).
- A range of environmental, social, and economic co-benefits.
- Cost levels, based on implementation and maintenance needs.

The complete methodology behind this system is detailed in D3.3 (Guerrero Hidalga & Couce Rodriguez, 2024), which includes the scientific rationale and criteria design. Through this functionality, the ICARIA DSS provides users with an actionable, evidence-based path to building resilient, locally appropriate climate adaptation strategies.

2.4 Climate Projections

Climate projections in ICARIA were produced in Task 1.2 (WP1), using two complementary downscaling approaches:

- **Statistical downscaling (FICLIMA)** – applies observed local weather patterns together with global climate model outputs to create high-resolution, bias-corrected climate projections. This approach was applied to all three case study regions.

- **Dynamical downscaling (AIT)** – uses regional climate models that simulate physical processes in detail, providing more realistic local information, especially in areas with complex terrain such as mountains and islands. This approach was applied in the Salzburg and South Aegean regions.

Together, these methods produced 867 projection layers (506 statistical, 361 dynamical), covering both mean climate variables and extreme indicators such as tropical nights, frost days, dry spells, heatwaves, and heavy rainfall indices. The list of indicators integrated into the DSS is as follows:

[4] https://www.icariastrategies.eu/measures

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For statistical downscaling:

1. CDDx - Maximum dry spell duration
2. EQ- Equatorial nights
3. FD - Frost days (for AMB region and SLZ region)
4. IN - Infernal nights
5. R100 - Days with extreme heavy rain, with a threshold of >100 mm
6. R50 - Days with extreme heavy rain, with a threshold of > 50 mm
7. Ra - Yearly and seasonal rainfall relative change
8. TM - Mean temperatures
9. TNm - Mean minimum temperatures
10. TR - Tropical nights
11. TXm - Mean maximum temperatures

For dynamical downscaling (in addition to the above):

12. R20 - Number of heavy precipitation days, with a threshold of > 20 mm.
13. Rx1 - Maximum rainfall intensity over 1 day
14. Rx5 - Maximum rainfall intensity over 5 days

The DSS includes the full set of projection layers in its Map Viewer. DRAXIS processed and styled the datasets, adding legends and metadata, so that they can be browsed consistently alongside other DSS layers. The rationale for this integration is to:

- Provide bibliographic transparency, showing the climate datasets that underpin ICARIA hazard and impact assessments.
- Allow users to visualise past and future climate conditions for each case study, independent of the hazard maps.
- Enhance usability of the open-access datasets: WP1 climate projections were uploaded by ICARIA partners to Zenodo for transparency and citation. DRAXIS added legends, styling, and metadata so they can be easily explored in the DSS Map Viewer and viewed consistently alongside other functionalities.

For more information on the work underpinning these results, please refer to D1.2 (Paradinas Blázquez & Bügelmayer-Blaschek, 2024), as well as the spatially distributed statistical downscaling dataset provided by Paradinas et al., 2024, and the dynamically downscaled projections generated by Bügelmayer-Blaschek et al., 2025.

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3 DSS Overview

This section outlines the key user groups the ICARIA DSS is designed to support and the real-world use cases it addresses within the context of climate risk and adaptation planning. These users interact with the platform to model and assess climate impacts, evaluate resilience, and identify effective adaptation strategies. The described use cases highlight how the DSS enables streamlined workflows, supports high-quality data integration, and facilitates evidence-based decision-making. To enable this, the platform includes a set of core features in its first release that enhance usability, promote collaboration, and ensure consistent and transparent outcomes throughout the climate adaptation planning process.

3.1 Target Users and Use Cases

The ICARIA DSS is designed to support climate adaptation and resilience decision-makers by helping them assess climate risks, evaluate adaptation options, and communicate results effectively. These users rely on the platform to integrate and interpret complex datasets, improve collaboration, and enable evidence-based decision-making in the context of extreme climate events.

The platform serves two main user groups across real-world applications:

- **Critical Infrastructure Managers & Technicians:** These technical users are responsible for assessing vulnerabilities and planning interventions for critical infrastructure systems exposed to climate hazards. They work with geospatial and asset-level data to conduct risk assessments and interpret resilience scores.
- **Academic Experts / Researchers:** Users in this category work in the field of climate risk analysis. They use the platform to model scenarios, test adaptation strategies, and contribute to scientific and policy-relevant knowledge creation.

In addition, a broader set of secondary users engages with the platform, including:

- *Regional and Local Authorities* such as Ministries of Environment, Urban Planning and Development Companies, and Civil Protection Agencies.
- *Asset and Service Managers*, including Utility Providers, Public Infrastructure Operators, and Resilience Consultants or Engineering Firms.

The ICARIA DSS supports three core functional use cases that align with these users' needs:

1. **Analyse climate risks and impacts on strategic infrastructure and vulnerable regions:** The platform provides users with a structured workflow to input hazard, exposure, and vulnerability data under specific scenarios. This enables targeted risk and impact assessments across different assets and geographies.
2. **Assess resilience capacity using integrated tools to support data-driven adaptation planning:** The platform integrates two resilience assessment methods - one focused on governance and planning (RAF) and another on critical infrastructure/specific metrics (RAT). These tools automate scoring, visualise results, and help identify resilience gaps.
3. **Evaluate adaptation options through comparison and prioritisation:** Users can browse, create, compare, and prioritise adaptation measures linked to specific hazards and impact contexts. A

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built-in prioritisation tool helps guide decision-making using cost, hazard type, and co-benefit indicators.

The abovementioned categories and cases were presented to the Horizon Results Booster expert, assigned to the ICARIA project, and were validated as representative user profiles aligned with the intended scope and functionality of the DSS.

3.2 List of Functionalities

Version 1 of the ICARIA DSS offers a suite of integrated features designed to support reliable and transparent climate risk assessments and planning:

- Project and scenario management via a dedicated Project Manager interface.
- Step-by-step risk/impact assessment workflows based on user-submitted data (hazard, exposure, vulnerability), supporting assessments for floods on properties, wildfires on natural areas and windstorms on electrical infrastructure.
- Dual Resilience Assessment tools: RAF (holistic assessment) and RAT (critical infrastructure-focused).
- Portfolio of Adaptation Measures with filters, creation, comparison, and prioritisation features.
- Interactive Map Viewer supporting base map switching, feature information, measurement tools, and scenario comparison.
- Centralised results viewer for visualising outputs and comparing results across scenarios.
- Exportable and shareable outputs (screenshots, charts, and summaries).
- Role-based access control and user profile management.
- In-app guidance and structured workflows to reduce user error and increase consistency.

The following chapter showcases all the above-listed functionalities.

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4 DSS interface

4.1 Navigation Structure

Once users log in, they are redirected to the Project Manager, which offers an overview of all projects they have created or that have been shared with them. From there, users can easily navigate through the platform using the "Jump to" button located in the header (Figure 15). This provides quick access to all core functional areas of the DSS, including risk and impact assessments, resilience evaluation, adaptation planning, and result visualisation. The tabs available through this menu include:

- **Project Manager (Risk/Impact Assessment)**
- **Resilience Assessment**
- **Adaptation Measures**
- **Map Viewer**
- **Results**

Each section is designed to support a specific phase of the decision-making process, while ensuring a consistent and user-friendly experience across workflows.

Users can also access supporting materials, including the project's About page and a comprehensive User Guide that explains all system workflows in detail.

Additionally, users can manage their account settings and securely end their session by selecting the log out option from the header.

Figure 16 presents the UI flow diagram of the DSS tool, illustrating how the key pages and features are interconnected.

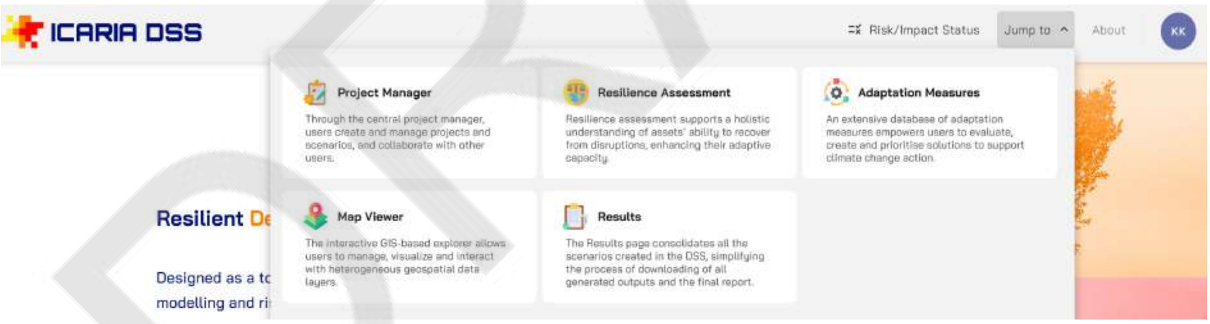

Figure 15: Jump to navigation.

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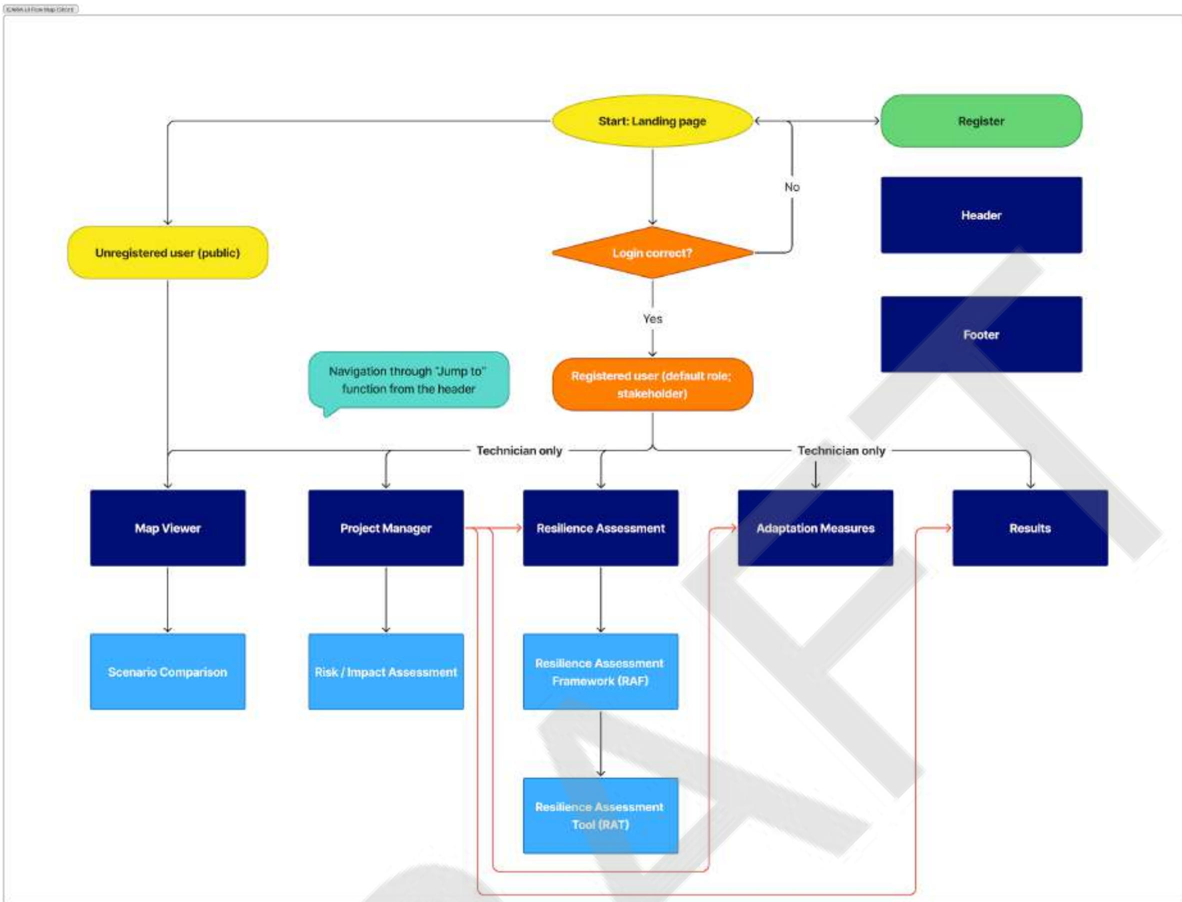

Figure 16: UI Flow Diagram - Main navigation.

The main navigation (black connectors) is performed through the "Jump to" option in the header. However, the Project Manager also provides access to certain DDS functionalities directly from its interface, without requiring the use of "Jump to" (red connectors).

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4.2 Functionalities Walkthrough

This sub-section aims to provide a concise, yet accurate description of each feature included in the DSS. The complete User Guide can be accessed from Appendix 6.

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

Unregistered users are directed to the landing page (Figures 17), which provides an overview of the platform, detailing the challenges it addresses and showcasing its key features and methodological approach. On the landing page, users can provide their feedback about the DSS via the footer (Figure 18), contact the DRAXIS team for any issues occur (Figure 19), learn more about the DSS's mission (Figure 20), sign in or create an account (Figure 21) to access the full functionality of the platform.

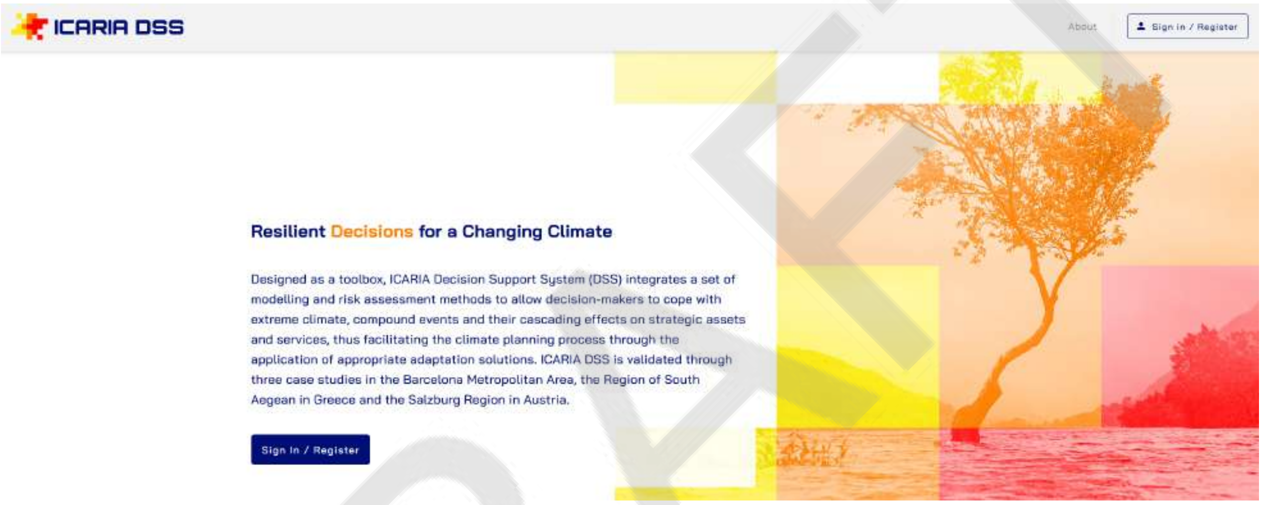

Figure 17: Landing page.

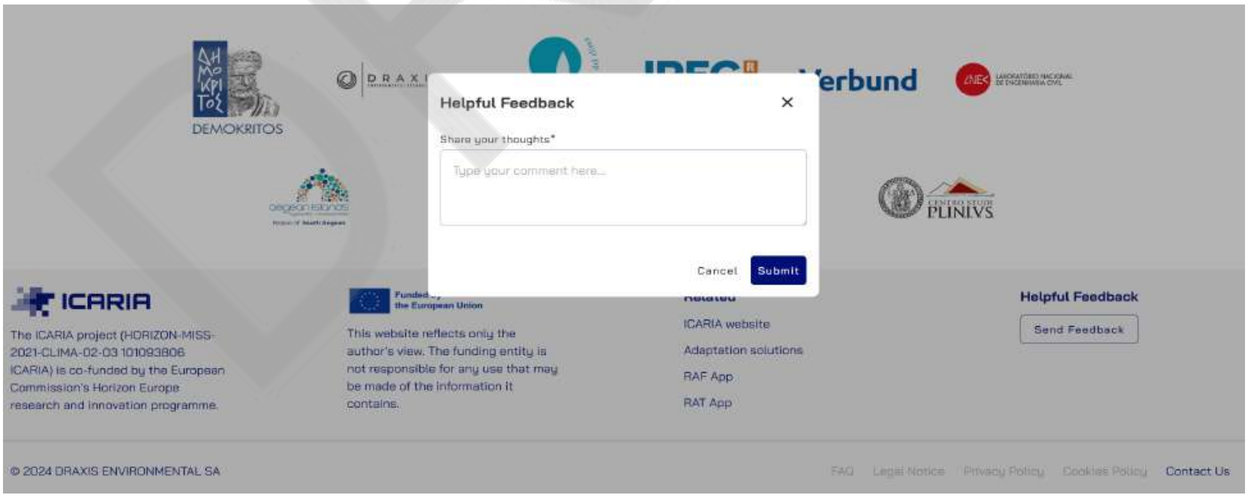

Figure 18: Helpful Feedback.

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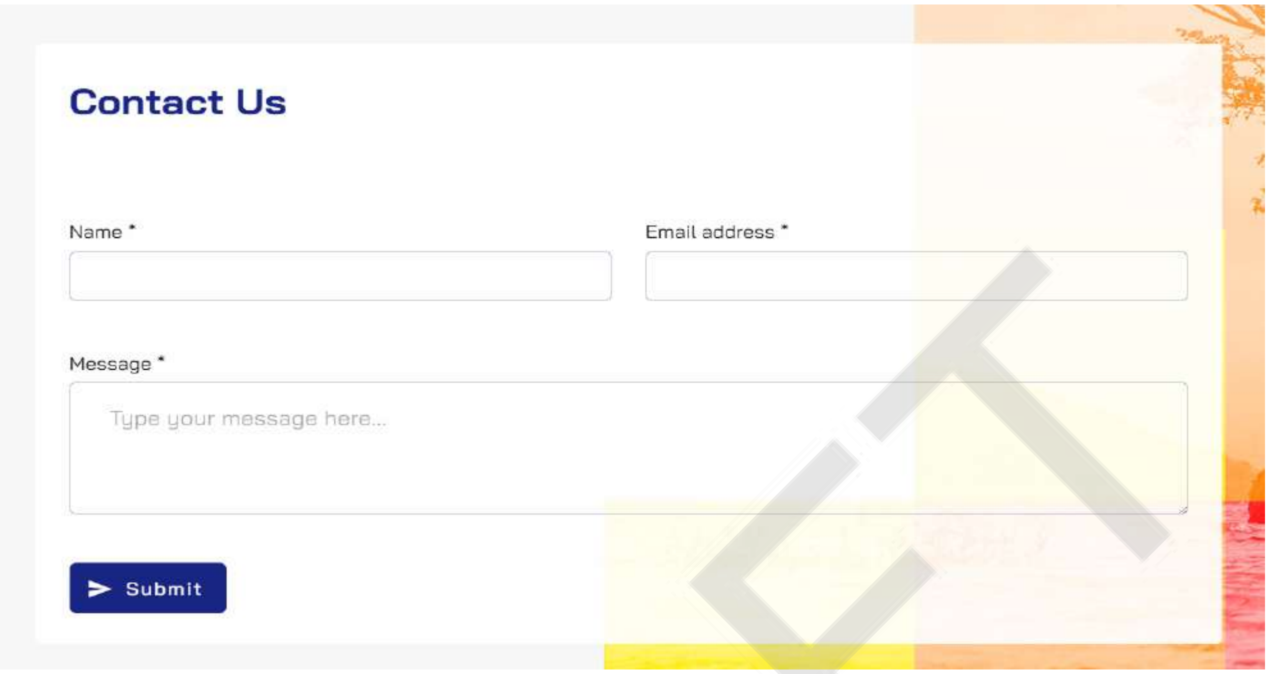

Figure 19: Contact page.

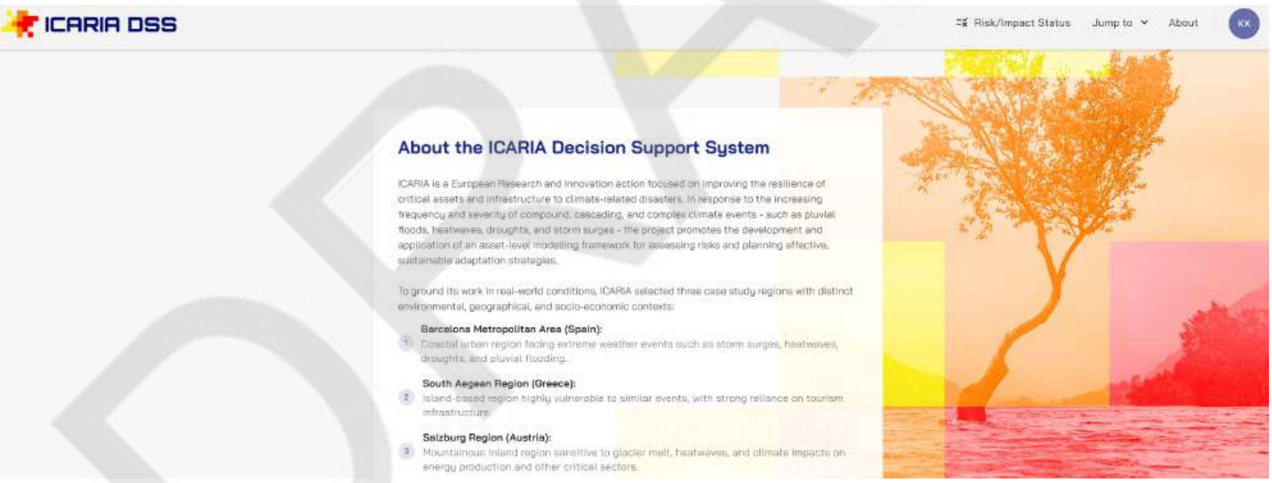

Figure 20: About page.

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Figure 21: Sign In - Sign Up pages.

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4.2.1 Project Manager

Upon entering the DSS, the user is directed to the Project Manager (Figure 22). The Project Manager serves as the user's central workspace for organising and managing projects and scenarios. Users can create new projects (Figure 23), or view, edit and share existing ones (Figures 24-27).

It is organised in 2 tabs:

- My Projects: Displays all projects created by the user.
- Shared Measures: Lists the projects that have been shared with the user by others DSS members.

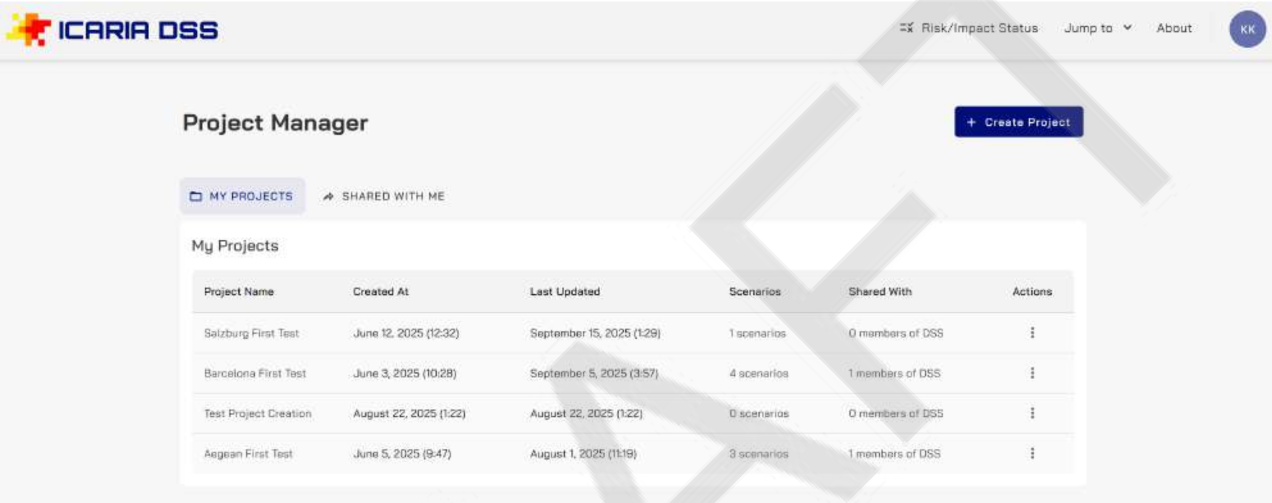

Figure 22: Project Manager.

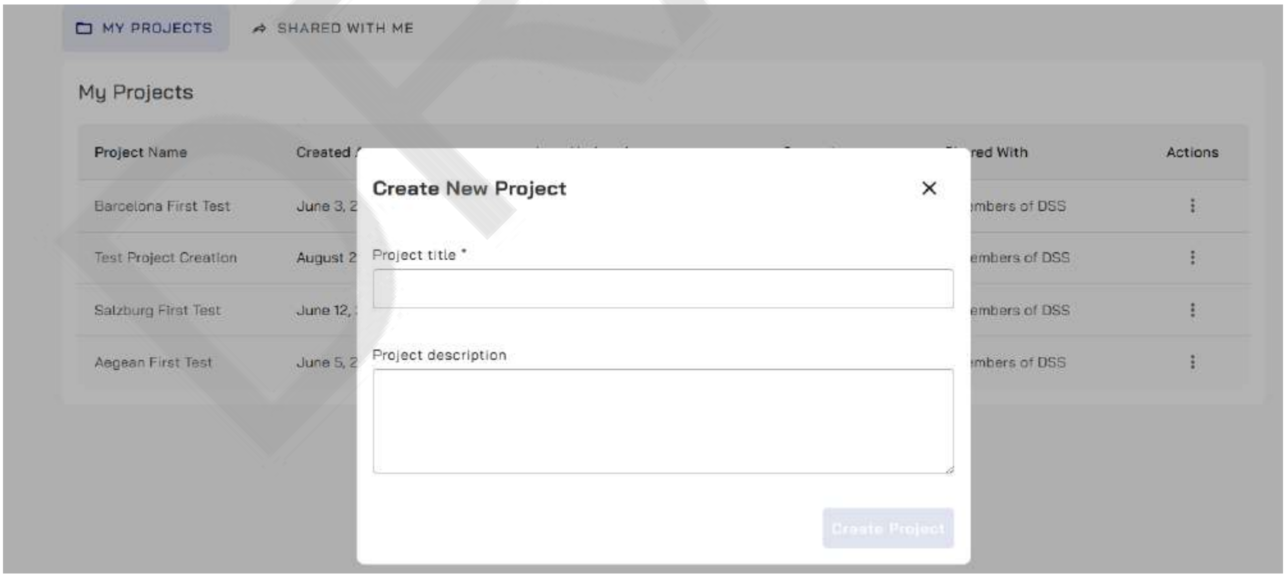

Figure 23: Project Manager - Creation of a project.

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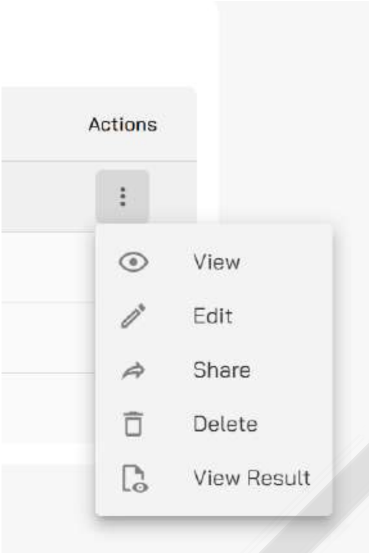

Figure 24: Project Manager - Actions column.

Within each project, users can create or manage multiple scenarios and carry out 3 distinct activities: assign adaptation measures, initiate resilience assessments, or perform risk and impact analyses. They can also review previous results, delete scenarios, and access comprehensive reports summarising the results of all scenarios within a project. For each scenario, users are required to select a scenario type, climate hazard, risk receptor, and country pertaining to the analysis they wish to conduct.

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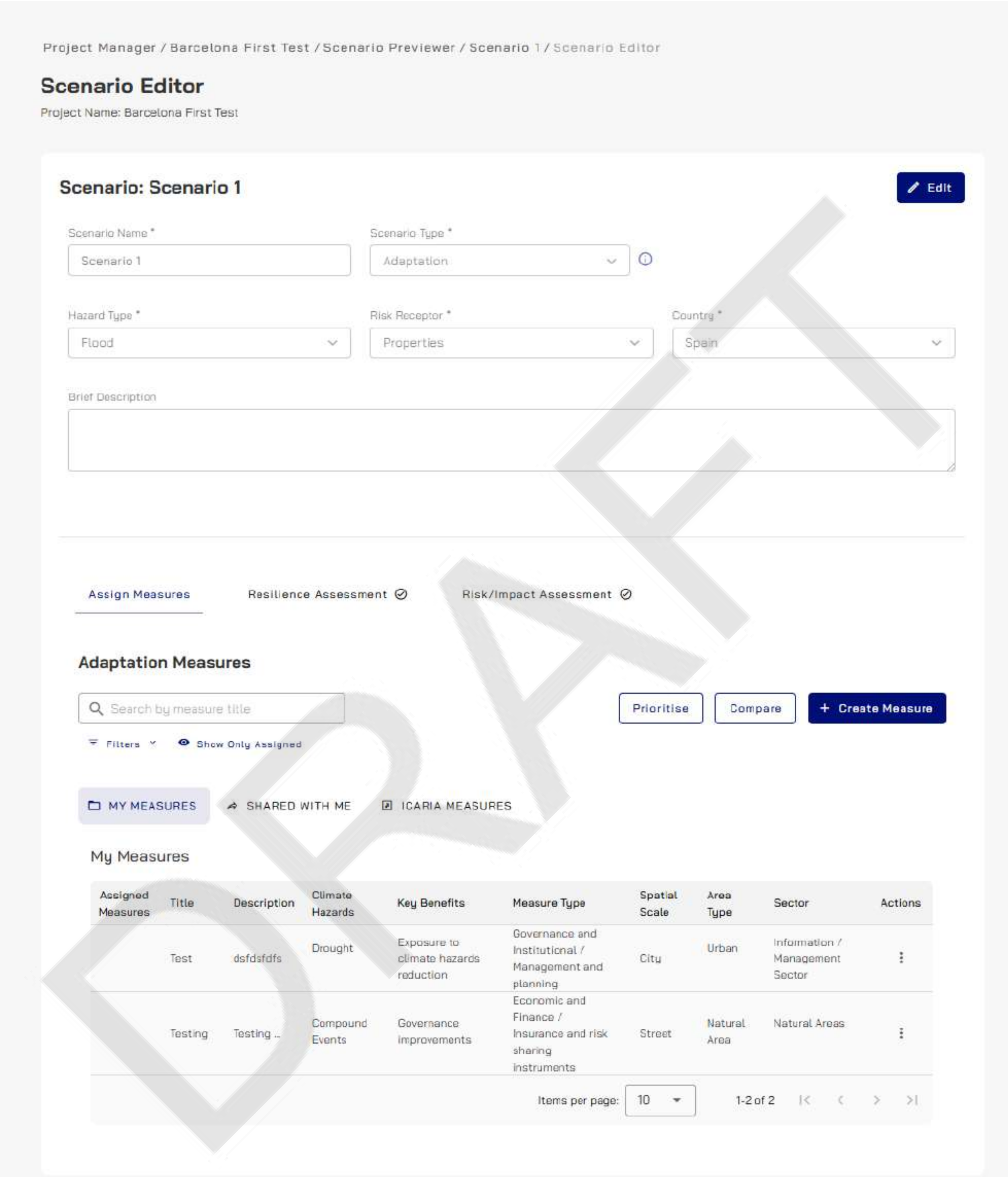

Figure 25: Project Manager - Scenario editing.

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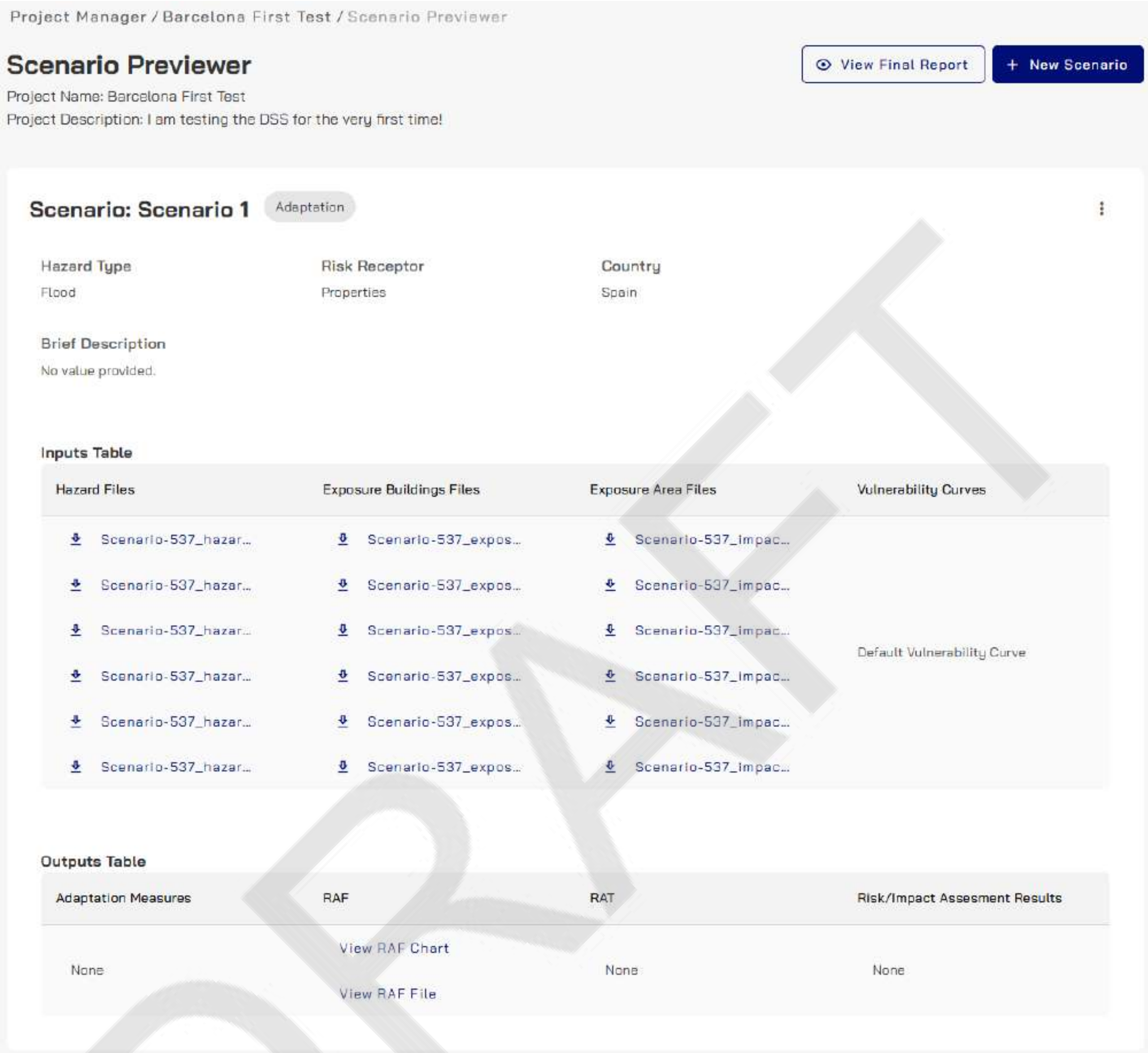

Figure 26: Project Manager - Scenario preview.

In the Scenario preview, users can view the complete list of inputs and outputs of each scenario. Each file can be downloaded and stored locally. Further details are provided in the following subsection.

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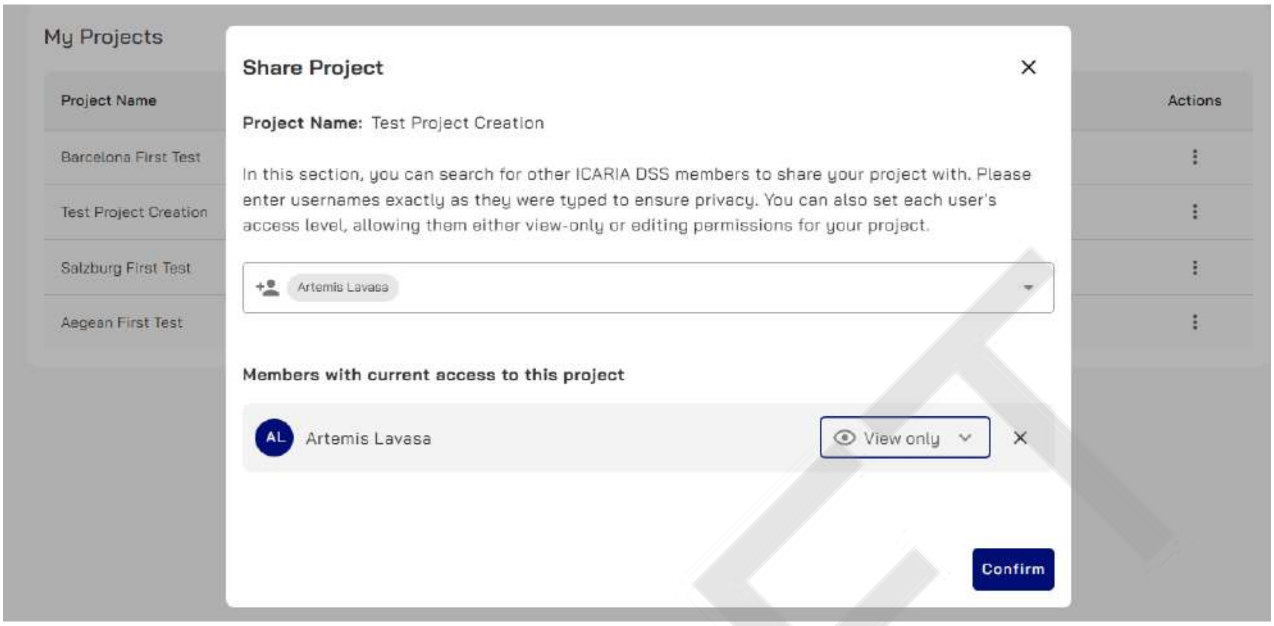

Figure 27: Project Manager - Sharing a project.

Users can share their projects with other DSS members (registered users) while controlling access levels, granting either view-only rights or editing permissions that allow collaborators to modify the shared project as needed. Upon sharing a project with a DSS member, all the created scenarios and results generated within that project are shared, including impact assessment results, created adaptation measures and resilience results.

Lastly, users can view the complete results of their projects and scenarios. For further details, see Section 4.2.6.

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4.2.2 Risk/Impact Assessment

Risk/Impact Assessment is accessible within the Project Manager after creating a scenario (Figure 28). It allows users to evaluate potential climate-related impacts within each scenario through a streamlined three-step process: uploading hazard data, exposure data, and vulnerability curves. For the vulnerability curves, users can either select the default ones provided by the system (adjusted per hazard type and risk receptor case) or insert their custom curves based on their needs.

Currently, this functionality supports the analysis of impacts of floods on properties, wildfires on natural areas and windstorms on electricity towers.

While the system processes the uploaded inputs, users can continue working on other scenarios and monitor progress via the Risk/Impact Status panel in the header. This triggers a floating and moveable status widget at the top-left of the screen, providing real-time updates on the status of each assessment.

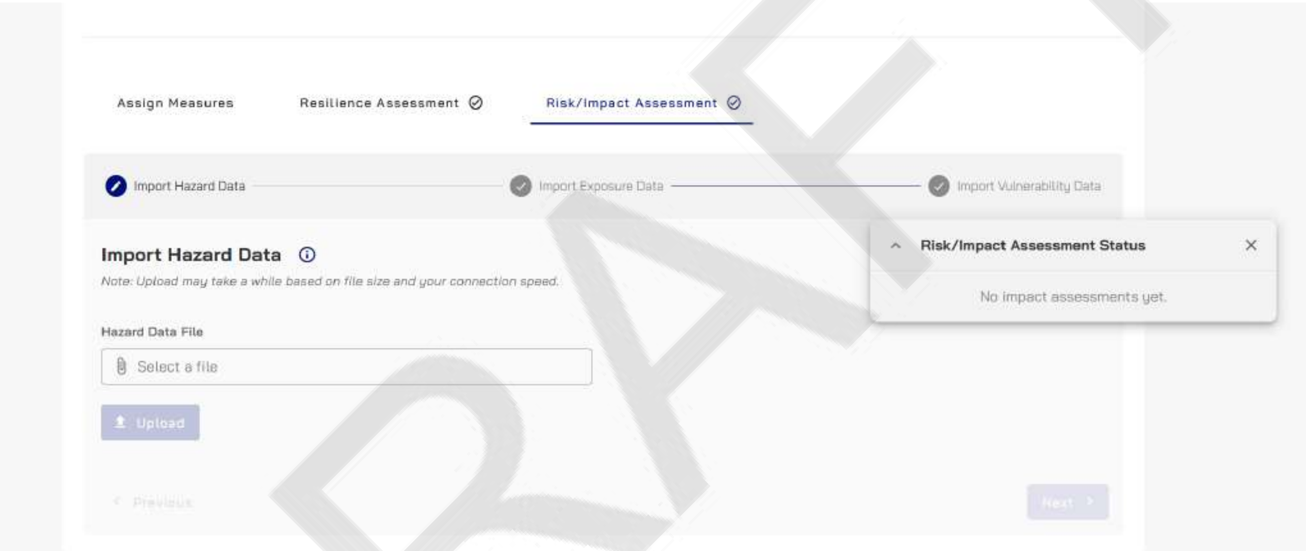

Figure 28: Risk/Impact Assessment.

Users can be informed on the kind of data that the system expects them to upload (formats, structures, required elements) in each step (hazard, exposure, vulnerability), depending on the selected hazard and risk receptor pair, by pressing the info icon next to the title of the step (Figure 29). The system validates each input and provides response to notify the user if the data was successfully validated.

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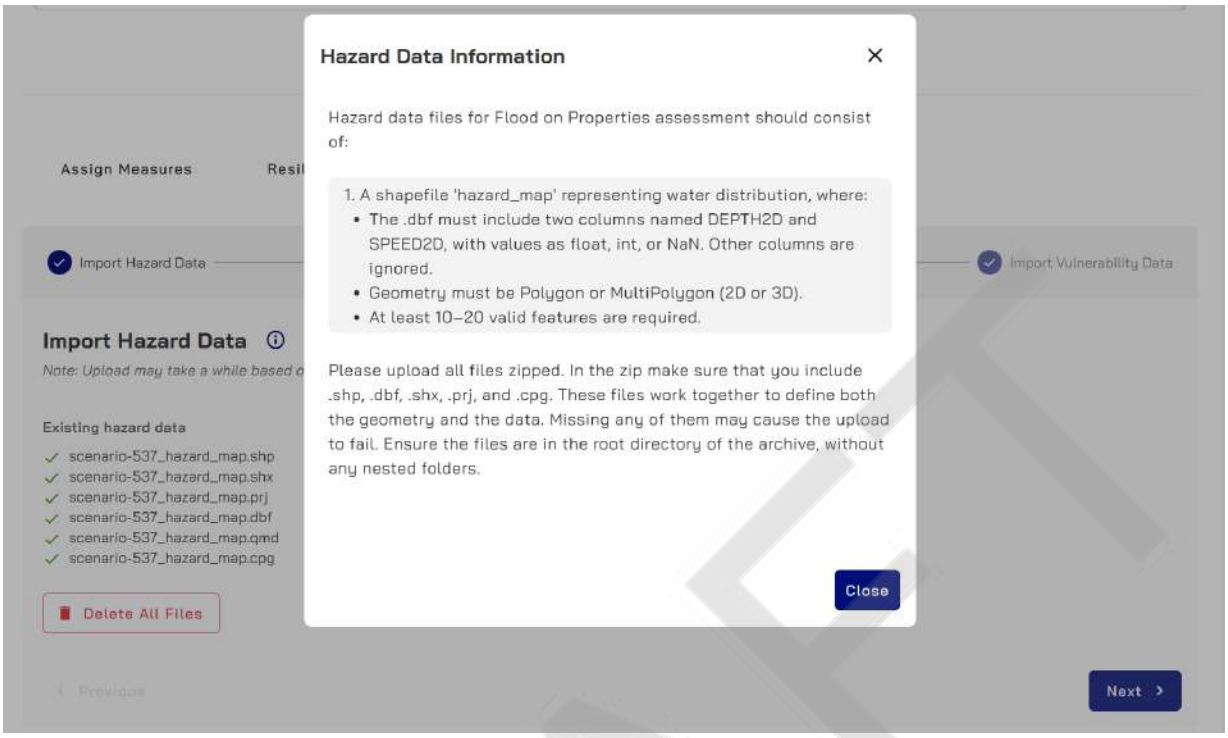

Figure 29: Risk/Impact Assessment - Guidance for Hazard Data.

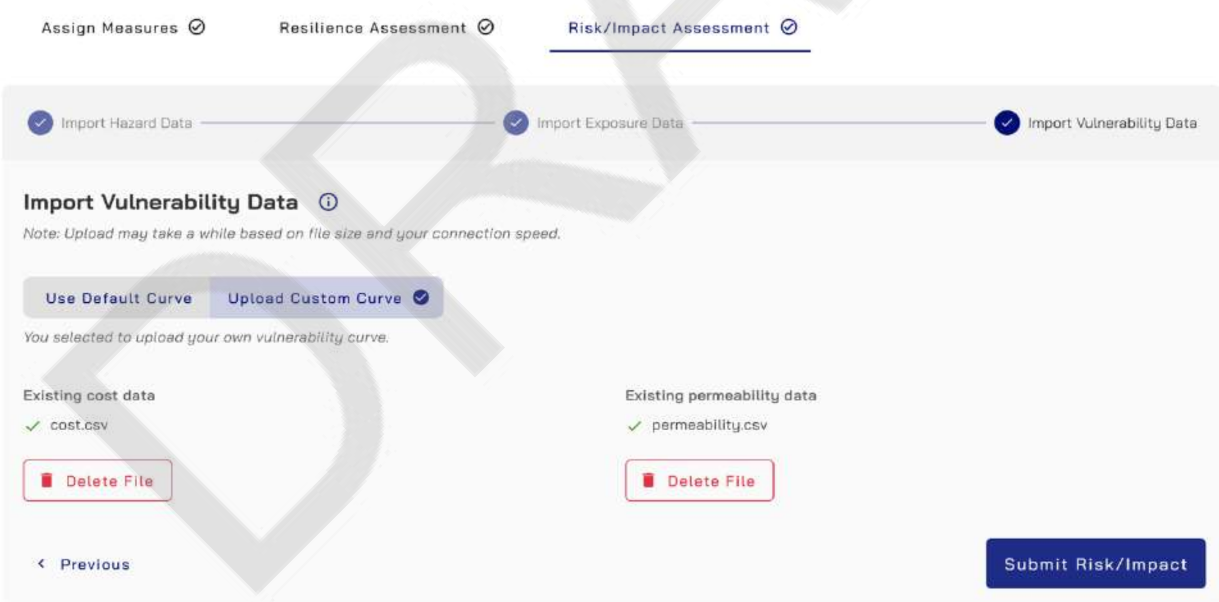

Figure 30: Risk/Impact Assessment - Submission of an Assessment.

Once completed, the results become available via the Map Viewer as geospatial layers for visualisation and interpretation. These layers are listed in the "My Layers" catalogue. For further details, see Figure 52 in 4.2.5.

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By clicking on a specific point on a layer, users can view its attribute table (Figure 31), which includes the results of the impact assessment calculation.

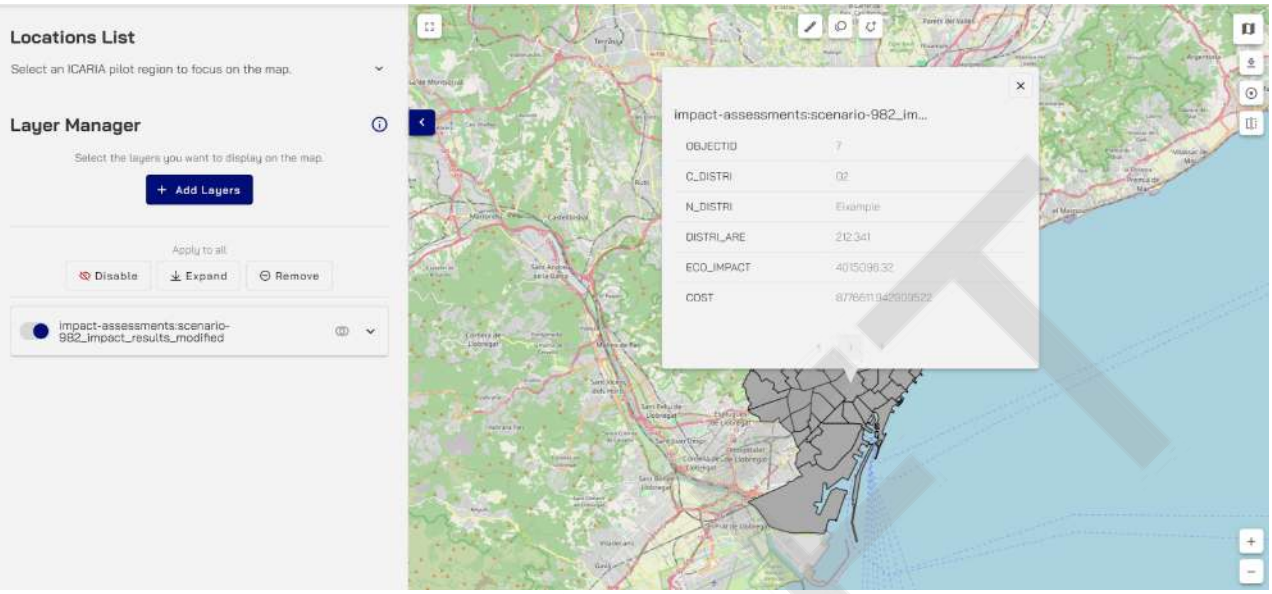

Figure 31: Risk/Impact Assessment - Results.

4.2.3 Resilience Assessment

Resilience Assessment is accessible via the “Jump to” button in the header or from inside a scenario in the Project Manager (as seen in Figure 25). The main menu displays two options: The RAF and the RAT (Figure 32).

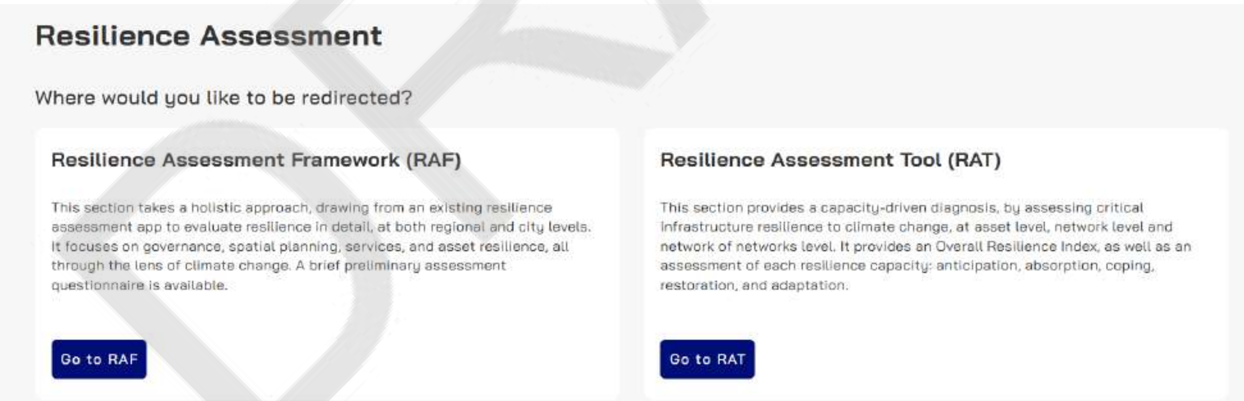

Figure 32: Resilience Assessment options.

The RAF is organised in 2 tabs (Figure 33):

- My Results: Displays all assessments created by the user.
- Shared Results: Lists the assessments that have been shared with the user by others DSS members.

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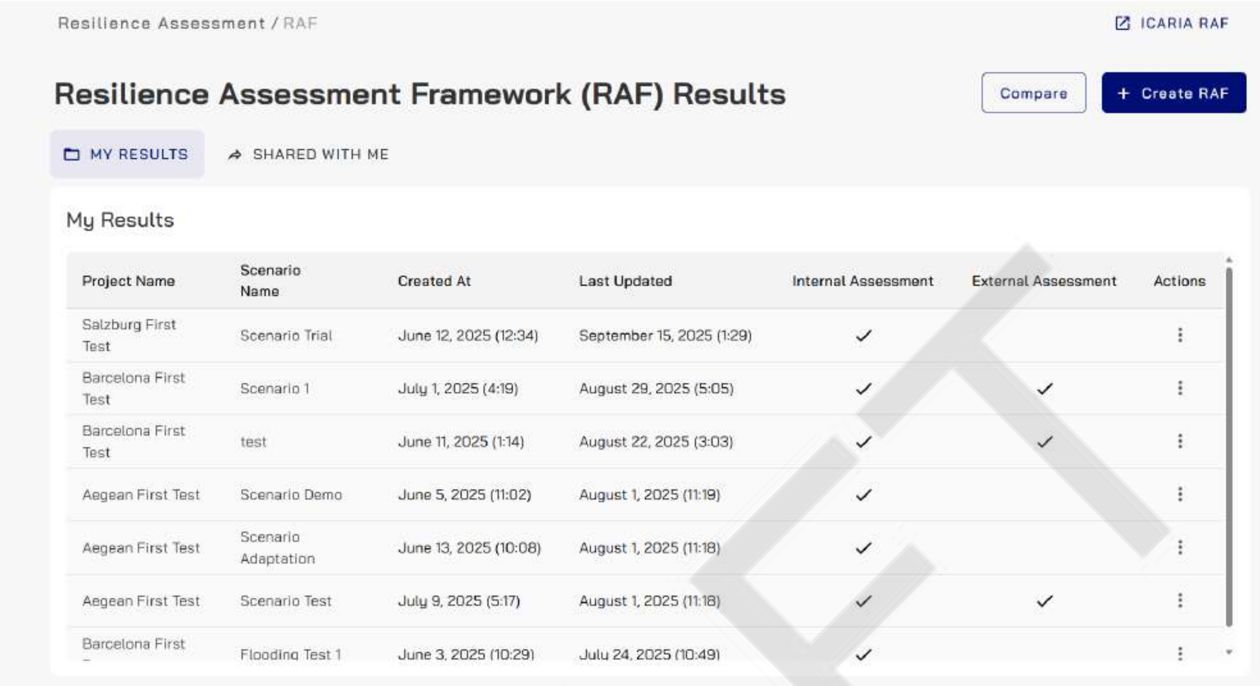

Figure 33: Resilience Assessment - RAF.

In the RAF, users can create new assessments directly within the DSS (by selecting a project and scenario) or import a summary report of external ones (which were already completed in the LNEC application), as seen in Figure 34. They can also compare two past assessments side-by-side (Figure 35), manage existing ones (Figures 36-38), or create clones of other scenarios (Figure 39).

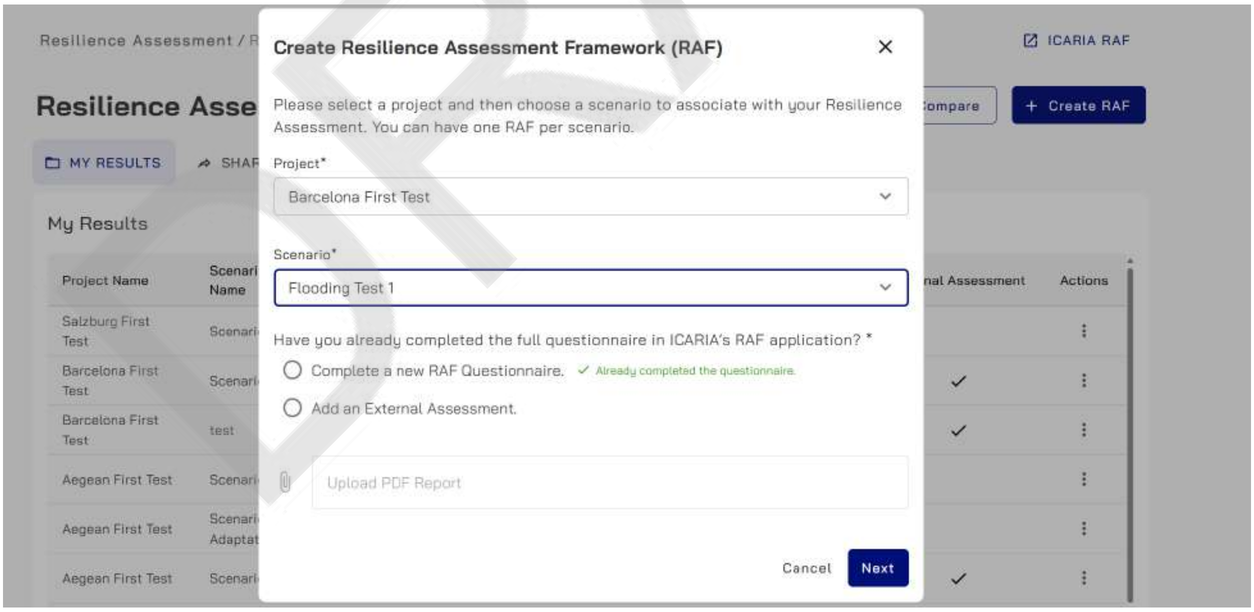

Figure 34: Resilience Assessment - RAF assessment creation.

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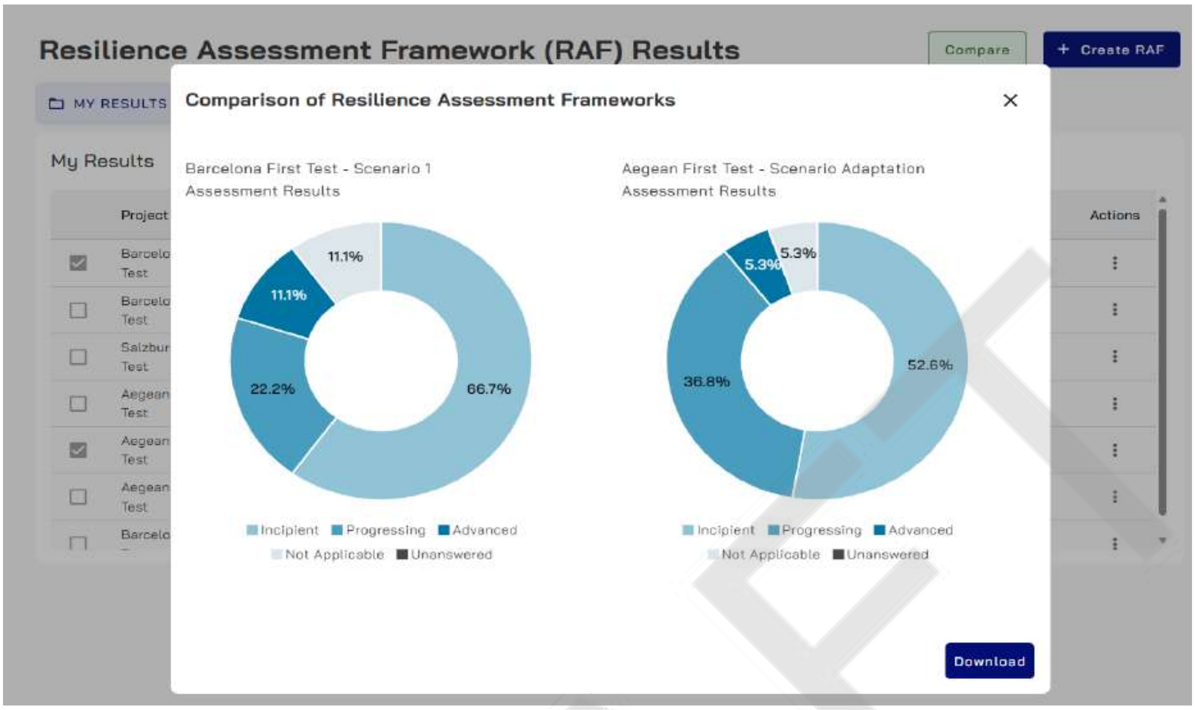

Figure 35: Resilience Assessment - RAF comparison.

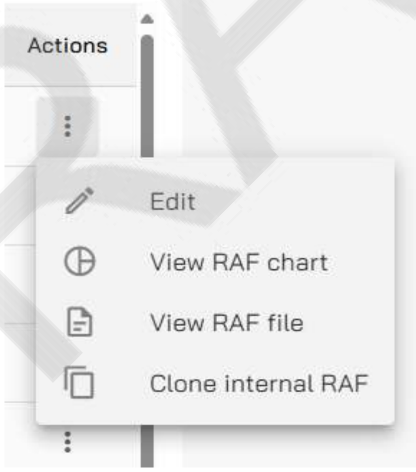

Figure 36: Resilience Assessment - RAF actions column.

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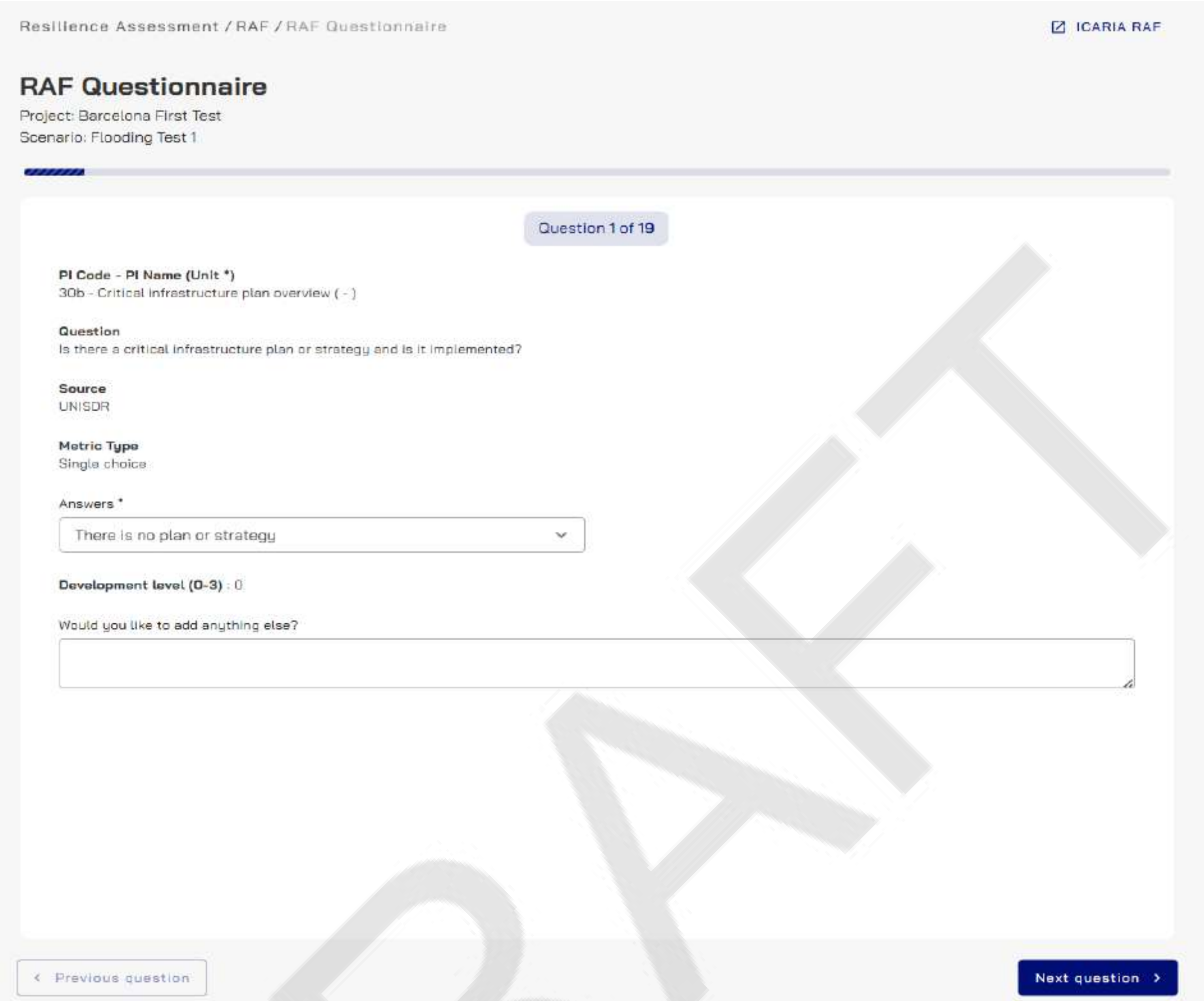

Figure 37: Resilience Assessment - RAF questionnaire.

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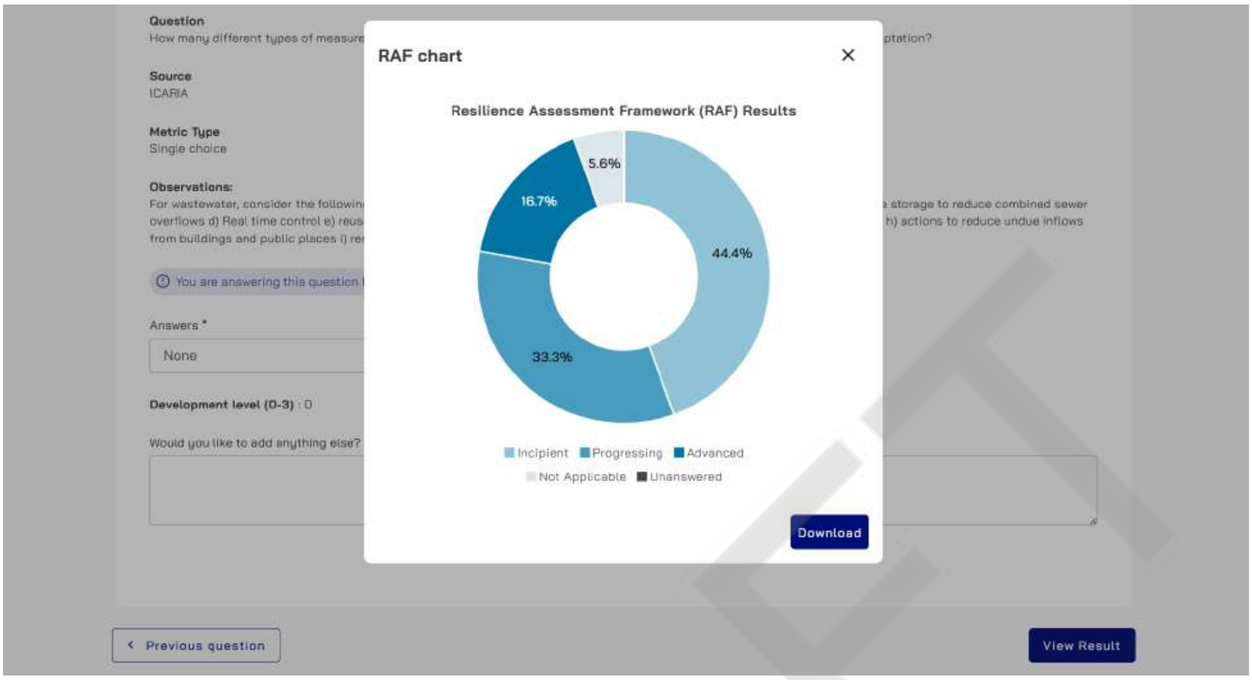

Figure 38: Resilience Assessment - RAF results.

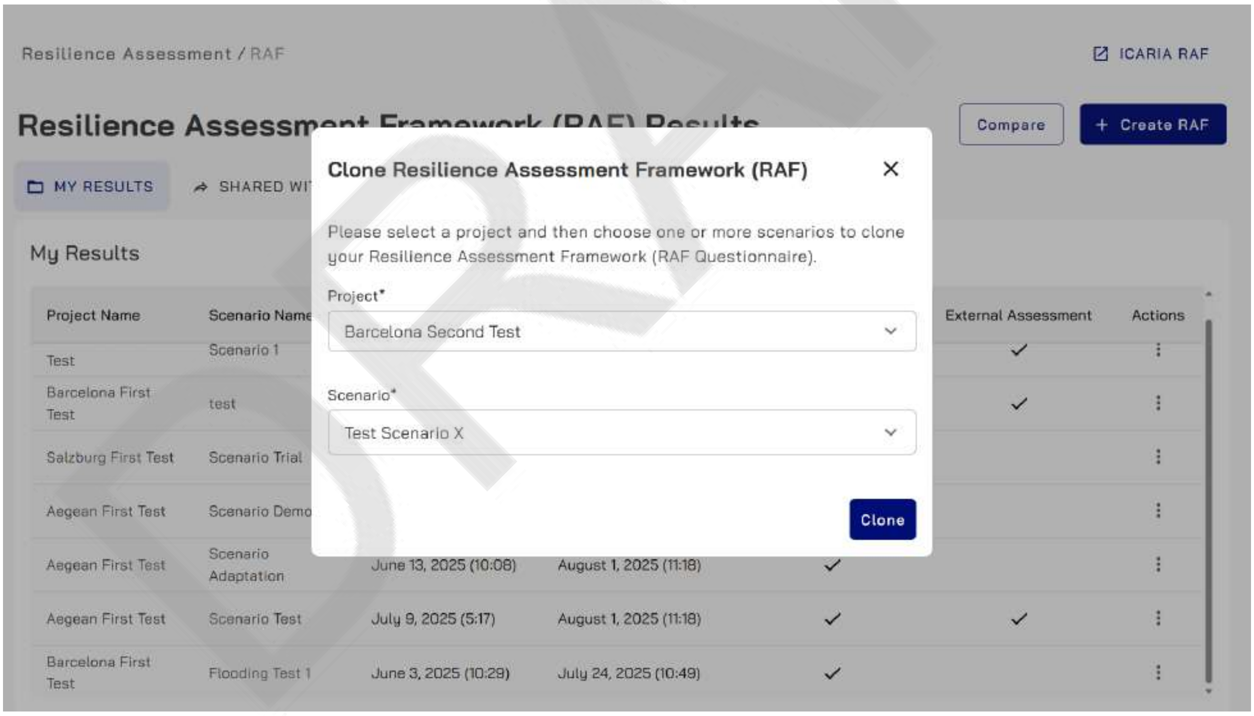

Figure 39: Resilience Assessment - Clone assessment.

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In the RAT, users select a project and scenario (Figure 40) and then respond to a targeted series of yes/no and multi-select questions (Figure 41). Upon completion, the tool generates a resilience index score and a radar chart that visually presents the results across the five core resilience capacities (mentioned in 2.2.2), providing a clear overview of strengths and vulnerabilities regarding critical infrastructure.

If there is an already existing assessment for the selected case, then the results will be immediately loaded into the screen, as depicted in Figure 42.

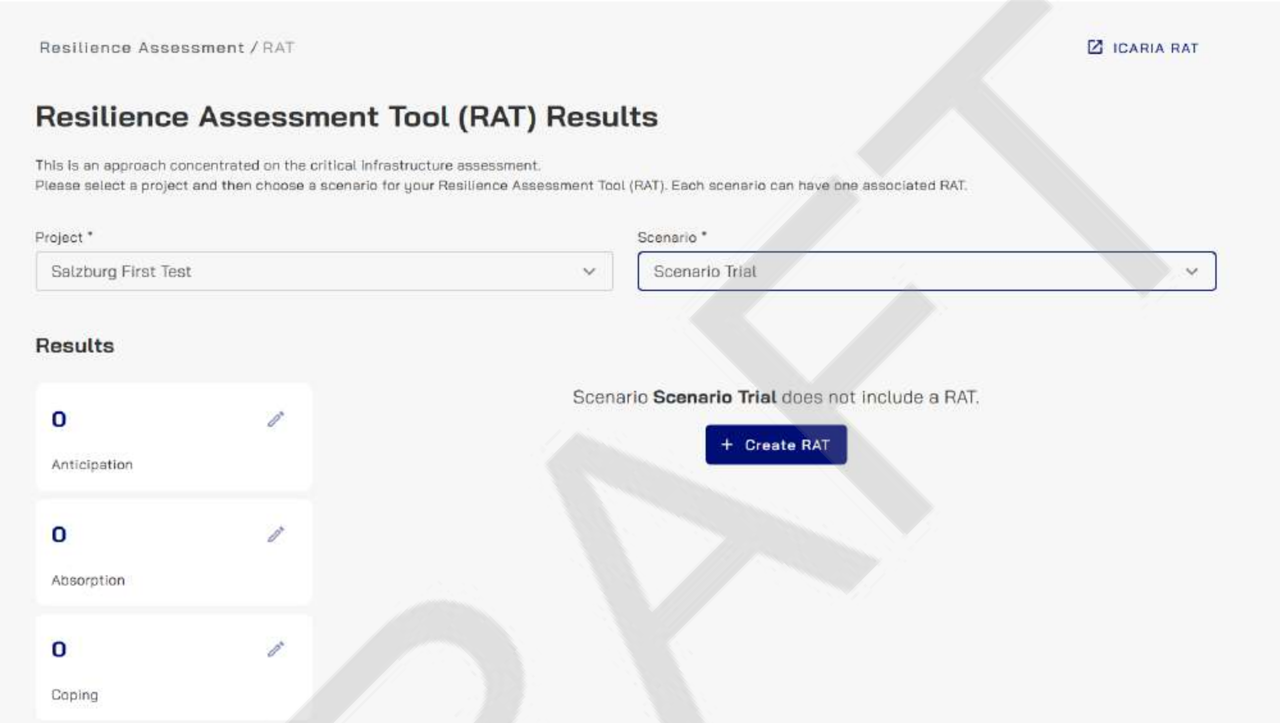

Figure 40: Resilience Assessment - RAT.

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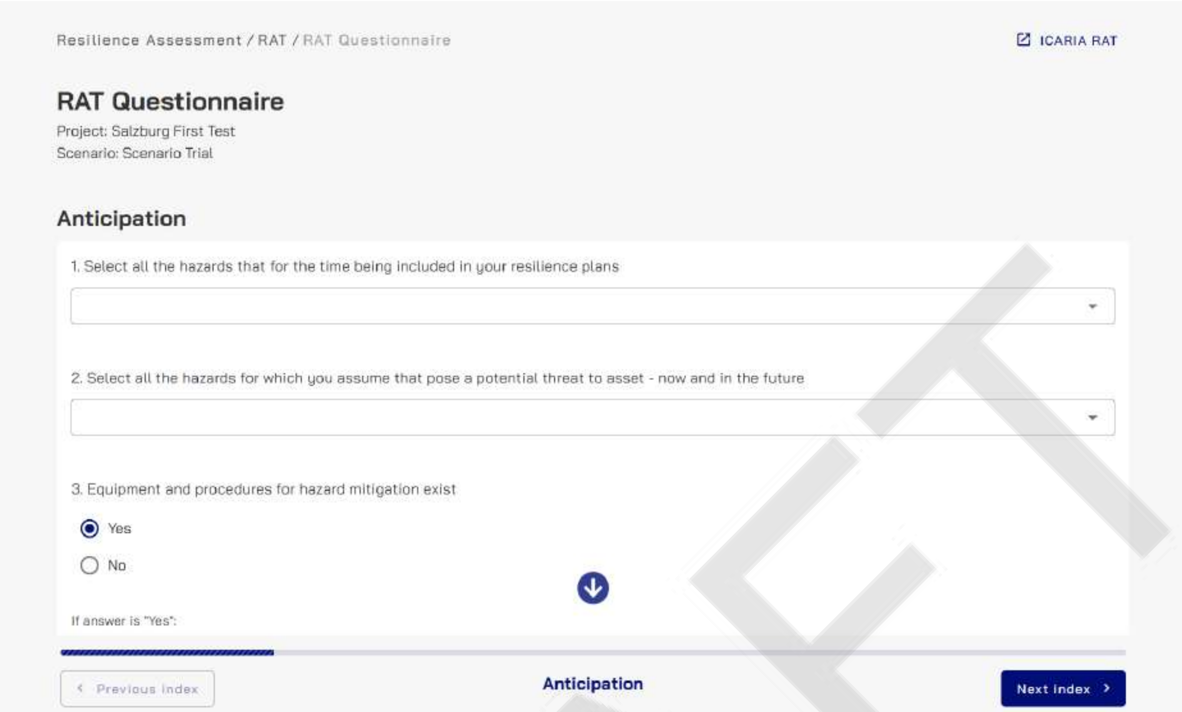

Figure 41: Resilience Assessment - RAT Questionnaire.

Figure 42: Resilience Assessment - RAT Results.

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4.2.4 Adaptation Measures

Adaptation Measures, accessible in the same way as Resilience Assessment, provides users with access to a structured portfolio of measures aimed at mitigating the risks and impacts of climate-related disasters. This functionality provides access to three lists of measures, organised into separate tabs (Figure 43):

- My Measures: Displays all adaptation measures created by the user locally on the DSS.
- Shared Measures: Lists the measures that have been shared with the user by other DSS members.
- ICARIA Measures: Features a selection of the measures derived from ICARIA's Adaptation Measures Portfolio.

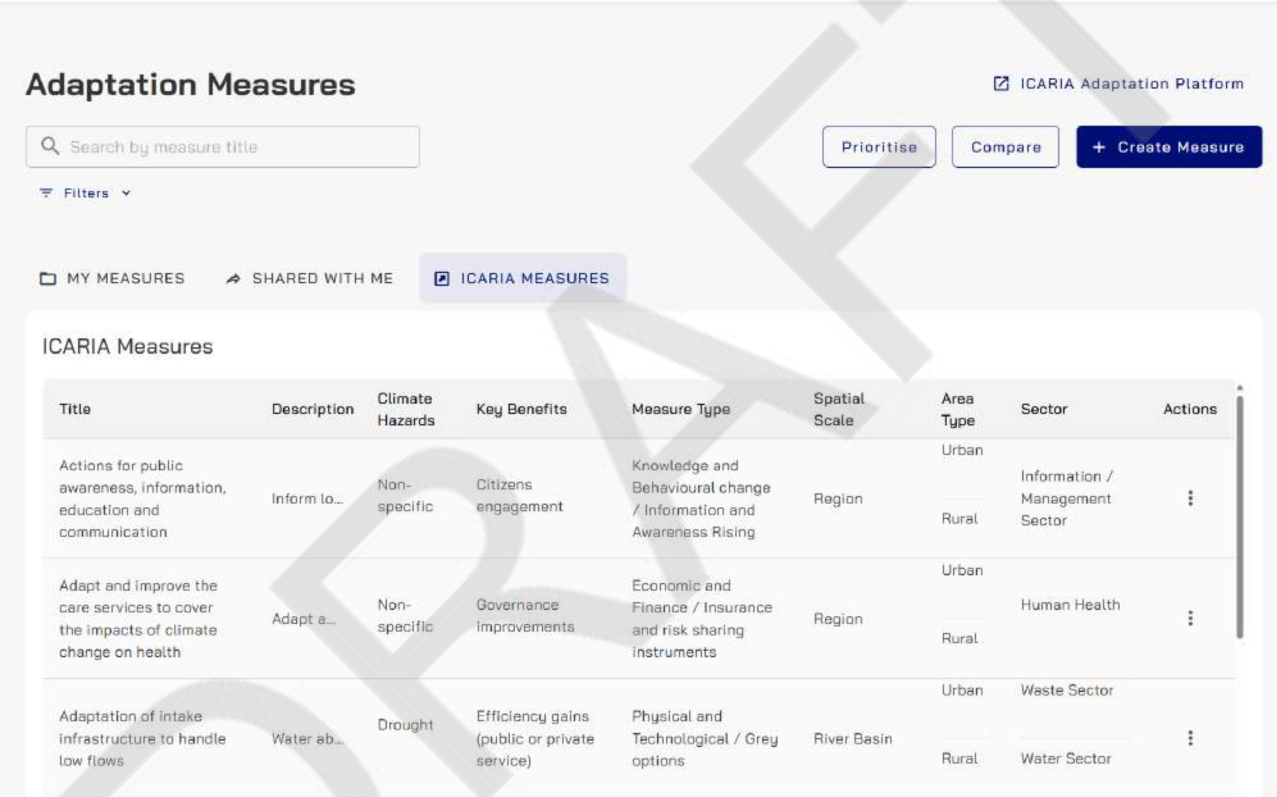

Figure 43: Adaptation Measures.

Users can create new measures from scratch following the same characterisation template defined in the ICARIA Adaptation Measures Portfolio (Figure 44), compare two existing measures side-by-side (Figure 45), or prioritise them based on selected attributes and co-benefit criteria such as environmental, social, and economic impacts (Figure 46). This prioritisation supports evidence-based decision-making tailored to local needs.

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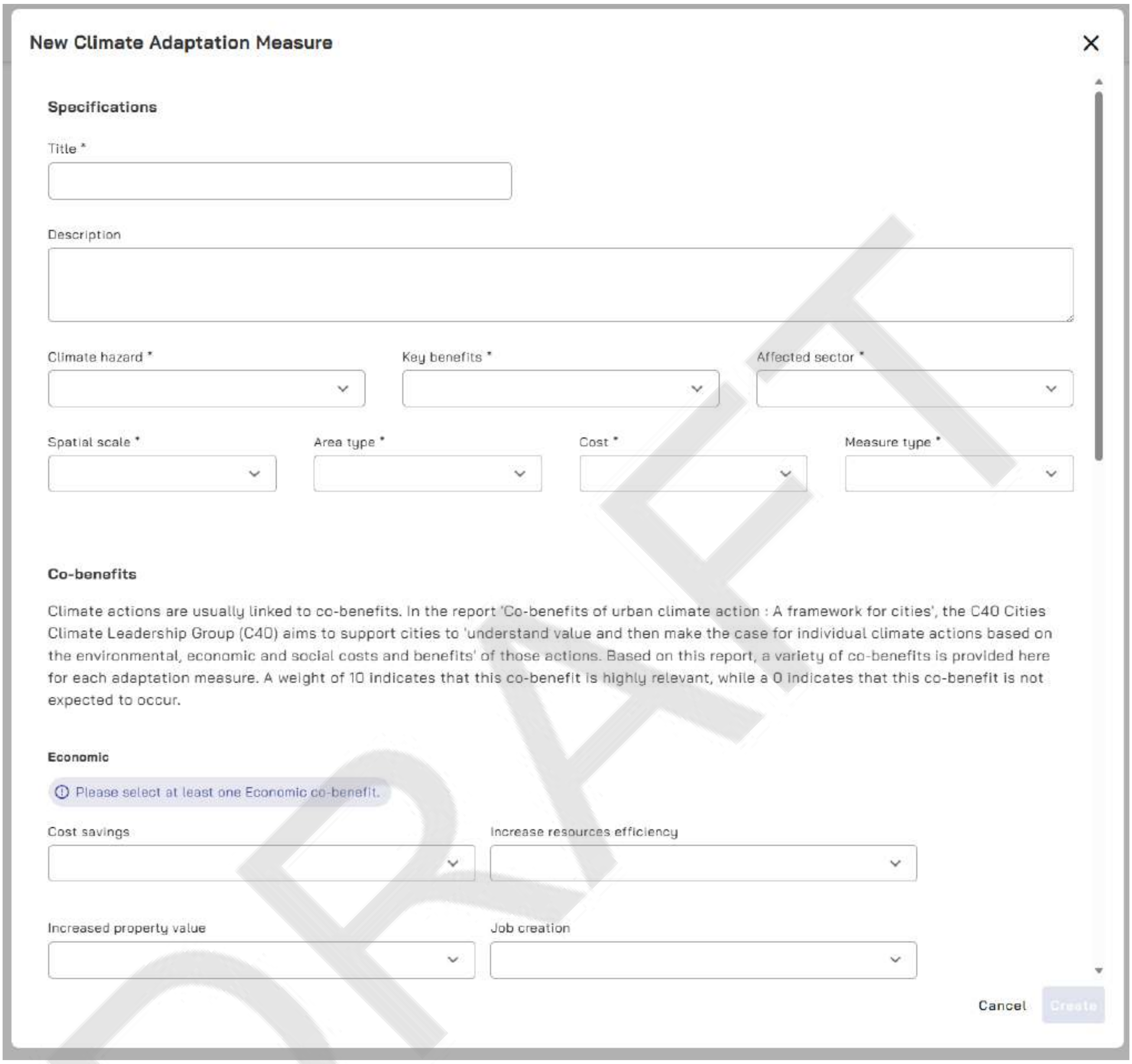

Figure 44: Adaptation Measures - Creation of a measure.

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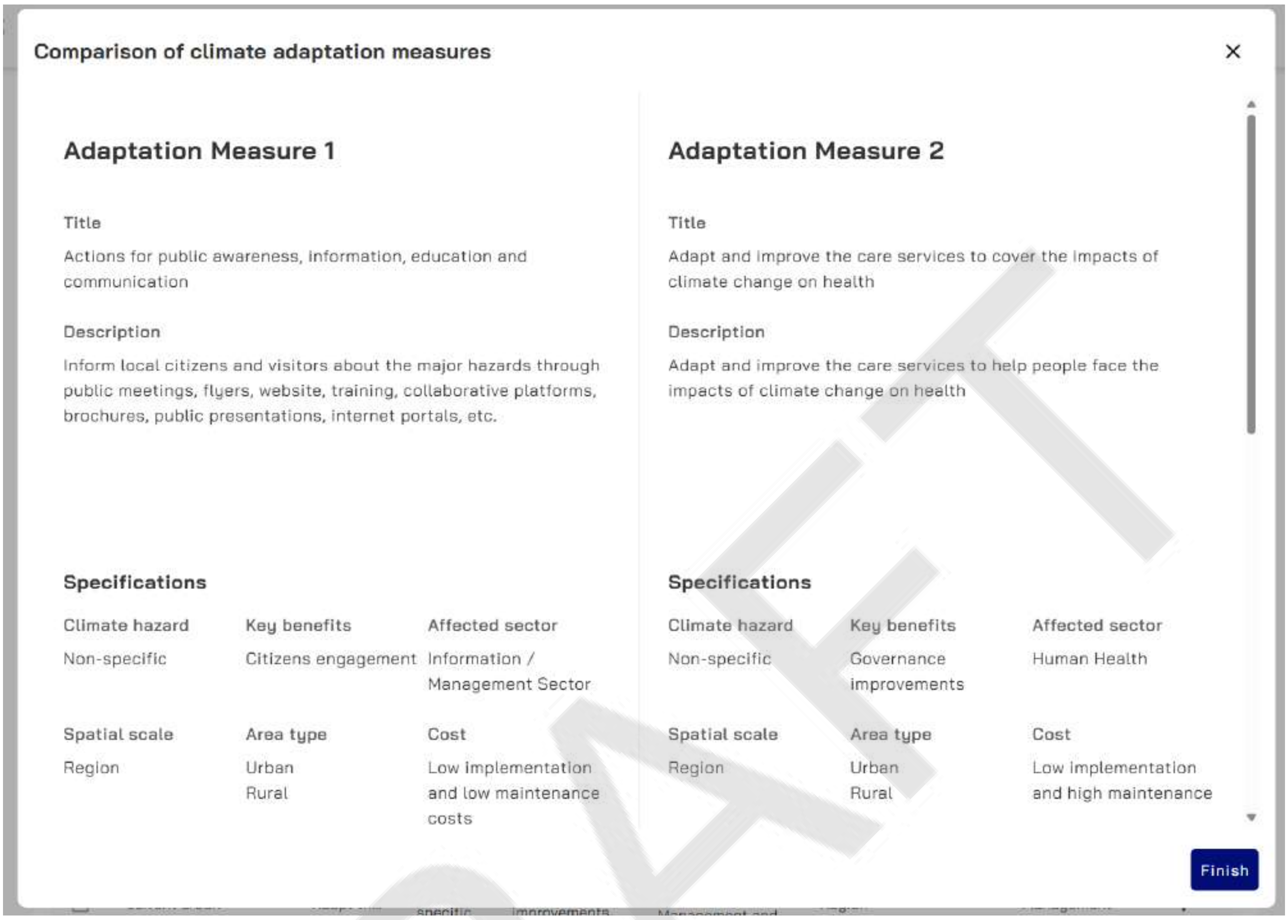

Figure 45: Adaptation Measures - Comparison of two measures.

In this multi-criteria approach, the weights assigned to co-benefits as well as the selection of a climate hazard and cost category at the same time allow the DSS to search the full database of solutions and propose the most appropriate ones (in order of relevancy) based on the criteria set by the user.

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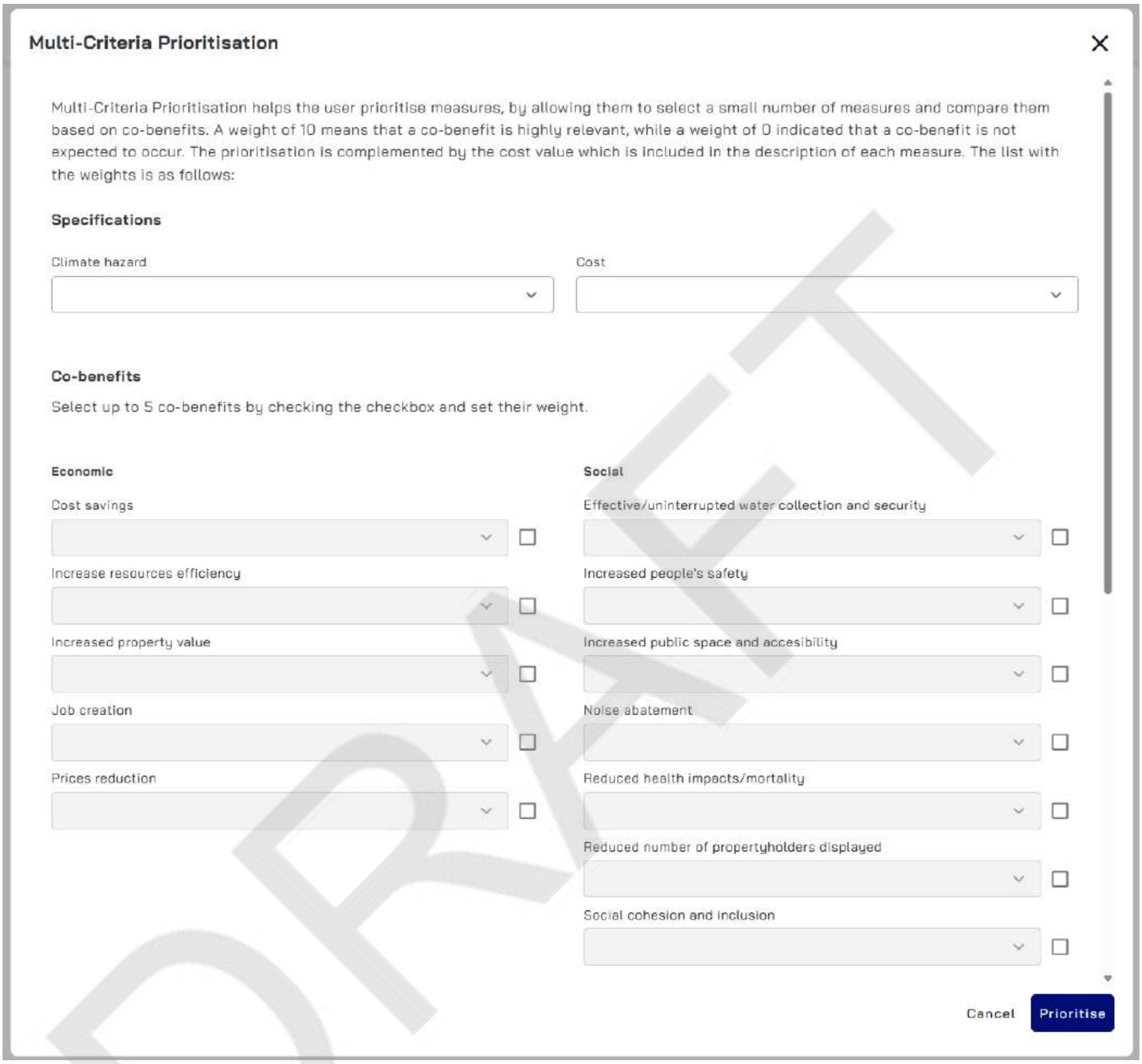

Figure 46: Adaptation Measures - Multi-Criteria prioritisation.

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Each measure can be reviewed in detail and easily assigned to a specific project or scenario, by selecting the relevant option from the actions column (Figures 47-48).

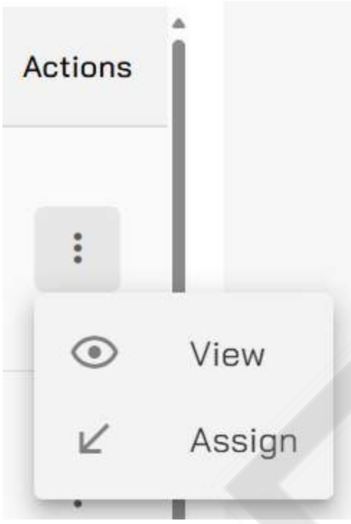

Figure 47: Adaptation Measures - Actions column.

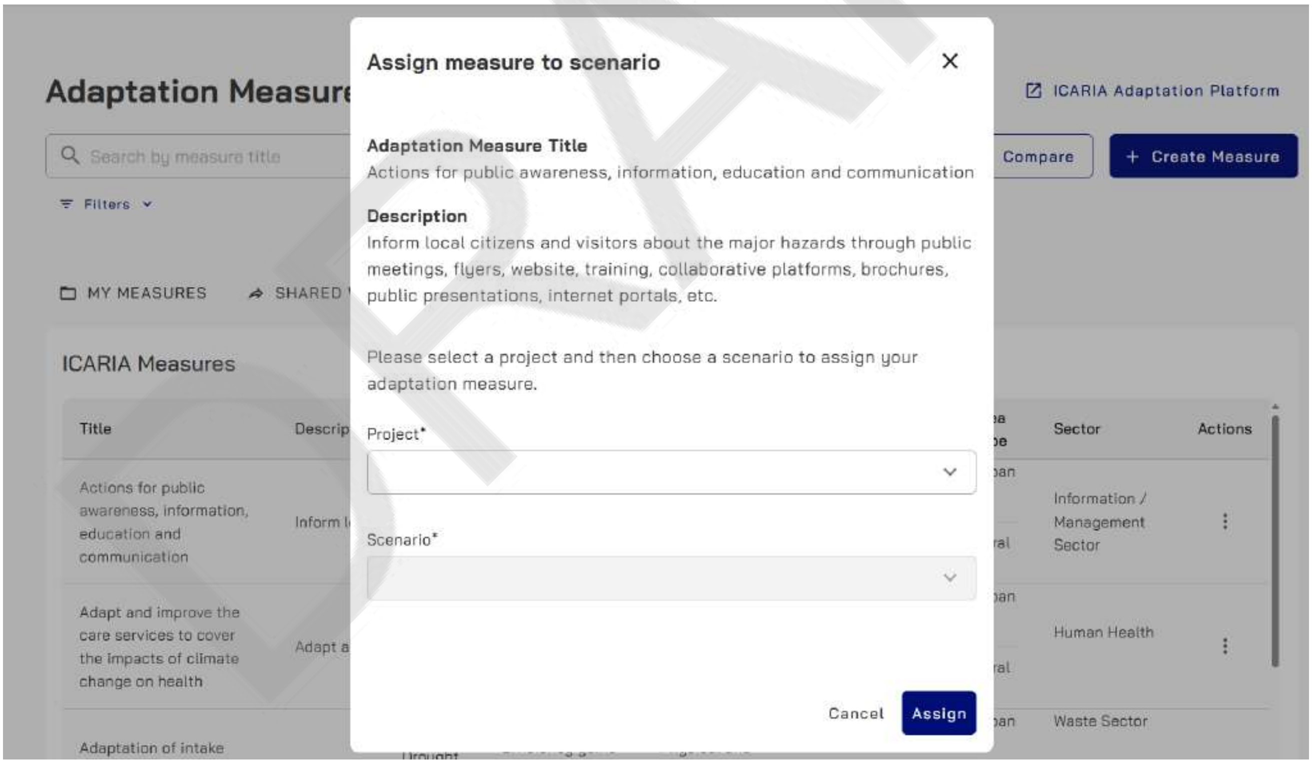

Figure 48: Adaptation Measures - Assign measure to scenario.

To improve usability, advanced filtering options are also available (Figure 49), allowing users to quickly narrow down their results.

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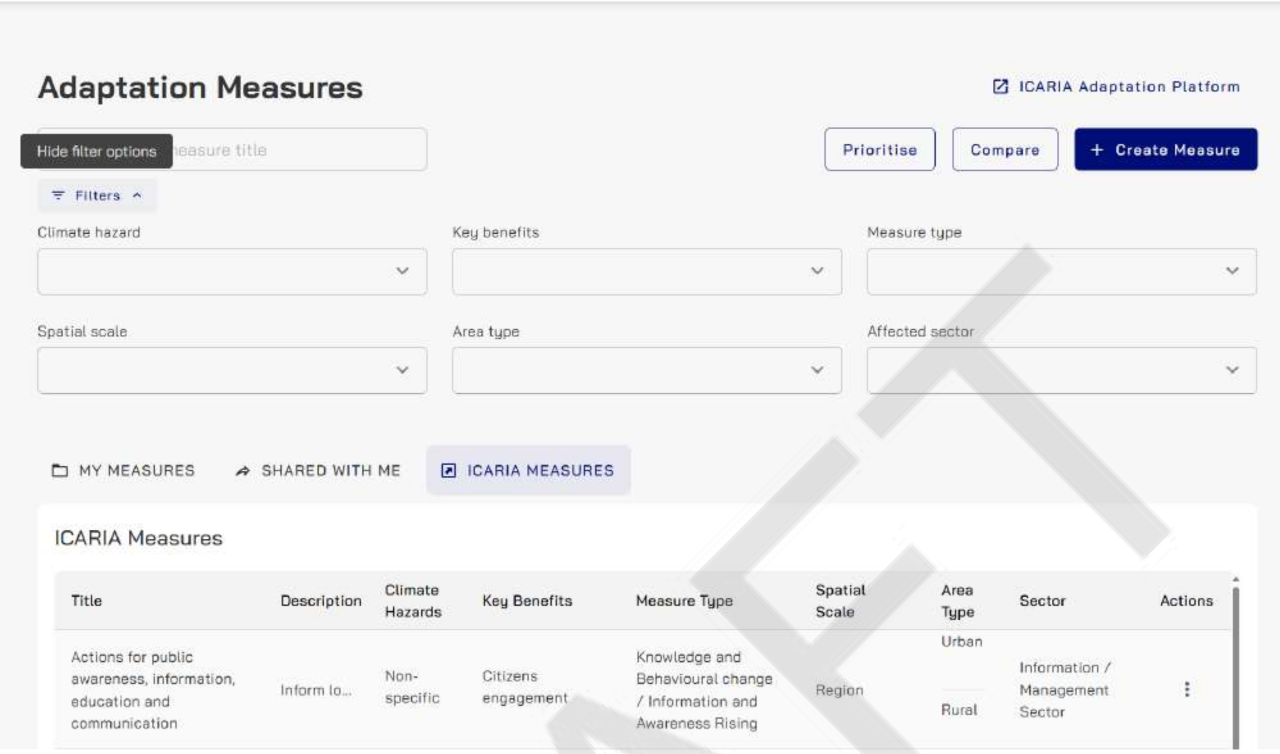

Figure 49: Adaptation Measures - Filtering.

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4.2.5 Map Viewer

Map Viewer (Figure 50), accessible via the “Jump to” button, serves as the visual hub for exploring and analysing the spatial outcomes generated through the impact assessment as well as visualising other geospatial data, such as the climate projection layers generated by the project.

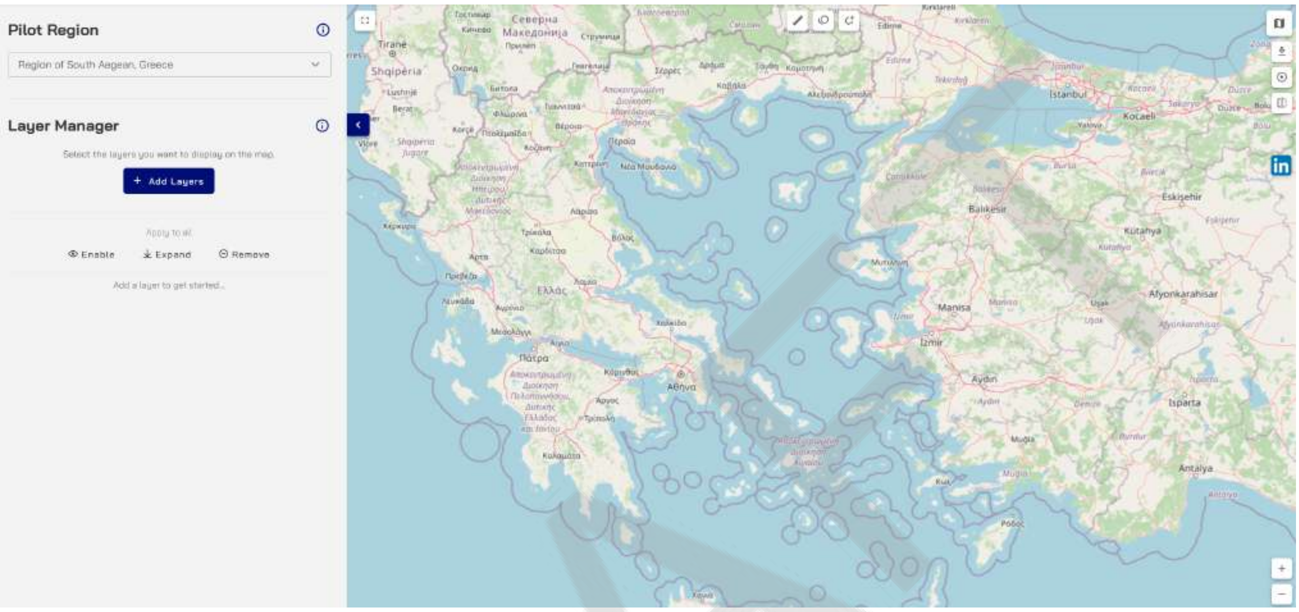

Figure 50: Map Viewer

To focus the map on a specific ICARIA case study area, users can select the region of their choice from the left-hand panel under “Locations List”. To explore the available layers, users may browse and select from a list accessible via the “Add Layers” button which opens the Layer Browser (Figure 51). These include layers they have been created from the impact assessment process, impact assessment layers shared with them by other DSS members, or static ICARIA layers representing the climate projections for each case study area. In the Layer Browser, the layers are structured into a multi-tier catalogue, enabling users to easily search, filter, and manage datasets by project, region, or topic. After adding layers to the map, users can examine the legend, adjust opacity, toggle visibility, re-order them or remove them completely from the map (Figure 52). Upon clicking on a point on a layer, a popup displays the metadata contained (as shown in Figure 31).

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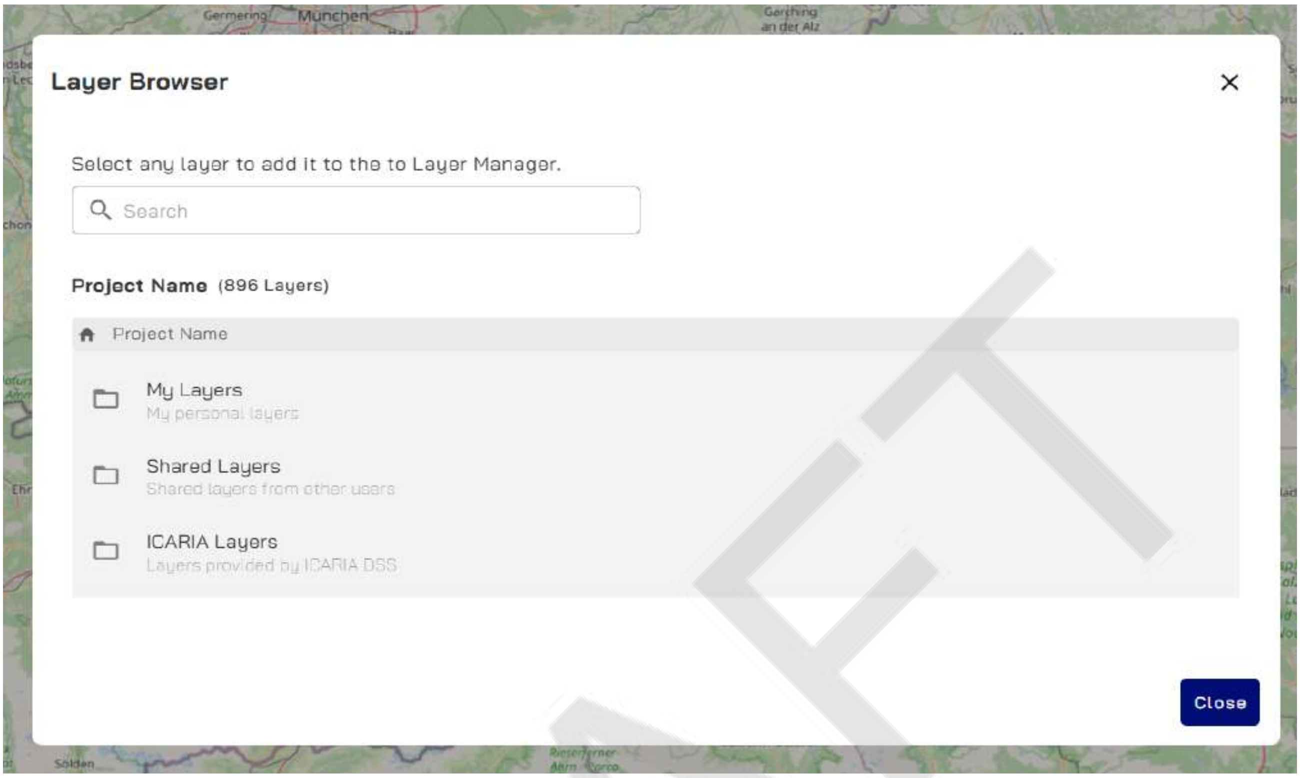

Figure 51: Map Viewer - Layer Browser.

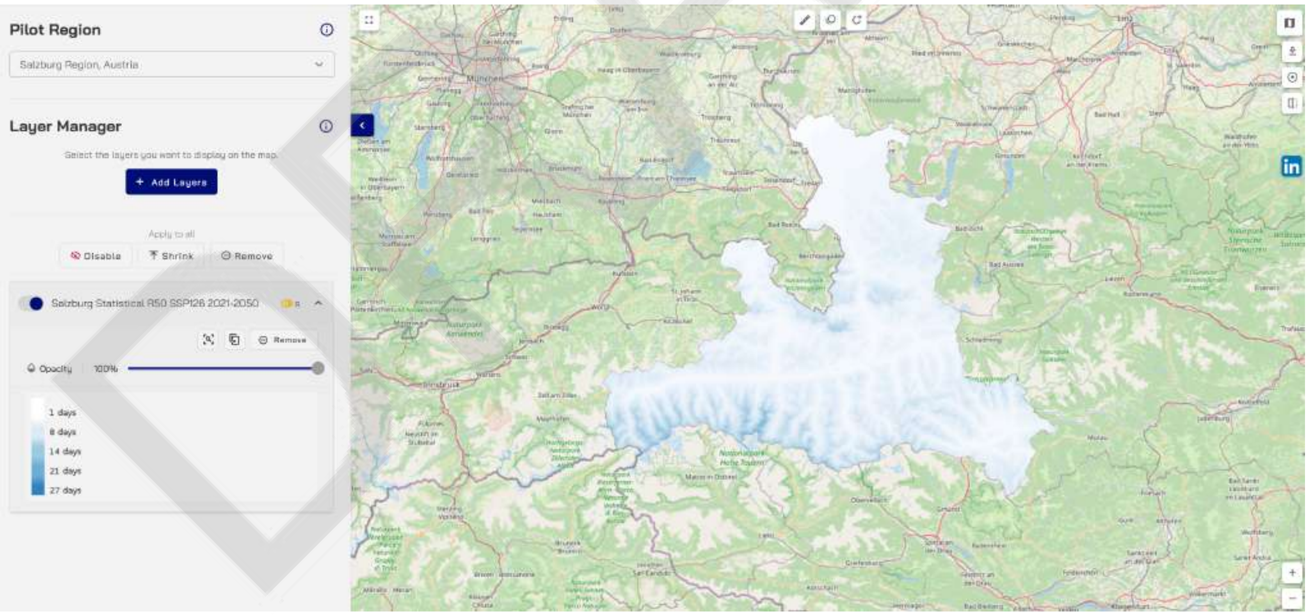

Figure 52: Map Viewer - Layer selected.

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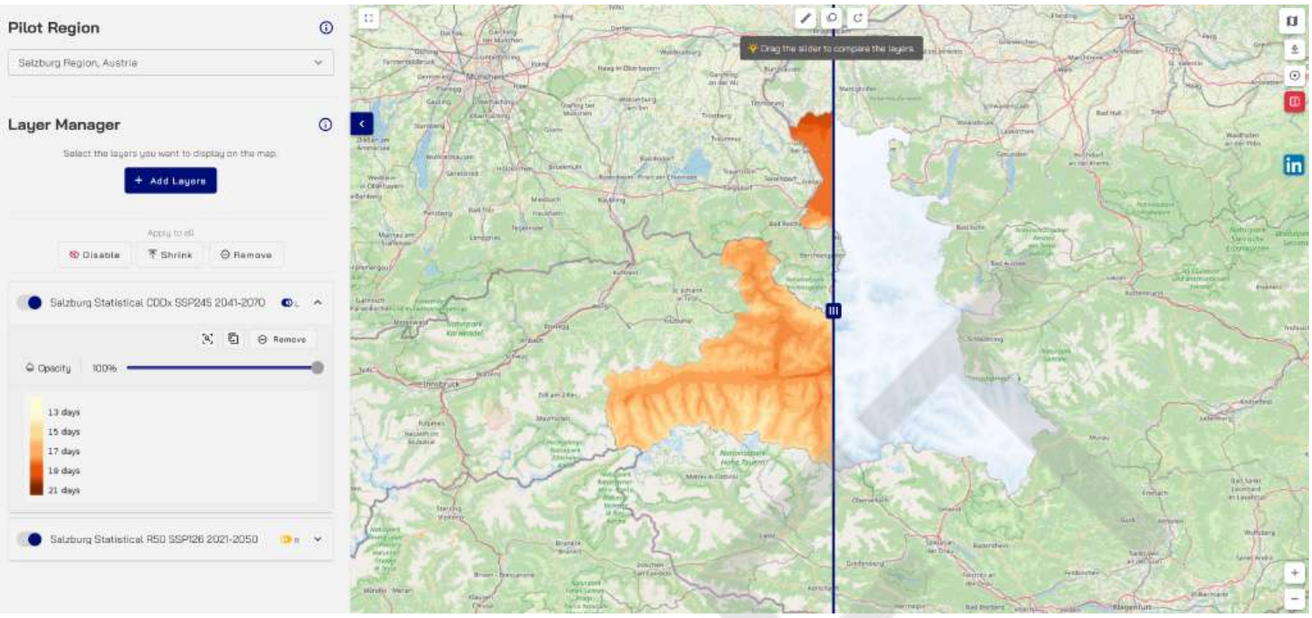

Figure 53: Map Viewer - Split screen.

Users can compare two layers (such as impact assessment results or climate projections) by enabling split-screen mode available on the right side of the interface (Figure 53). They can then select which layer appears on each side and use the slider to adjust the relative space allocated to each layer.

Users can share a snapshot of their work on LinkedIn as seen in Figure 54.

To further assist exploration, the Map Viewer includes several additional tools found on the top and right side of the map. Users can measure distances and areas, change the basemap, record or export current sessions as an image or video (in PNG and MP4 formats respectively), and navigate interactively using pan and zoom functions (Figures 55-56). These features support spatial interpretation and communication of results in planning discussions or reporting.

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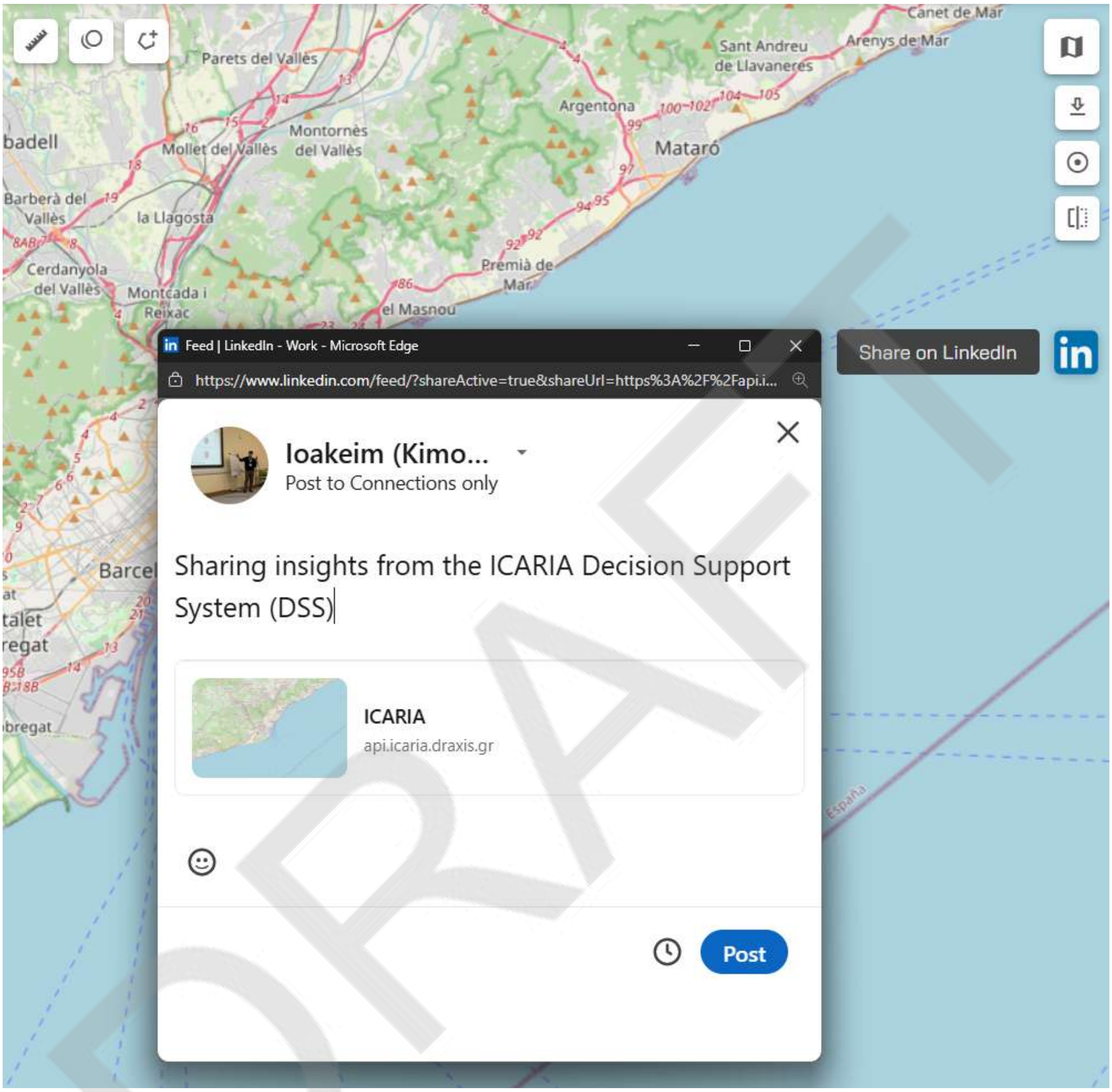

Figure 54: Map Viewer - Social media sharing.

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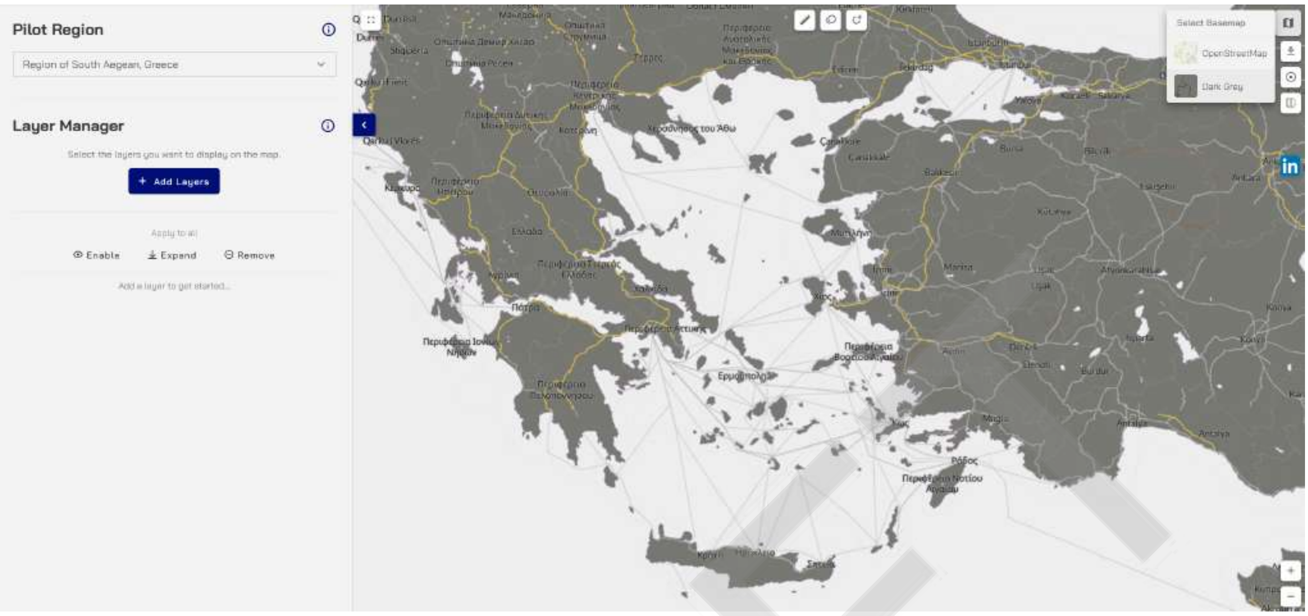

Figure 55: Map Viewer - Basemap selection.

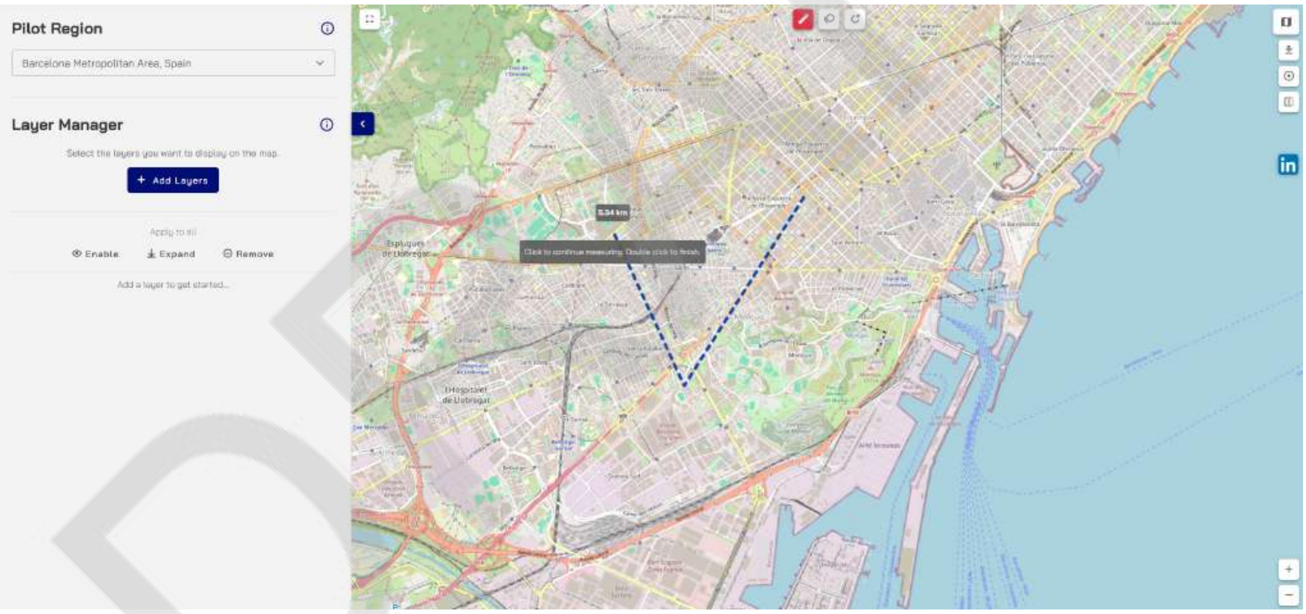

Figure 56: Map Viewer - Distance measurement.

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4.2.6 Results

Results, accessible in the same way as Resilience Assessment, offers users a consolidated overview of all projects they have either created or that were shared with them (Figure 57). Unlike the Project Manager, this section is dedicated exclusively to viewing and exporting project outcomes rather than editing or managing scenarios.

From this interface, users can open any listed project to review its full set of results, including all associated scenarios, risk and impact assessments, resilience evaluations, and assigned adaptation measures. Additionally, users have the option to download a complete PDF report of the project, which compiles all scenarios and results therein into a shareable, offline document (Figure 58).

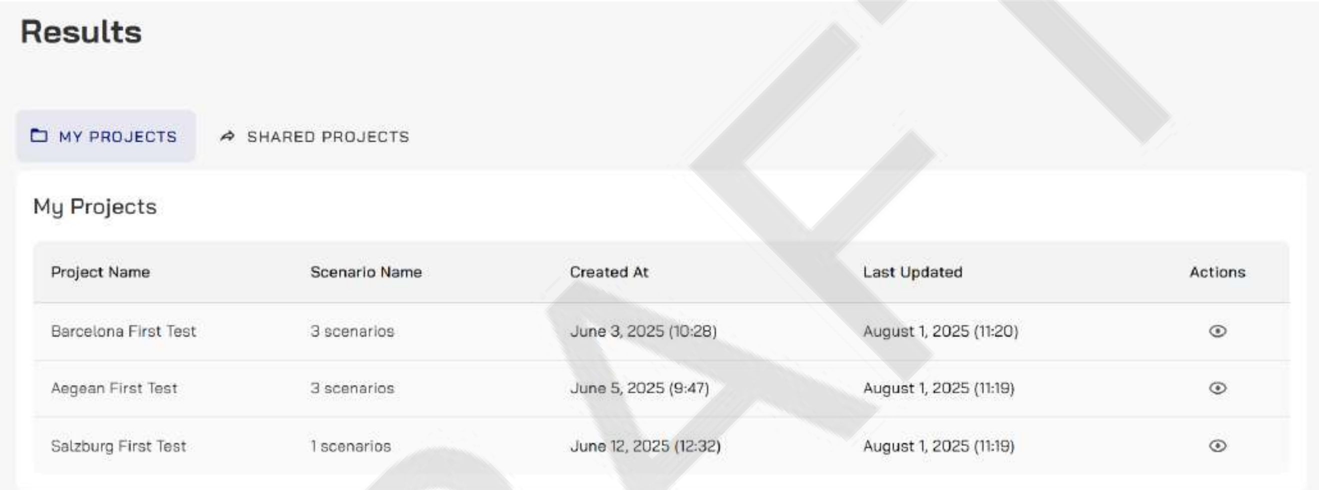

Figure 57: Results.

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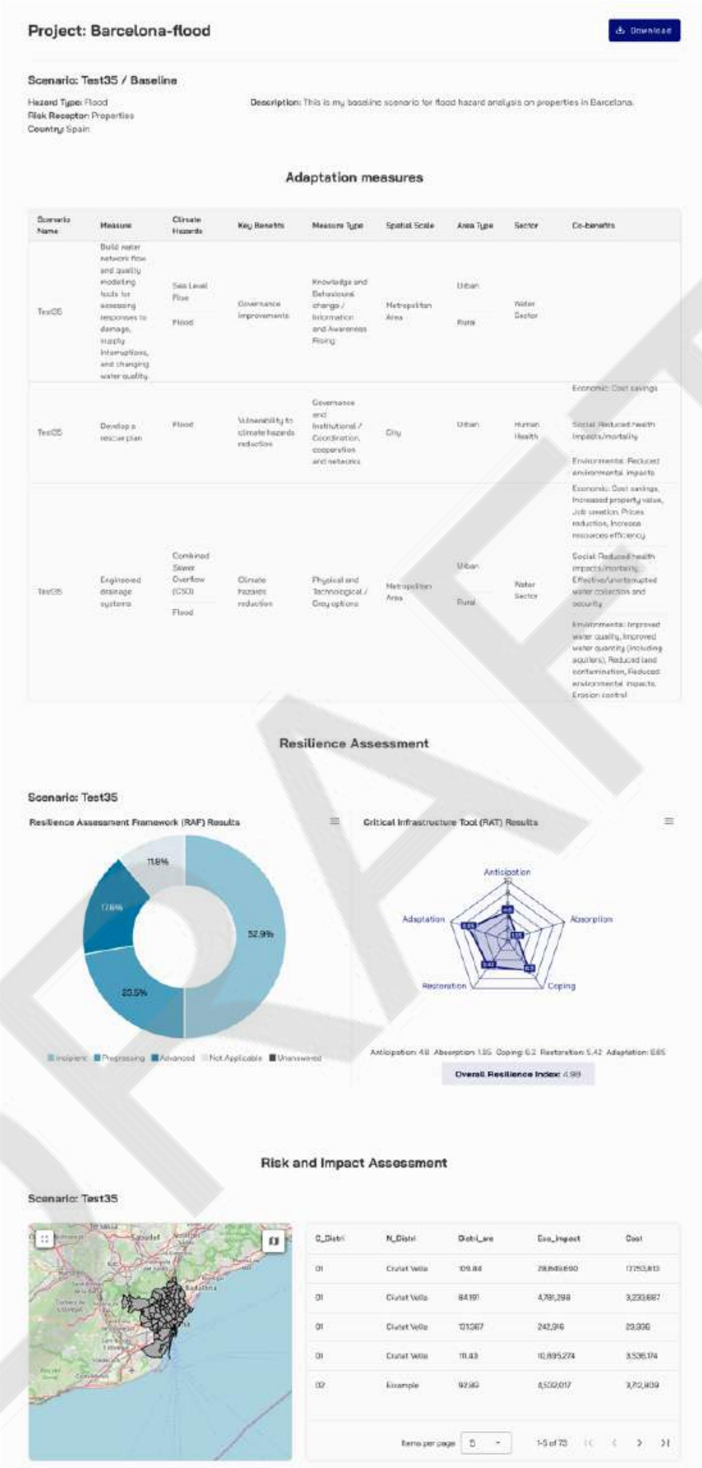

Figure 58: Results - PDF Report of Project with a Completed Scenario.

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4.2.7 Account

The Account section centralises user account settings and provides quick access to listed projects. Account credentials and management settings are handled through Keycloak (an open-source access management tool), accessible via a dedicated link in the DSS tab (Figures 59-60). Moreover, users can access a part of the Project Manager with viewing and sharing options available (Figure 61). Lastly, it provides a dedicated option to submit feedback on the platform's overall performance and appearance (Figure 62).

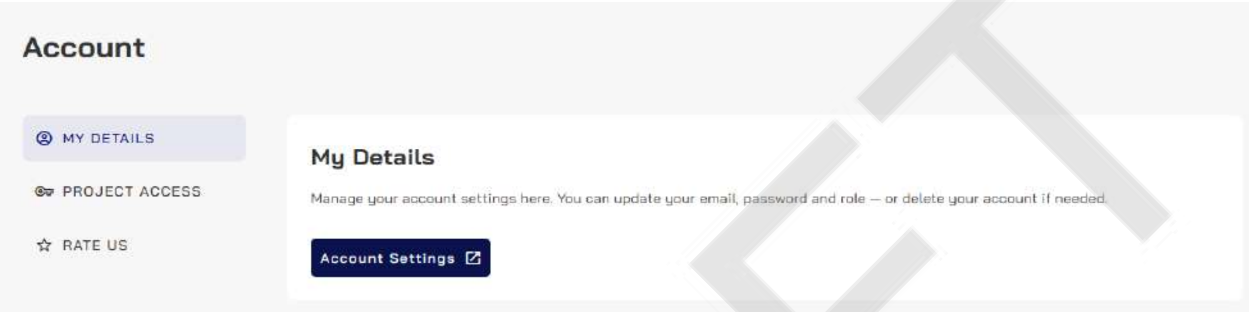

Figure 59: Account - Details.

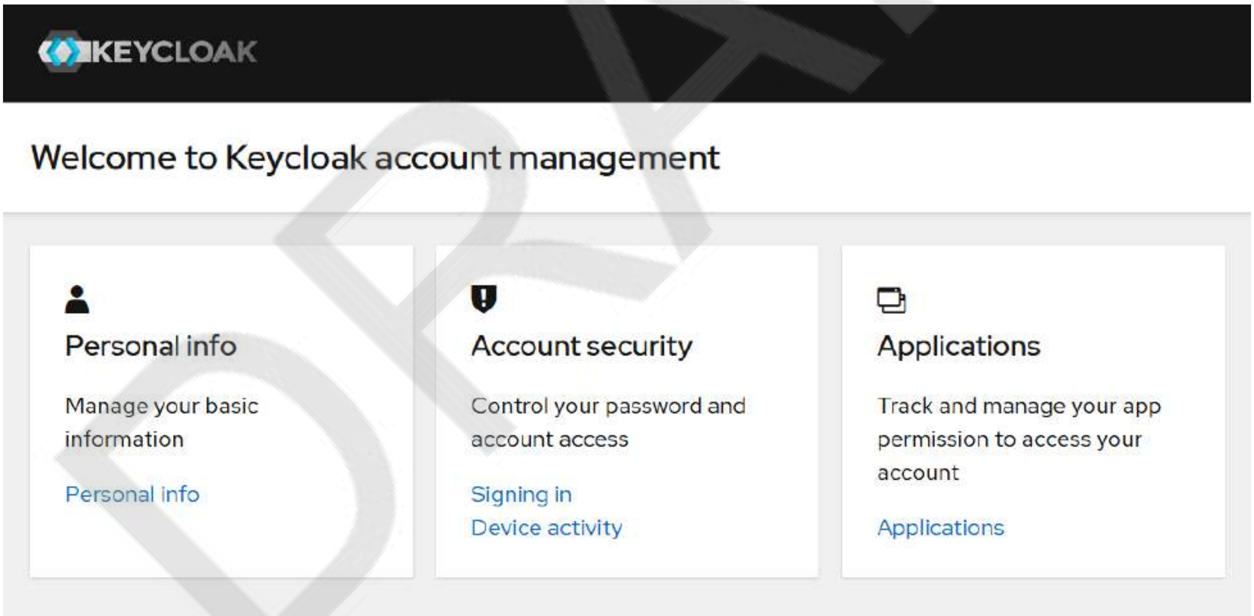

Figure 60: Account - Keycloak access.

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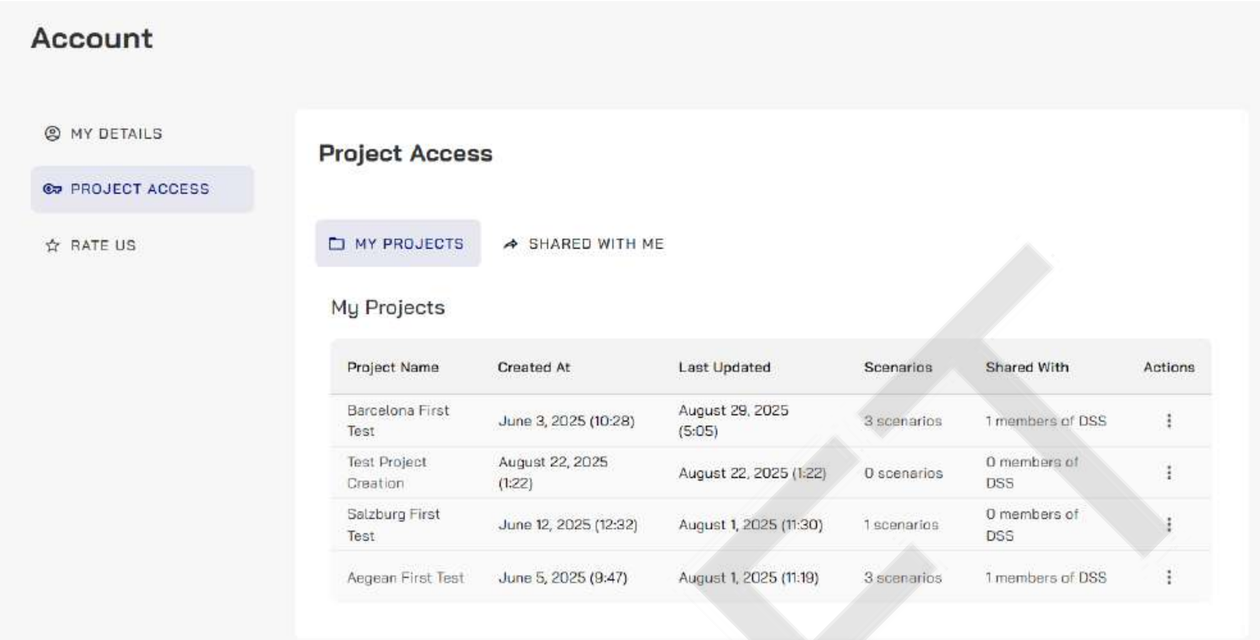

Figure 61: Account - Project access.

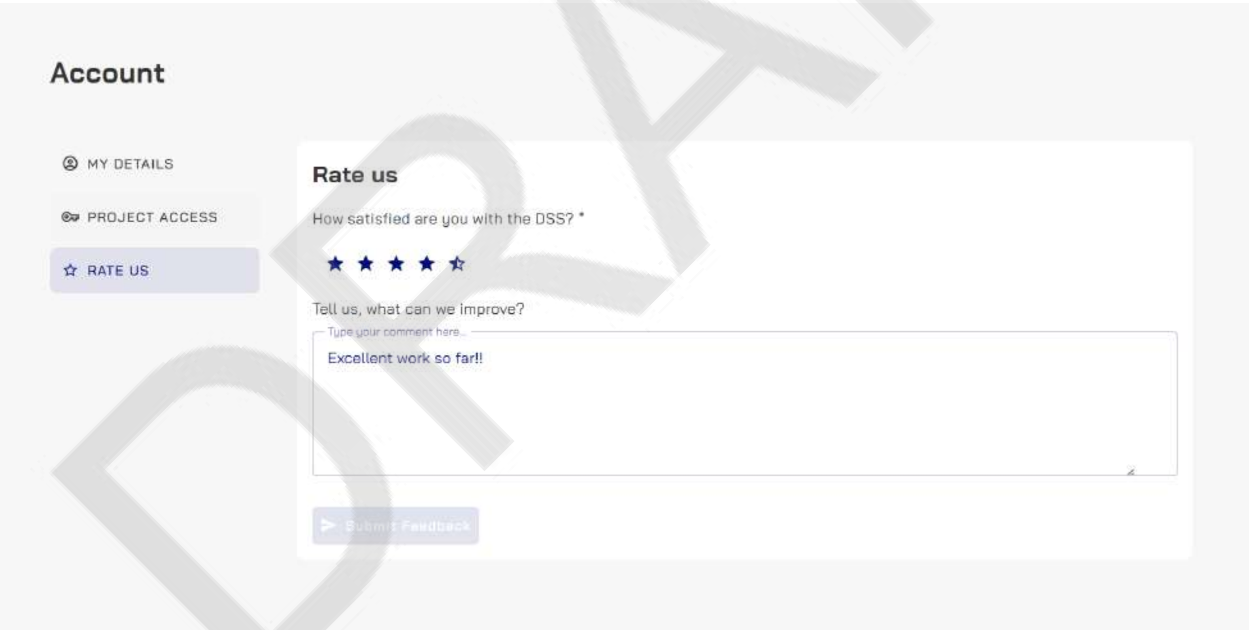

Figure 62: Account - Rating.

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5 System Architecture

The platform is designed with a modular, service-oriented architecture. Each service operates independently, encapsulated in Docker containers, promoting maintainability, scalability, and secure integration with external systems. Layers are clearly separated by function (UI, logic, data, etc.), ensuring a clean and extensible system.

This layered architecture supports:

- Independent deployment and scaling of services
- Robust geospatial data handling and real-time processing
- Secure authentication and access control
- API-first interoperability with external systems
- Consistent environments across development, staging, and production via containerisation

5.1 System Topology

The platform is composed of distinct, interoperable services organised into the following layers (Figure 51):

- **User Interaction Layer:** Vue-based frontend with Vuetify
- **Business Logic Layer:** Django backend exposing REST APIs
- **Geospatial Services Layer:** PostgreSQL with PostGIS + GeoServer for spatial data
- **Authentication Layer:** Keycloak and OAuth2-based flows
- **Integration Layer:** Connects with APIs such as RAT by Demokritos and risk systems
- **Orchestration Layer:** Docker containers for isolated, reproducible deployments

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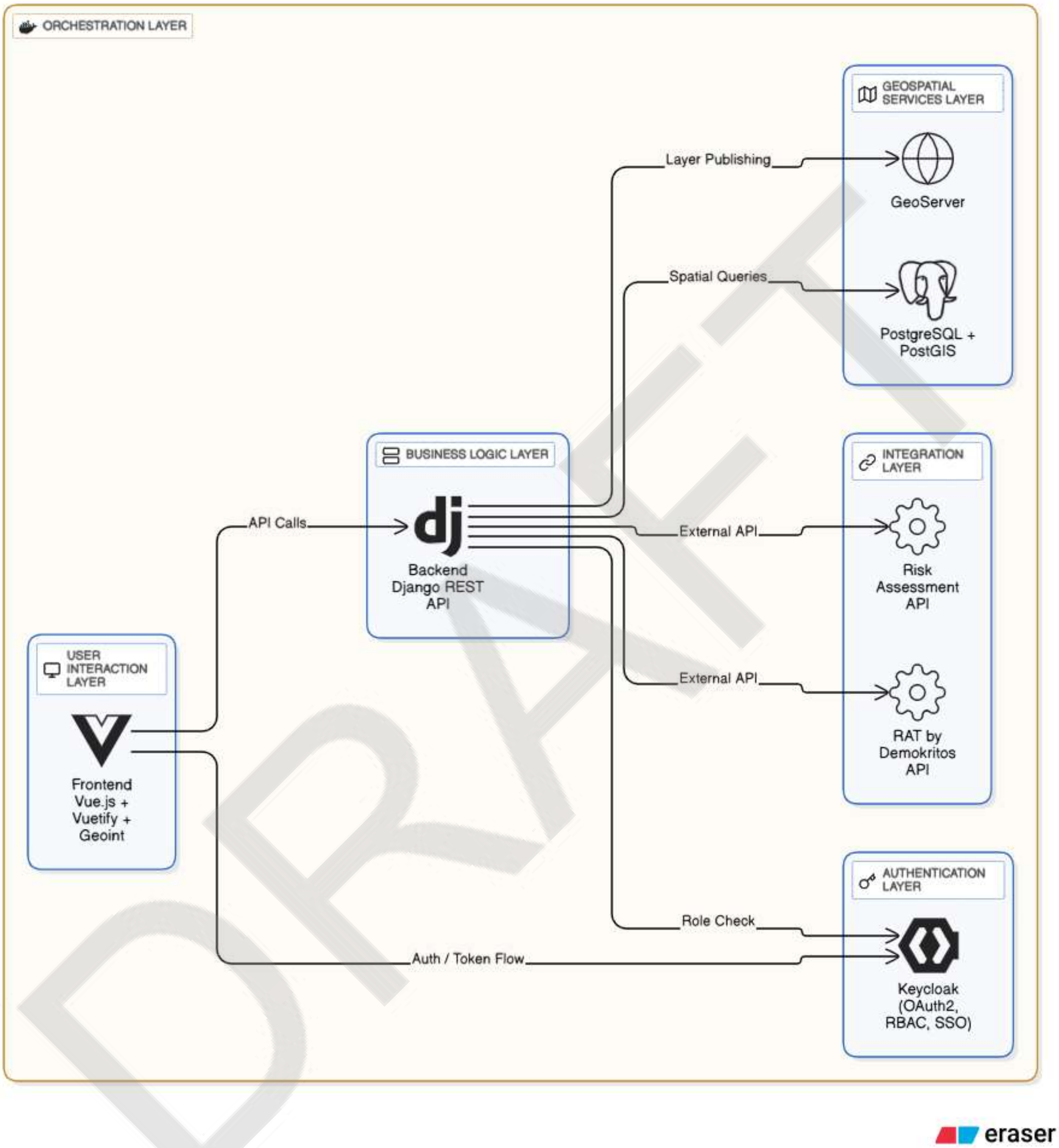

Figure 63: System Topology

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5.2 Technical Stack

Table 11: 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

5.3 Main Components

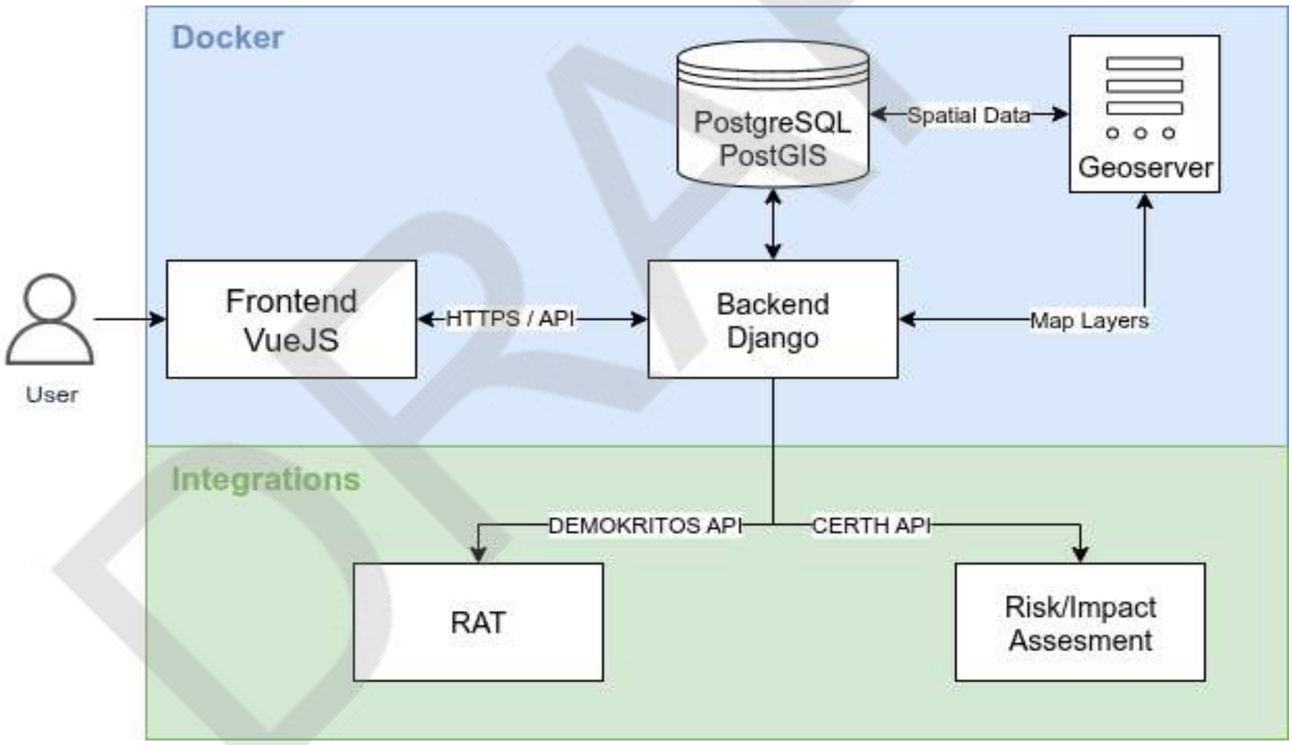

Figure 64: Main Components structure.

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5.3.1 Frontend

A map-centric interface built with Vue 3, enhanced by Vuetify for styling. It allows users to input data, view maps, and interact with system outputs dynamically.

5.3.2 Backend (Django)

Handles business logic, user requests, and integrates with the database and external services. Exposes REST APIs for frontend communication.

5.3.3 Database (PostgreSQL + PostGIS)

Stores structured and spatial data, allowing advanced queries and supporting the system's geospatial features.

5.3.4 GeoServer

Publishes spatial data layers using Open Geospatial Consortium (OGC) standards (WMS/WFS). Used for internal and external consumption of environmental datasets.

5.3.5 Authentication (Keycloak)

Manages user login and role-based access across the platform using OAuth2/OpenID protocols.

5.3.6 Containerisation (Docker)

Each service runs in an isolated container, ensuring reproducibility and consistency across environments.

5.4 Data Flow and Integration Points

5.4.1 Data Flow

- User inputs data → Frontend
- Frontend sends request → Django (API)
- Backend writes/reads → PostgreSQL/PostGIS
- Auth tokens verified via → Keycloak
- Dashboards rendered → based on data + user roles

5.4.2 External Integrations

- RAT by Demokritos: Impact analytics via REST API
- Measures Implementation API: JSON, inbound via cron
- Risk Impact Assessment API: Two-way REST interaction (JSON/form-data)

Appendix 7 provides the detailed documentation of the ICARIA Processing API for Impact Assessment for the flood and wildfire workflows.

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5.5 Quality Assurance

The QA strategy for this platform ensures that the application is reliable, secure, and performs consistently under expected and extreme conditions. A combination of manual testing, automated checks, and industry-standard tools is used throughout the development lifecycle to validate functional correctness, code quality, scalability, and security.

5.5.1 Functional Testing

Functional testing is primarily conducted through manual testing by developers and QA testers. This includes validating user flows such as authentication, form inputs, Create, Read, Update and Delete (CRUD) operations, and role-based permissions across both development and staging environments.

Manual testing allows the team to iterate rapidly during feature development and ensures early detection of bugs and UX issues. Edge cases are verified based on predefined test scenarios, especially following significant updates or code refactors.

5.5.2 Load and Stress Testing

To evaluate performance under real-world and extreme conditions, the system is subjected to automated load and stress tests. These tests simulate user activity and measure the system's responsiveness and stability.

Load Testing: Simulates 100 concurrent users over a 10-minute period using Apache JMeter. Metrics tracked include API response time, server load, and throughput. The system maintained an average response time below 850 ms and a max latency under 1.5 seconds.

Stress Testing: Introduced 500 virtual users in 30 seconds to simulate traffic spikes. Despite increased load, the system continued to process requests with an error rate below 2.5%, confirming its resilience and graceful degradation.

All test metrics met or exceeded success criteria, demonstrating strong performance and system stability under load.

5.5.3 Security Testing

The platform's security model relies on Django's robust security features, along with secure practices in API design and user session handling:

- **CSRF Protection:** Enabled via Django middleware to block unauthorised cross-origin requests.
- **SQL Injection Prevention:** Ensured by Django ORM's query parameter binding.
- **XSS Protection:** Django templates automatically escape output unless explicitly marked as safe.
- **Authentication & Access Control:** Keycloak handles secure login, password hashing, login throttling, session management, and route protection.

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These built-in features significantly reduce the attack surface and protect against common web vulnerabilities.

5.5.4 Code Quality and Linting

Consistent code style and maintainability are enforced through automated formatting and linting tools integrated into the CI/CD pipeline:

- Backend (Django / Python): Code quality is maintained using tools like black and flake8 to enforce styling, catch syntax errors, and ensure clean architecture.
- Frontend (Vue 3): ESLint with Vue plugins is used to enforce component structure, detect unused variables, prevent anti-patterns, and standardise formatting.

These tools help reduce code review effort, improve readability, and prevent regressions.

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6 Deployment and Access

The deployment and access strategy for the application is designed to balance operational control, security, and ease of use for both technical administrators and end-users. By leveraging containerisation and a dedicated hosting environment, the system ensures consistent performance, straightforward maintenance, and a high degree of reliability. The deployment pipeline is optimised for repeatability and scalability, allowing the development team to manage updates and environment changes with minimal disruption.

6.1 Hosting Environment

The application is deployed on a dedicated server, ensuring full control over the hosting environment and system resources. The entire stack is containerised using Docker, allowing consistent and isolated environments for the frontend, backend, database, and authentication services.

The deployment setup includes:

- **Docker Compose** to orchestrate multi-container services (e.g., Laravel backend, PostgreSQL, Keycloak, Vue frontend).
- **Environment configuration files** (.env) for managing deployment variables.
- **Routine maintenance and deployment** are handled directly on the server via SSH.
- **Docker CLI**, allowing for straightforward updates and scalability.

This setup offers flexibility, isolation between components, and simplifies environment replication for staging or testing purposes.

6.2 Access

Below are the access methods and configurations:

6.2.1 User Access

The application is accessible via a secure web URL. All users are required to authenticate through Keycloak, which handles login, session management, and user role enforcement. The only part that is accessible without any authentication mechanism is the map viewer feature.

6.2.2 Developer/Administrator Access

Administrative access is granted via SSH into the dedicated server. From there, developers and system admins can manage docker containers, view logs, and apply updates.

6.2.3 Environment Configuration

Access credentials, domain settings, and other environment-specific parameters are managed via .env files within the docker setup.

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This setup ensures secure, reliable access for both end-users and technical administrators while maintaining a streamlined deployment workflow.

6.3 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. The following roles are available in version 1. Two more roles will be available in version 2, namely a Stakeholder role addressed to less technical users (such as decision makers) who mainly need to access results generated by Technicians, and a General Public role which refers to the unregistered users with limited access to the Map Viewer.

6.3.1 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 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.

6.3.2 Registered User: Technician

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

- **Project management:** Create, view, share and edit 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.
    - **Scenario comparison**: View and compare results from different scenarios.

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

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7 Next Steps

7.1 Planned Features for Version 2

The development of ICARIA DSS v2 will focus on enhancing the platform based on feedback received from the case study trials (WP4). The main priorities are:

- Implement targeted updates based on structured feedback from facilitators (AIT, AQUA, DMKT) during trial and mini-trial activities.
- Explore the feasibility (in terms of time, scope and partner input availability) for multi-hazard impact assessment (together with WP2 partners).
- Expand and refine role configurations, to create additional distinct roles for stakeholders, and public users as per the Grant Agreement.
- Extend impact assessment workflows on the DSS to support analysis on 3 more risk receptors, namely buildings and population for wildfires, and powerlines for windstorms, connecting the DSS with CERTH's backend implementation concerning these additional risk receptors (per Chapter 2.1).
- Add further guidance for the impact assessment functionality, including contextual explanations, step-by-step instructions, and examples to support technicians.
- Improve user interface and user experience consistency, ensuring smoother navigation and visual clarity.
- Updates to the user guide and static pages of the DSS (e.g. About page).
- Update and refine technical documentation, including the API documentation for windstorms.
- Conduct cross-case QA testing, involving partners from all case studies to validate stability and interoperability.
- Develop dissemination materials (e.g. demo videos, social media posts) in collaboration with WP5, to showcase DSS functionalities and support wider outreach and market uptake.

These additions are aimed at improving system usability, data handling, user guidance and stakeholder engagement.

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7.2 Timeline of Action

Table 2 presents the planned action points for the final phase of the project

Table 12: Action plan of version 2.

#	Action	Until
1	Support for elaboration of trials in pilot areas (WP4), collect structured feedback from WP4 trial and mini-trial facilitators and stakeholders	M34-M35
2	Advanced feature exploration: assess the feasibility of multi-hazard impact assessment in collaboration with ICARIA partners	M36
3	Development of version 2 (front and backend)	M36-M38
4	Continuous support for service integration: RAT application, adaptation measures, Impact assessment calculation service	M34-M38
5	Extend impact assessment workflows to allow for analysis of impacts on more risk receptors	M34-M37
6	Internal QA testing	M36-M38
7	Update guides and technical documentation	M37-M38
8	Mini trials and final system validation	M37-M38
9	Outreach and dissemination support	M37-M38
10	Deliverable D3.5 preparation and submission	M38

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8 Conclusions

The ICARIA DSS marks a significant milestone in supporting regions' plans and responding to the growing challenges of climate change. It brings together diverse and often complex data into a single, user-friendly environment, supporting authorities, technical teams, and infrastructure managers as they assess risks, evaluate resilience, and identify the most effective adaptation measures for their local context.

What makes the ICARIA DSS especially valuable is its ability to combine scientific depth with practical usability. Each of its core functionalities is based on sound methodologies developed by a diverse team of experts across the project. These methods have been adapted to work effortlessly within the platform, making sure that users can benefit from robust analysis tools without needing advanced modelling or GIS expertise.

A key advantage of the DSS is its ability to compare results from different scenarios: current conditions, future projections without action, and futures shaped by targeted adaptation. By looking at indicators such as resilience capacity, potential impacts, and adaptation performance, users are equipped to make informed, evidence-based decisions that are both efficient and locally relevant.

The platform also hosts a rich portfolio of 320 adaptation measures, carefully selected and categorised to match real-world challenges. Users can explore this library, manage their own or shared measures, and prioritise options using a built-in decision-support method that balances costs, benefits, and local priorities.

At the heart of the visual experience is the Map Viewer. It is an intuitive interface that lets users interact with geospatial data, including climate projections and user-uploaded layers. Equipped with tools for analysis and comparison, it makes it easier to understand spatial dynamics and communicate insights clearly.

The ICARIA DSS is being tested and applied in three case study regions: Barcelona Metropolitan Area, South Aegean Region, and Salzburg Region. Each region brings different challenges, from urban flooding and heatwaves to island-specific vulnerabilities and mountainous terrain. The feedback that will be collected from the upcoming trials, will shape the next version of the platform.

Looking ahead, DSS Version 2 will expand on what has been built so far: improving usability, adding and refining features, and connecting more directly with the trial results of the ICARIA project.

Beyond Version 2, the ICARIA DSS will also play a role in the project's wider dissemination and exploitation strategy. Future work will explore how the platform can be scaled and replicated beyond the three case study regions, including its potential use in training, teaching, and policy adoption. These activities, together with plans for maintaining the DSS's impact beyond the project lifetime, will be further detailed in the final version of this deliverable (D3.5), as well as the final exploitation deliverable (D4.5).

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Appendix 1: User Scenarios

A total of 22 user scenarios were developed to provide a comprehensive description of the DSS's features during the design phase of the DSS. These scenarios are step-by-step narratives that illustrate how typical users are expected to interact with the system. Their purpose was to clarify user needs, ground the system design in real decision-making processes, and ensure that the DSS functionalities respond to practical use cases prior to development. Below is an indicative subset of these scenarios, more specifically for the Project Manager and Map Viewer functionalities:

Table 13: Project Manager user scenario.

UC-009	Project manager
Goal	Enable users to access project manager and create new projects
Primary role	Technicians
Preconditions	The user is logged into the DSS
Trigger	• User clicks on the "Start now" button from the landing page • User clicks on the "Project Manager" button from the "Jump to" in the header • User clicks on the "Risk and Impact Assessment" button from the "Jump to" in the header
Basic flow	
1 User clicks on the "Project Manager" button from the "Jump to" in the header or clicks on the "Start now" Button from the landing page. 2 System redirects user to the Project Manager. 3 System displays Project Manager with a table containing the list of projects that have already been created with their information and action buttons. 4 System displays a "Shared with me button" which when clicked displays a table to the list of projects shared with the user by other Technicians. 5 User selects a project from either table by clicking anywhere along the desired table row. 6 System opens the Scenario Previewer with the information for each scenario created under the selected project per **UC-010**.	
Alternative flows	
UC-009.1: New project 1 At step 3, user navigates to the "New project" section. 2 User enters the required information for the creation of their project. 3 System displays a transition where the "Create new project" button brightens from low opacity to full opacity, becoming clickable. 4 System creates a new entry in the database. 5 System displays a message "Your project has been successfully created". 6 System displays new project in the user's list of projects. 7 The flow returns to step 3 of the Basic Flow.	
Extensions	
UC-009.2: Project sharing 1 At step 3 of the Basic Flow, user opts to share their project with other members by clicking on the share icon in the list of projects. 2 Flow continues per **UC-007.3B**.	

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UC-009.3: Project editing 1 At step 3 of the Basic Flow, user opts to edit a project they have editing permissions by clicking on the pencil icon in the list of projects. 2 System opens an "Edit project" section, replacing the "New project" section. 3 User enters the required information for the update of their project. 4 System displays a transition where the "Update project" button brightens from low opacity to full opacity, becoming clickable. 5 System updates the entry in the database. 6 System displays a message "Your project has been successfully updated". 7 System updates the project in the user's list of projects. **UC-009.4: Project deletion** 1 At step 3 of the Basic Flow, user opts to delete an entire project by clicking on the bin icon in the list of projects. 2 System displays a popup, asking the user to confirm or cancel the action along with a complimentary text to explain the impact. 3 User clicks the "Delete project" button. 4 System deletes the entry from the database and the project manager. 5 System displays a message confirming the successful deletion of the project "Your project has been successfully deleted".	
Exceptions	
UC-009.5: User cancels an action in the popup 1 At step 3 of Extension UC-009.4 the user cancels the action via the "Cancel" button in the popup. 2 System retains the existing state and no changes are made. 3 The flow returns to step 1 of Extension UC-009.4.	
Clarifications	
1 The Project Manager table includes the following for each project entry: A) Actions column with options to i) Edit, ii) Share, iii) Delete a project, B) Project (name), C) Creation (datetime), D) Last save (datetime), E) Files (number of files uploaded), F) Scenarios (number of scenarios contained in the project). 2 The Shared with me table includes the same information as in Clarification 1 with the addition of G) Created by (username); depending on the access level grated the action icons remain as in the Project Manager table or are switched to a "View only" button. 3 "Last Save" within the Project Manager and Shared with me tables should show a tooltip when hovering displaying the username who last saved. 4 The required information to create a project is: A) Project name, B) A brief description (optional). 5 The "New project" section is always visible. 6 The Edit button is only available in the Scenario Previewer when the user has editing permissions for a project.	
Outcomes	• Success: User is able to see their list of projects (their own and shared projects), as well as create new ones and edit, share or delete existing ones. • Failure: The user cannot create new projects. The user cannot access the list of projects.

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Table 14: Map Viewer user scenario.

UC-014B	Map Viewer (Data catalogue)
Goal	To enable users add, remove and manage data layers on the Map Viewer
Primary role	Technicians, Stakeholders, General Pubic
Preconditions	-
Trigger	• User clicks on the Layers icon from the map control panel in the Map Viewer • User is directed to the catalogue with layers already imported by clicking "Export to map viewer after completing an impact assessment
Basic flow	
1 User clicks on the Layers icon from the map control panel. 2 System displays a group focus on the left side of the screen, with two buttons: A) Add layers and B) Switch basemap along with some explanatory text. 3 User clicks on the "Add layers" button. 4 Systems displays a different group focus with three different layers lists: A) ICARIA layers, B) My layers and C) Shared layers. 5 User navigates through each list via the different tabs. 6 User selects one or multiple layers through clicking on the checkbox available next to each list item. 7 System displays a transition where the "Add layers" button brightens from low opacity to full opacity, becoming clickable upon at least one layer being selected. 8 System imports the selected layers. 9 System displays a side menu on the left where it lists the imported layers. 10 User selects one or multiple layers from the checkboxes next to each layer to render them on the map. 11 System renders the selected layers on the map. 12 System displays a legend for the selected layer/s inside the side menu. 13 System displays a temporal control bar at the bottom centre of the map. 14 User clicks on a specific point at an area of the map where data was rendered. 15 System opens a popup, containing feature table with data of the selected point. 16 User closes the popup through the "X" button at the top right. 17 User exits the Layers by deselecting the Layers icon from the map control panel.	
Alternative flows	
UC-014B.1: Switch basemap 1 At step 2 of the Basic Flow, User clicks on the "Switch basemap" button. 2 System expands different options to switch from the current basemap to another style. 3 User selects a different basemap option. 4 System switches basemaps. 5 User clicks on the "Switch basemap" button again to hide the basemap options. 6 The flow returns to step 2 of the Basic Flow.	
Extensions	
UC-014B.2: Download layer 1 At step 9 of the Basic Flow, user selects the Download icon for a specific layer. 2 System generates a copy of the specific layer and locally stores it to the user's system. 3 System displays a confirmation message "Layers downloaded". 4 Flow returns to step 9 of the Basic Flow.	

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UC-014B.3: Layer information

1 At step 9 of the Basic Flow, user selects the Info icon for a specific layer.
2 System opens a popup, containing information about the selected layer.
3 User closes the popup through the "X" button at the top right.
4 Flow returns to step 9 of the Basic Flow.

UC-014B.4: Remove layer

1 At step 9 of the Basic Flow, user removes one or multiple active layers by clicking on the "X" icon.
2 System removes layer from the side menu and stops rendering it on the map.
3 Flow returns to step 9 of the Basic Flow.

Exceptions

UC-014B.4: User cancels an action in the popup

1 At step 2 of the Basic Flow, user cancels the action via the "X" button in the popup.
2 System retains the existing state and no changes are made.
3 Flow returns to step 2 of the Basic flow.

Clarifications

1 Users have the option to view layers from 3 distinct lists, from the 3 buttons: A) ICARIA Layers, B) My layers and C) Shared layers. "My layers" is not an option for the Stakeholder role, since they cannot create new projects. Similarly, "ICARIA layers" is the only list that appears for the General Public role since they cannot create new projects, nor can the technicians share projects with them.
2 "ICARIA layers", "My layers" and "Shared layers" are sorted in grouping categories both in the "Add layers" popup and the imported layers side menu. In "My layers" and "Shared layers", the broadest category is the scenarios; within the scenario category layers are split into "Input files (files the user uploaded to the system during an impact assessment) and "Output files" (results of the impact assessment returned by the system upon calculation of the impacts). If a scenario contains no data (i.e. has not started or completed the impact assessment) the scenario is not available in the list.
3 Next to each imported layer, the system displays 3 icons: A) Checkbox, B) Remove, C) Download and D) Info. Deselecting a layer from the checkbox will simply stop rendering it on the map but will not remove it from the side menu.
4 The temporal control bar only appears for specific types of data, namely containing information across different time points or intervals.
5 If multiple layers are active, the legends are placed one after the other vertically inside the imported layers side menu, allowing the user to scroll down. The legends can also be minimised to allow for less scrolling down.
6 The popup opening upon clicking on the info icon next to each layer contains descriptive metadata about the layer, such as author attribution, title, description, temporal coverage, license, external links.
7 Available basemap options can include: 2D map in colour with place names, 2D map in grey map with place names, satellite view.
8 On the side of the layers group focus, there is a small side arrow attached to it. User can click on the arrow to minimise it to save space in the map. By clicking the arrow once again (which is now located at the side of the screen) the group focus appears once again.
9 User can interact with the temporal control bar, by pressing the play icon and seeing the projected evolvement of the layers over the years or by dragging the cursor to their preferred year to see the respective layers.

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	10 The user can drag and drop active layers in the side menu to indicate which one should be rendered on top of the rest. 11 Any popup which does not have a cancelling option can close simply by clicking outside of the box.	
Outcomes	• Success: The user successfully adds, removes and manages data layers on the Map Viewer • Failure: The user cannot add, remove and manage data layers on the Map Viewer	

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Appendix 2: User Stories / Requirements

This appendix contains user stories collected from ICARIA partners, written as short functional requirements from the perspective of different types of users. Each story expresses a specific need (e.g. "As a decision-maker, I want to…") that the DSS should address. These stories were used to translate stakeholder expectations into concrete technical specifications and guided the prioritisation of functionalities during development.

Table 15: User Stories / Requirements.

#	ID	User Story	Requested by	Functionality
1	us01_v1	As a decision-maker, I want to get information about the risk and impact of the most relevant climate hazards in my region, so that I can develop an effective adaptation plan	CETAQUA	Impact assessment & Scenario comparison
2	us02_v1	As a policymaker, I want to see adaptation measures and be able to understand the costs and the benefits in terms of changes in damages, so that I compare and prioritise them	CETAQUA	Adaptation measures
3	us03_v1	As a decision-maker, I want to graphically see the difference between alternative intervention options, so that I can easily choose one and facilitate communication with other people	LNEC	Scenario comparison
4	us04_v1	As a decision-maker, I want to see maps highlighting more fragile areas, so that I can direct my attention to those areas of the city	LNEC	Impact assessment & Map viewer
5	us05_v1	As a decision-maker, I want to see different solutions to protect my city for different periods, so that I can plan the actions/budget with a planning horizon in my mind	LNEC	Adaptation measures & Scenario comparison
6	us06_v1	As a policy maker, I want to be able to compare more than one adaptation scenario to the BAU scenario at the same time (displaying impact costs of each scenario)	AQUA	Impact assessment & Scenario comparison

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7	us07_v1	As a Critical Infrastructure Operator, I want to see the specific cost of impacts (direct and indirect) associated to each specific critical infrastructure considered	AQUA	Impact assessment
8	us08_v1	As a Critical Infrastructure Operator, I want to see a "menu/link to" of the list of adaptation measures from the portfolio of D3.3. Such a menu should pre-select the options that fit the kind of sector or asset that is being assessed.	AQUA	Adaptation measures
9	us9_v1	As a decision-maker I want to prioritise assets based on their criticality (less resilient to have access to funding)	PMT	Resilience assessment
10	us10_v1	As a research organisation, I want to exchange information with stakeholders in a standardised way and get assessments that are commonly understood	PMT	Results
11	us11_v1	I want to be able to simultaneously compare the results of different adaptation measures on the same asset, so that I can see the best measure possible, connected with costs	PMT	Adaptation measures
12	us12_v1	As a regional developer, I want to understand future extreme precipitation events and the capacity of dealing with excess water, so that I can plan for future flood protection	PMT	Map viewer

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Appendix 3: Design Mockups

This appendix presents selected mock-ups created during the DSS design phase. The mock-ups illustrate the planned layout, navigation flow, and key functionalities of the system, such as the Project Manager, Resilience Assessment, Adaptation Measures, Map Viewer, and Results sections. They served as a visual guide to align developers and stakeholders on the intended look and behaviour of the DSS before full implementation. The following images represent a selected subset of the created mock-ups.

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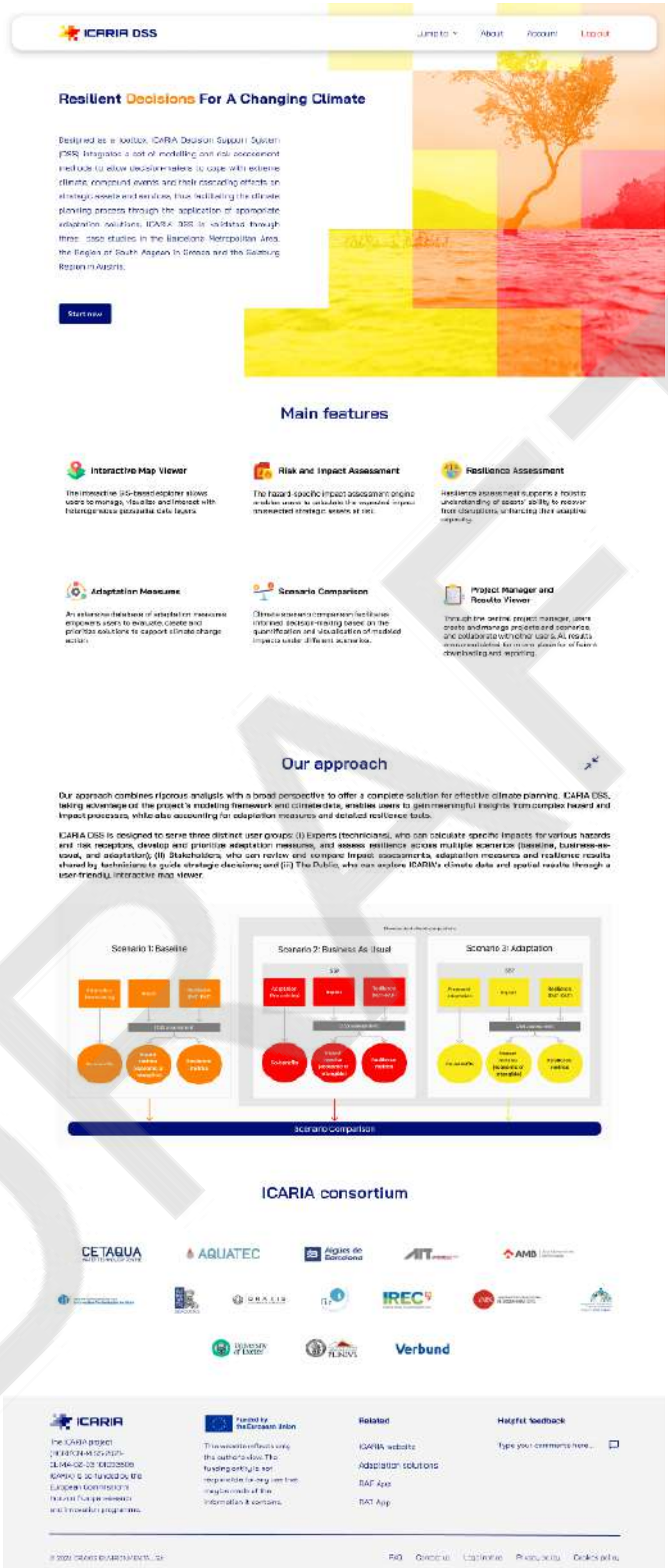

Figure 65: Landing page mockup.

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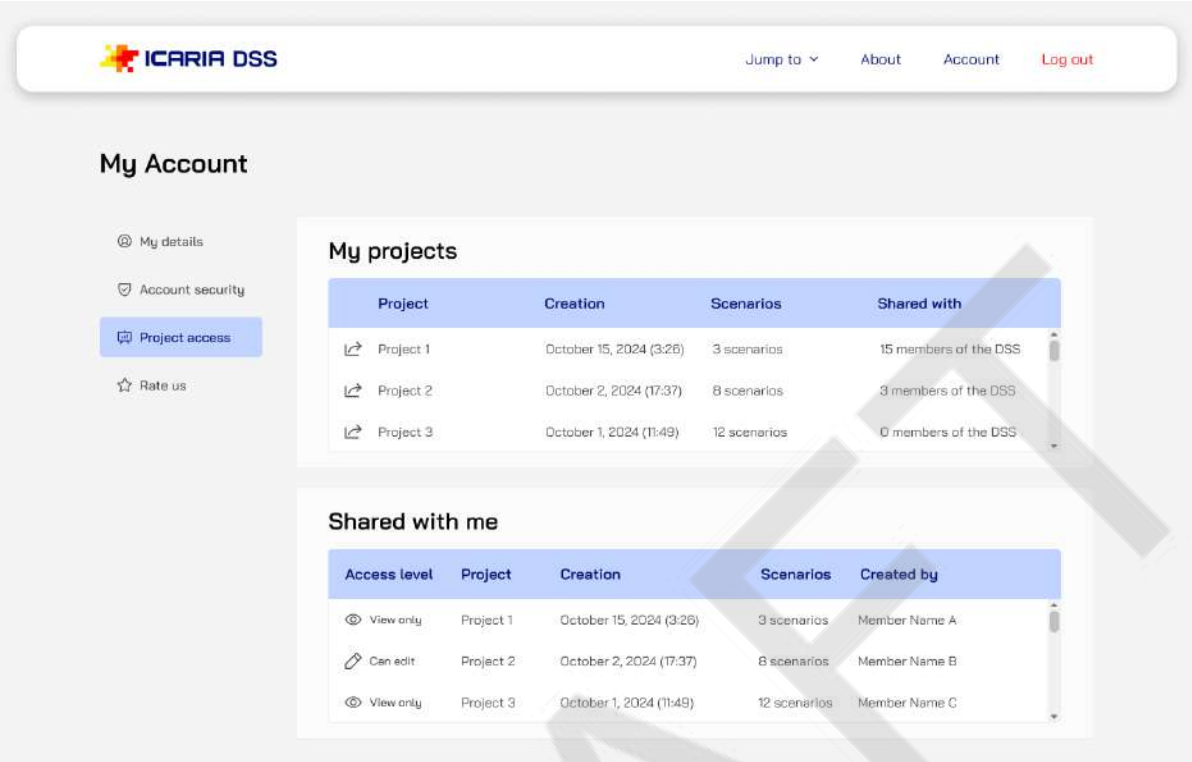

Figure 66: Account page mockup.

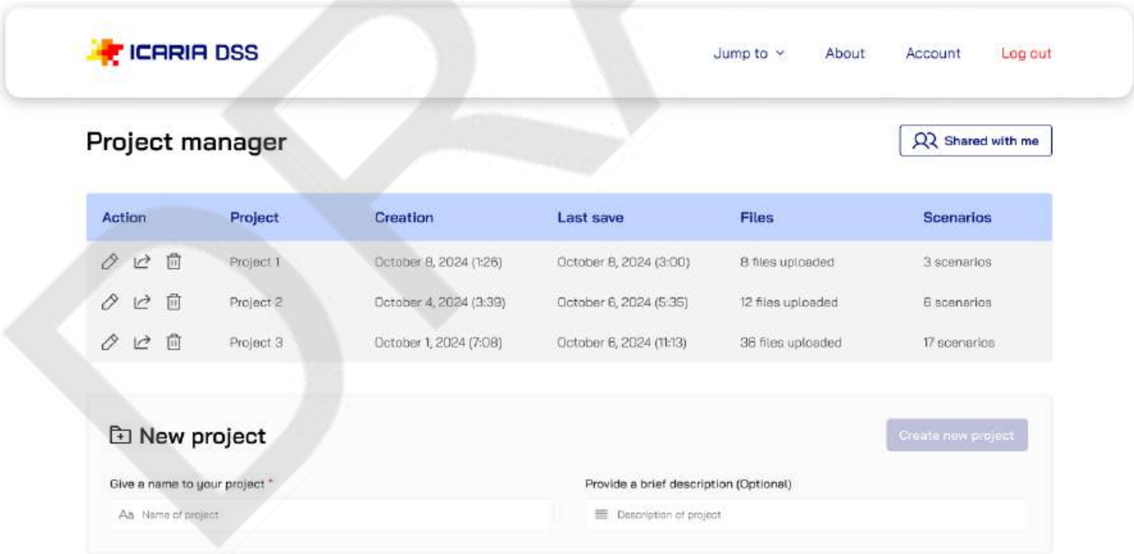

Figure 67: Project Manager mockup.

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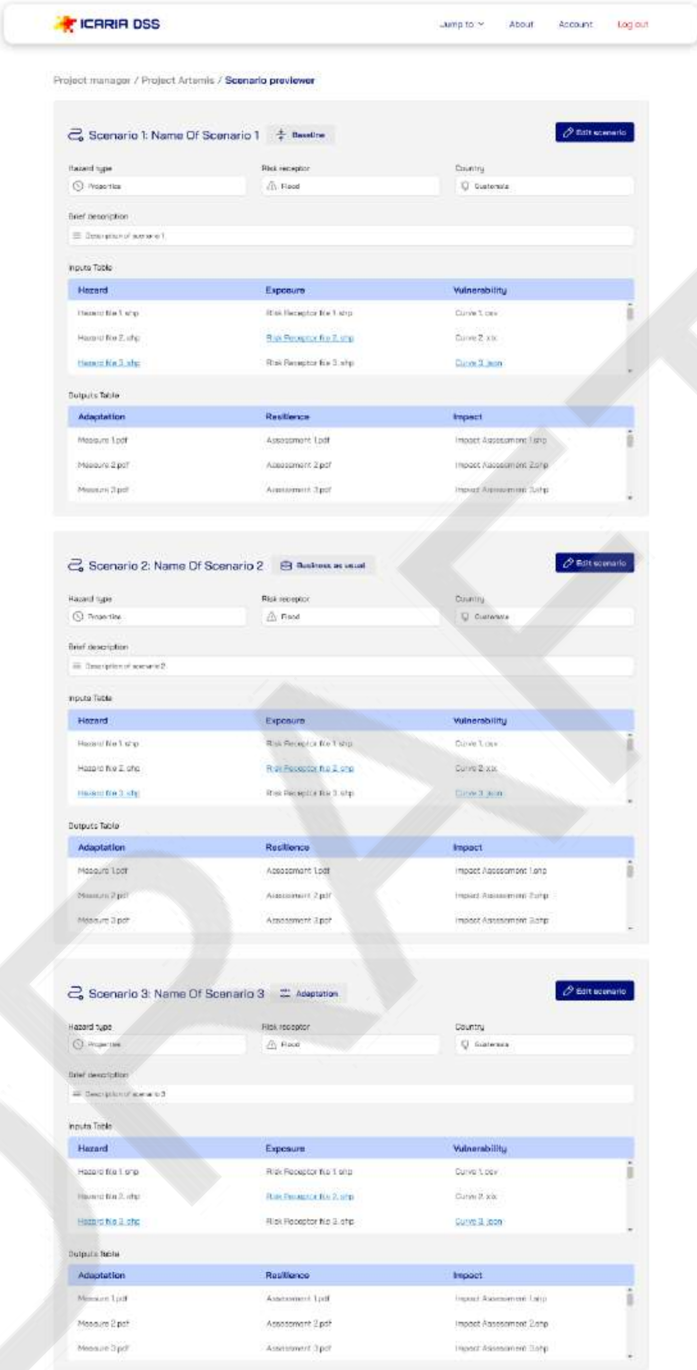

Figure 68: Project Manager - Scenario preview mockup.

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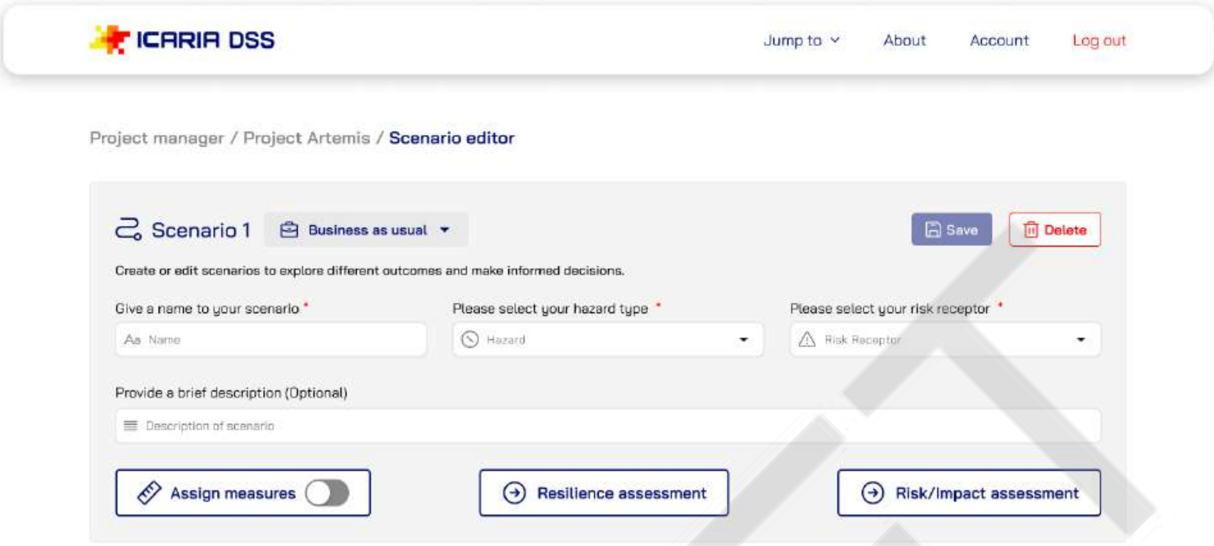

Figure 69: Project Manager - Scenario editing mockup.

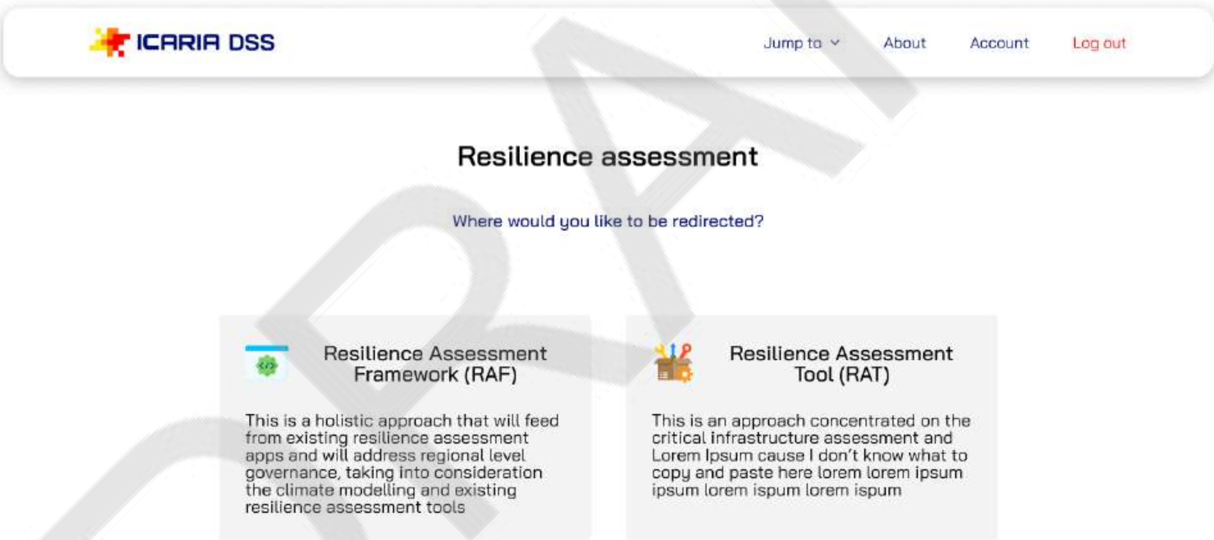

Figure 70: Resilience Assessment App Selection mockup.

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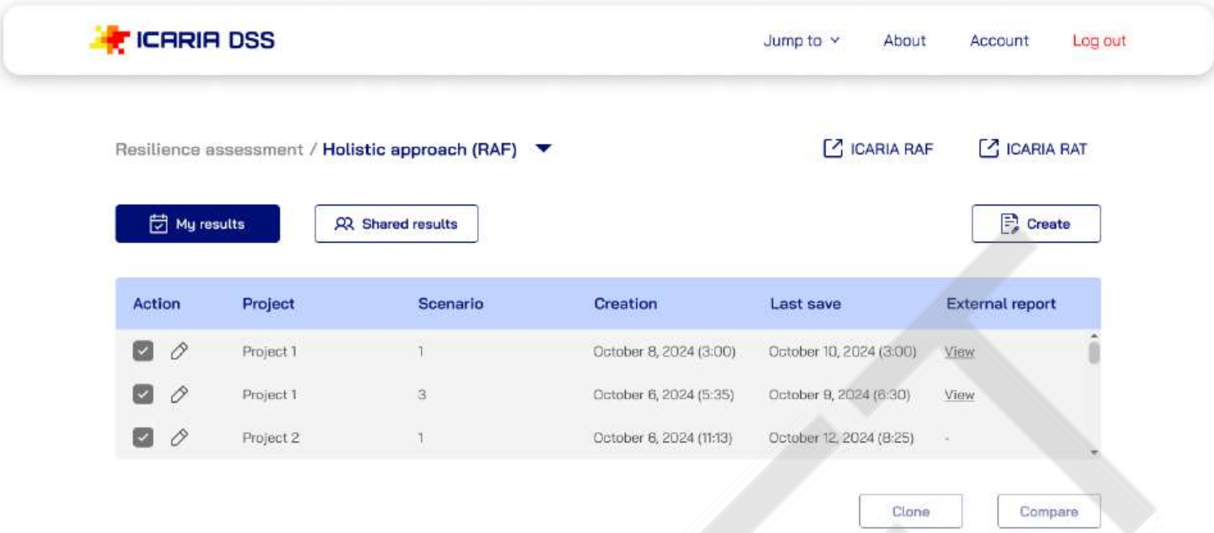

Figure 71: Resilience Assessment - RAF 1 mockup

Figure 72: Resilience Assessment - RAF 2 mockup.

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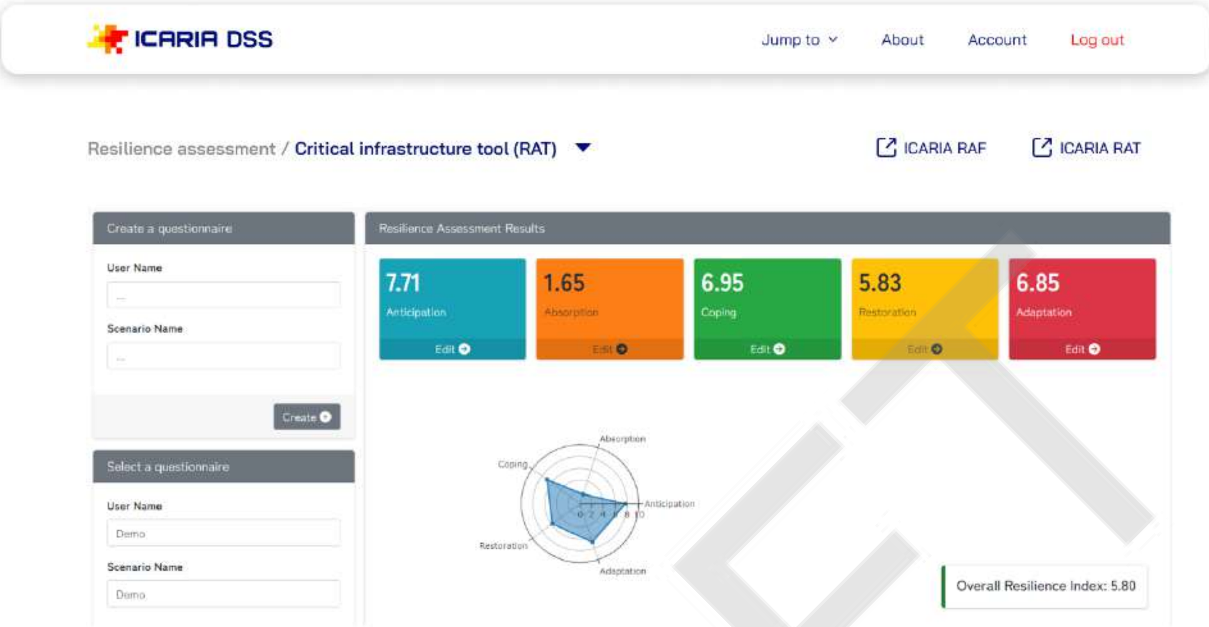

Figure 73: Resilience Assessment - RAT mockup.

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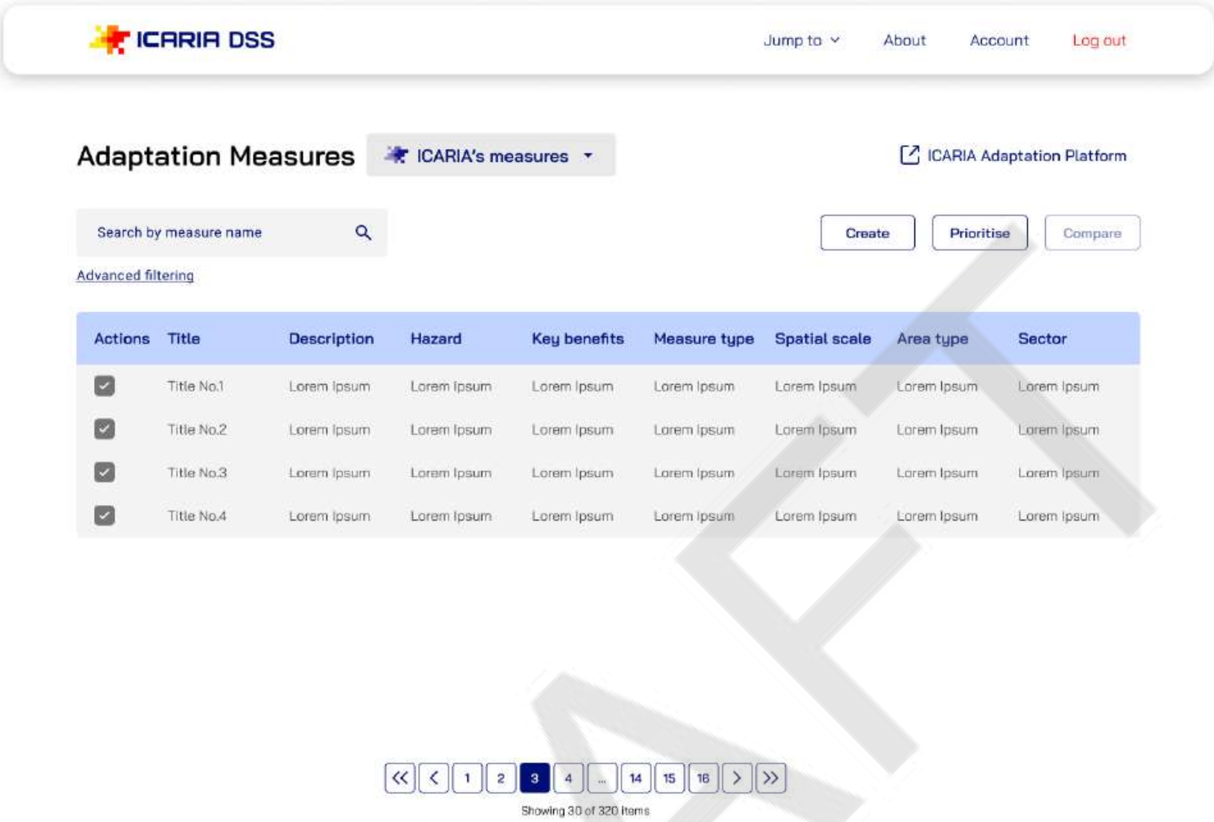

Figure 74: Adaptation Measures mockup.

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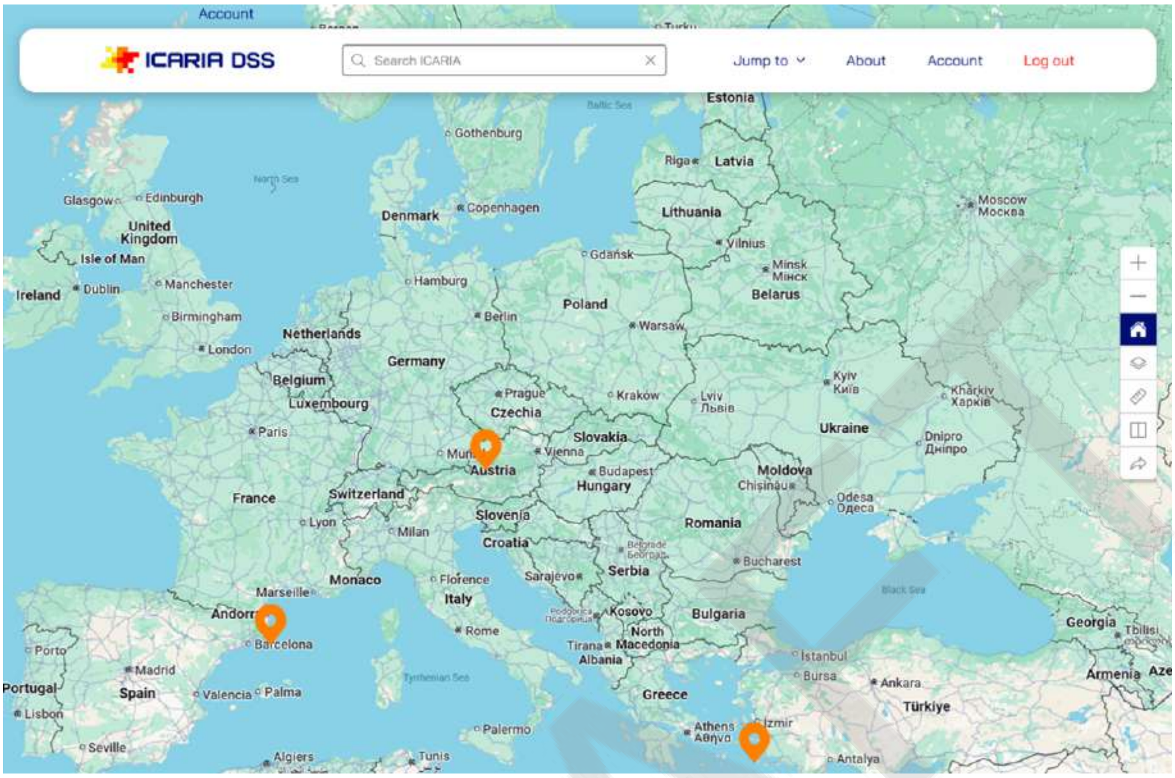
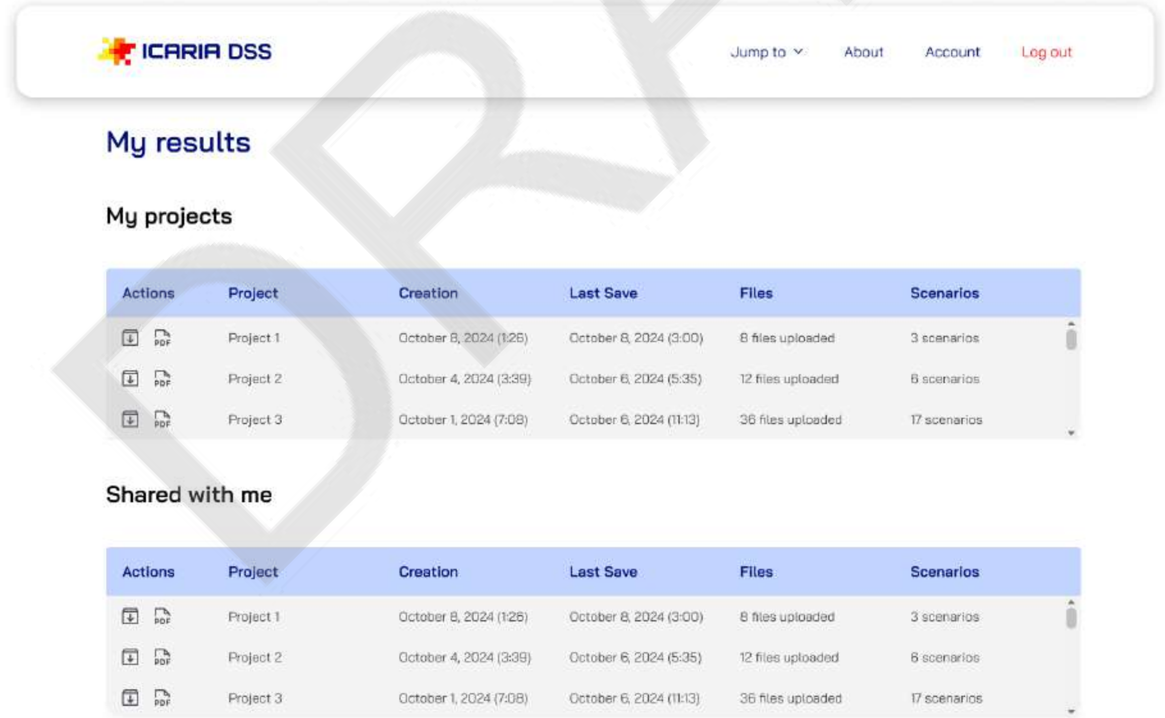


Figure 75: Map Viewer mockup.



My results

My projects

Actions	Project	Creation	Last Save	Files	Scenarios
PDF	Project 1	October 8, 2024 (1:26)	October 8, 2024 (3:00)	8 files uploaded	3 scenarios
PDF	Project 2	October 4, 2024 (3:39)	October 6, 2024 (5:35)	12 files uploaded	6 scenarios
PDF	Project 3	October 1, 2024 (7:08)	October 6, 2024 (11:13)	36 files uploaded	17 scenarios

Shared with me

Actions	Project	Creation	Last Save	Files	Scenarios
PDF	Project 1	October 8, 2024 (1:26)	October 8, 2024 (3:00)	8 files uploaded	3 scenarios
PDF	Project 2	October 4, 2024 (3:39)	October 6, 2024 (5:35)	12 files uploaded	6 scenarios
PDF	Project 3	October 1, 2024 (7:08)	October 6, 2024 (11:13)	36 files uploaded	17 scenarios

Figure 76: Results mockup.

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Appendix 4: User Testing Scripts

This appendix provides examples of user testing scripts, which include instructions and tasks to be carried out during the system trial. These scripts will be applied in WP4 to evaluate the usability and effectiveness of the DSS. By standardising the testing process across regions, they help ensure that feedback is collected consistently and can be compared to refine the DSS in subsequent iterations. Some elements are highlighted in red to indicate that they will be refined by the facilitators after delivery of the DSS and before the start of the trials. The current scripts are therefore considered preliminary.

Table 16: Testing Script 1: Project Manager.

Prerequisites	Goal	Steps	
Credentials have been provided	N/A	**1. Login** From the landing page, click the "Sign in / Sign up" button located in the top-right corner or ""Start now"" Enter the credentials provided to you and log in. **2. Create a project** Once in the Project Manager, click "Create Project". Fill in the required fields and create the project. After creation, locate your project in the list and click on it to open. **3. Create a scenario** Inside the project, click the "New Scenario" button. Fill in all required fields and click "Save".	
Component tested	**Expected behavior**	**Estimated time to complete**	**Notes**
Authentication Project Manager	System successfully: → Signs the user in → Creates and saves new projects → Creates and saves new scenarios	≈3-5 minutes	1. The Project Manager remains accessible from the "Jump To" button on the header

Table 17: Testing Script 2: Risk/Impact Assessment + Map Viewer.

Prerequisites	Goal	Steps
User is logged in A project has been created A scenario has been created Sample data has been provided (optionally)	As a risk owner in regional government / As an expert in hazard risk assessments, I want to understand the expected risk/impact of hazard to risk receptor in region and find out how climate parameters are projected to change	**1. Risk/Impact assessment** From the Project Manager, select a project from the list by clicking on it. Click on the ""Edit"" button on the created scenario for which to conduct the impact assessment. Select the tab labeled "Risk/Impact Assessment" which appears below your scenario. Following the provided instructions, upload data for Hazard, Exposure, Vulnerability Once all data is uploaded and validated, click "Submit Risk/Impact Assessment" to initiate impact calculation. **2. Monitor progress and view results**

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		Monitor calculation progress via the R.I.A. Manager, located in the bottom-right corner and in the header. When the assessment is complete, click on the completed entry in the R.I.A. Manager. You will be redirected to the Map Viewer to see the results. **3. Explore the map and inspect data** Use click and drag to navigate the map. Zoom in/out using your mouse scroll wheel or the +/– buttons at the bottom right. Click on a data point in the relevant area of the map to open a popup showing the attribute table for that point. **4. Add climate projection layers** Still in the Map Viewer, click "Add Layer" at the top-left. From the catalogue, select the desired downscaled climate projection layers by clicking "Add". Close the catalogue window once done and explore the selected layers as in step 3.

Component tested	Expected behavior	Estimated time to complete	Notes
Risk/Impact Assessment Data Visualisation / Maps	System successfully: → Processes, validates and saves the uploaded data → Executes the impact assessment algorithm for the selected hazard/risk receptor pair → Returns a geospatial layer with the results of the impact assessment → Displays the risk/impact results and climate change projections on the map	≈10-15 minutes (depending on data size and upload speed)	1. It is possible to delete and re-upload the required data for an impact assessment for a given scenario 2. In the map viewer you can temporarily disable or enable individual layers by the toggle button to reduce the number of active data layers on the same area

Table 18: Testing Script 3: Adaptation Measures + Resilience Assessment.

Prerequisites	Goal	Steps
User is logged in A project has been created A scenario has been created"	I want to understand what measures for mitigating hazard risks I could use and to find out the current resilience of risk receptor to hazards	**1. Resilience assessment** From the ""Jump to"" button in the header, select Resilience Assessment. Choose the Resilience Assessment Framework (RAF) option. Click "Create RAF" in the top-right corner to start a new assessment. Select the project and scenario you want to assess. Check the box to "Complete a new RAF Questionnaire" and click "Next". Fill in all questions in the questionnaire with appropriate responses. **2. View RAF results**

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		Once the questionnaire is complete, click "View Result". Review the results displayed in the RAF donut chart. When finished, close the popup. **3. Explore adaptation measures** Again from the ""Jump to"" button in the header, select Adaptation Measures. Use the search bar and/or filters to explore relevant adaptation measures. For any measure of interest, click the three dots under the ""Actions"" column and select "View" to see more details.

Component tested	Expected behavior	Estimated time to complete	Notes
Adaptation Measures Resilience Assessment Framework (RAF)	System successfully: → Offers a list of relevant mitigation measures based on user needs → Provides targeted resilience results	≈15-20 minutes	1. To access the Resilience Assessment or Adaptation Measures functionality from the Project Manager, select a project from the list by clicking on it and then click on the ""Edit"" button on the desired scenario 2. It is possible to assign multiple measures to a scenario 3. This script can also run with RAT instead of RAF

Table 19: Testing Script 4: Multiple Functionalities.

Prerequisites	Goal	Steps
User is logged in A project has been created A baseline scenario has been created Sample data has been provided (optionally)"	I want to understand how the impact of a hazard would change if some of the selected measures are implemented, and also look at how resilience changes	**1. Create adaptation scenario** In the Project Manager select a project from the list by clicking on it. Click on the "New Scenario" button. Create a new scenario with the same parameters as the Baseline one, but select Scenario Type=Adaptation. **2. Assign adaptation measures** Find the measures you want to assign from the list by using the search bar and/or filters. To assign a measure to your scenario, click the three dots under the ""Actions"" column and select "Assign". Choose the appropriate project and scenario from the dropdown lists. Confirm the assignment by clicking "Assign". **3. Resilience assessment** Switch to the next tab labelled ""Resilience Assessment"" and choose the Resilience Assessment Framework (RAF) option. Check the box to "Complete a new RAF Questionnaire" and click "Continue". Fill in all questions in the questionnaire with appropriate responses.

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		4. View RAF results Once the questionnaire is complete, click "View Result". Review the results displayed in the RAF donut chart. When finished, close the popup. **5. Risk/Impact assessment** From the ""Jump to"" menu in the header select the Project Manager. Return to the project and scenario you were working on. Select the tab labelled "Risk/Impact Assessment" which appears below your scenario. Following the provided instructions, upload data for Hazard, Exposure, Vulnerability which take into account the changes introduced by the assigned adaptation measures. Once all data is uploaded and validated, click "Submit Risk/Impact Assessment" to initiate impact calculation. **6. Monitor progress and view results** Monitor calculation progress via the R.I.A. Manager, located in the bottom-right corner and in the header. When the assessment is complete, click on the completed entry in the R.I.A. Manager. You will be redirected to the Map Viewer to see the results. **7. Explore the map and inspect data** Use click and drag to navigate the map. Zoom in/out using your mouse scroll wheel or the +/– buttons at the bottom right. Click on a data point in the relevant area of the map to open a popup showing the attribute table for that point. **8. Extract report** From the ""Jump to"" menu in the header head to Results. Find the project you have been working from the list and click on the View option under the Actions column. Upon clicking you will generate the report which shows the outputs of both baseline and adaptation scenarios for easy comparison and reporting on the resilience and impact metrics. Download the report in PDF

Component tested	Expected behavior	Estimated time to complete	Notes
Project Manager Adaptation Measures Resilience Assessment Framework (RAF) Risk/Impact Assessment	System successfully: → Creates new scenarios → Offers a list of relevant mitigation measures based on user needs → Provides targeted resilience results	≈25-30 minutes (depending on data size and upload speed)	1. This script can also run with RAT instead of RAF

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Data Visualisation / Maps Results Reporting	→ Processes, validates and saves the uploaded data → Executes the impact assessment algorithm for the selected hazard/risk receptor pair → Returns a geospatial layer with the results of the impact assessment → Displays the risk/impact results and climate change projections clearly on the map → Generates report showing differences in both impact and resilience scores		

Table 20: Testing Script 5: Map Viewer.

Prerequisites	Goal	Steps	
User is logged in	I want to consult ICARIA's climate projections to inform my modelling or understand future climate events for indicators of interest	**1.Add climate projection layers in the map viewer** Navigate to the Map Viewer from the ""Jump to"" button in the header. Click "Add Layer" at the top-left and navigate the catalogue of available layers by clicking on the folders. Select the desired downscaled climate projection layers by clicking "Add" next to each one. Close the catalogue window once done. All added layers will be listed on the left panel and active on the map. **2. Explore the map and inspect data** Use click and drag to navigate the map. Zoom in/out using your mouse scroll wheel or the +/– buttons at the bottom right. Click on a data point in the relevant area of the map to open a popup showing the attribute table for that point. **3. Compare data** To compare two climate projection layers, click on the Split view button on the right side of the screen. Once activated, select two layers to proceed with the comparison by clicking on the icon with the circles appearing next to each layer on the left panel. The two layers will be placed each on one side of the map. Drag the slider left or right to expose more data on either side. **4. Export** From the buttons on the right side of the screen, click on the Record or Screenshot options to document what is rendered on the map for external use.	
Component tested	**Expected behavior**	**Estimated time to complete**	**Notes**

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Authentication Data Visualisation / Maps	System successfully: → Allows loading and selection of climate projections → Offers the ability to compare climate projection layers side-by-side → Extracts information for use in external communications or reports	≈8-10 minutes	1. If multiple layers have been selected, from the list of added layers on the left panel, click and drag a layer (up or down) to change the order of appearance on the map. The topmost layer on the left panel will be overlayed on top of all other layers on the map 2. Use the toggle button next to each layer to enable or disable it from appearing on the map

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Appendix 5: RAF Assessment Questions

This Appendix lists the questions included in the DSS as part of the RAF questionnaire.

Table 21: Questions included in the RAF Questionnaire.

PI Code - PI Name (Unit *)	Question	Source	Metric Type	Observations
30b - Critical infrastructure plan overview	Is there a critical infrastructure plan or strategy and is it implemented?	UNISDR	Single choice	-
101 - Knowledge of exposure and vulnerability to each hazard	Existence of scenarios setting out area-wide exposure and vulnerability from each hazard level	UNISDR	Single choice	-
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	UNISDR	Single choice	-
105- Urban footprint at risk for climate change scenarios	Percentage of urban footprint at risk, according to climate change scenarios	RESCCUE	Single choice	Consider urban footprint as a spatial extent of urbanized areas on a regional scale.
105b- Natural areas at risk for climate change scenarios	Percentage of urban footprint at risk, according to climate change scenarios	ICARIA	Single choice	-

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106 - Economic activity at risk for climate change scenarios	Percentage of economic activity at risk from climate change scenarios	UNISDR	Single choice	-
109 - Urban design solutions that increase resilience	Does the city implement urban design solutions tasked to improve resilience?	UNISDR	Single choice	If the answer is yes, this metric allows to specify solutions in comments.
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?	ICARIA	Multiple choice	Please select one or more of the options provided as answers. Final development level equals the Sum the selected answers. In "other", some examples might be, among others: access to people with disabilities; creation of air ventilation corridors between buildings; water efficiency in internal water networks; overall energy efficiency of the buildings.
118 - Existing protective infrastructure	Is existing protective infrastructure designed and built according to risk information?	UNISDR	Single choice	Protective infrastructures such as: sea walls, levees and flood barriers, shelters (e.g. tornado/hurricane shelters).
123 - Trends in ecosystem services health	Change in health, extent or benefit of each ecosystem service in last 5 years	UNISDR	Single choice	-

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125 - Availability of green and blue infrastructures (m2/inhabitant)	Estimated green and blue area per inhabitant	RESCCUE	Single choice	It includes greening streets, squares, roadsides and parks, greening roofs and facades, urban agriculture, green corridors, natural water filtration, open urban rivers, wetlands, lakes and other waterways.
F13 - Expected service interruptions according to climate change scenarios (% of affected area)	Percentage of the area expected to be affected by service interruptions exceeding 6h according to climate change scenarios	ICARIA	Single choice	The answer might depend of the service under assesment: water supply, wastewater management, waste collection
P21 - Use of design solutionsby utilities to improve the resilience of the area	The design of the infrastructure by utilities incorporate the use of the following solutions to improve overall resilience	RESCCUE	Multiple choice	Design solutions used by service providers that contribute to the city's resilience. E.g., any entity in its office buildings may have green roofs or porous floors in the parking lot. Please select one or more of the options provided as answers. The answer might depend of the service under assesment: water supply, wastewater management, waste collection,... Please select one or more of the options provided as answers. Final development level equals the Sum the selected answers.

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P23 - Greenhouse gas emission target	There is a prediction of GHG emissions reduction, aiming at the targets defined at the strategic planning level, from the following components of assets:	RESCCUE	Multiple choice	The answer might depend of the service under assesment: water supply, wastewater management, waste collection,... Please select one or more of the options provided as answers. Final development level equals the Sum the selected answers.
P25 - Exposure of critical infrastructure assets to the most probable scenario (%)	Percentage of critical infrastructure assets exposed to different hazards for climate change scenarios	RESCCUE	Single choice	The answer might depend of the service under assesment: water supply, wastewater management, waste collection,...
F52 - Implemented measures to address climate change mitigation and adaptation	What type of measures are implemented to address climate change mitigation and adaptation?	ICARIA	Multiple choice	Please select one or more of the options provided as answers. Final development level equals the Sum the selected answers.
P28 - Implemented infrastructural measures to address climate change mitigation and adaptation[5]	How many different types of measures were implemented in infrastructure design to address climate change mitigation and adaptation? Please select the services under assessment: - Water supply	ICARIA	Multiple choice	(Observations are dynamic, based on the service selected)

[5] P28 generates more questions based on the selection of services under assessment. For each selected service a single-choice question is created where the user answers how many different types of measures were implemented in infrastructure design to address climate change mitigation and adaptation.

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	- Wastewater - Stormwater - Waste - Energy - Mobility - Natural areas			

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Appendix 6: User Guide

This appendix provides the link to the User Guide accompanying the DSS. The guide explains how to use the DSS, describes its main components, and provides step-by-step instructions for navigation, supporting accessibility and broader uptake of the tool. Because the document is extensive, it is not reproduced here in full. Instead, it is directly integrated into the "About" page of the DSS platform, where all users (even unregistered visitors) can access detailed instructions while working with the platform.

https://icaria.draxis.gr/about

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Appendix 7: ICARIA Processing API for Impact Assessment

This section introduces the ICARIA Processing API and how users can work with it in practice. The API provides asynchronous geospatial processing for **flood** and **wildfire** impact assessments over simple HTTP endpoints. The service is implemented in Python[6] using FastAPI[7] for the HTTP layer and Pydantic[8] for request validation and response serialisation. Long-running- geospatial computations run as Celery[9] tasks so the API can return immediately while work continues in the background; Celery manages the task queue and executes jobs outside the web process. Redis[10] serves as the message broker and state backend for Celery, and it also powers a lightweight publish/subscribe channel used by the SSE status stream. The API runs on Uvicorn[11] (ASGI) and is typically packaged with Docker[12] and orchestrated with **docker-compose** for deployment. In parallel, development of the windstorm (air) endpoints is advancing, with their integration planned for a forthcoming release of the DSS. This extension will broaden the processing capabilities of the API by adding windstorm assessments alongside the already operational flood and wildfire services.

Base URL: http://[HOST]:8050/ and includes a built-in Swagger UI, which is available at GET /api-docs for interactive exploration.

Users submit inputs via multipart/form-data and immediately receive a *job_id* and a *task_id*. Processing continues in the background. Users can follow progress in real time with **Server Sent Events** at GET /stream/{job_id} or, if streaming is not possible, by polling GET */jobs/{job_id}/status?task_id=*"…"*.* When the job completes successfully, users download a ZIP of GISready outputs from GET */jobs/{job_id}/download*. Optionally, a callback_url may be included when creating the job, so that the service sends a notification to the client system upon completion of processing.

Every job follows the same sequence: inputs are submitted, a *job_id* and *task_id* is issued, the status is monitored, and finally the results are downloaded once they are available. The streaming status endpoint emits compact JSON messages such as {*"job_id": "…", "status": "SUCCESS" | "FAILURE"*}. The polling endpoint returns one of the following states: *PENDING*, *STARTED*, or *SUCCESS*; failures are exposed as HTTP 500 errors with a descriptive message. When a job reaches SUCCESS, the archive must be fetched from the download endpoint. Result archives are temporary and are scheduled for deletion approximately ten minutes after a successful download. If a *callback_url* is provided, the service will notify the system upon completion

What's included:

[6] https://www.python.org/
[7] https://fastapi.tiangolo.com/
[8] https://docs.pydantic.dev/latest/
[9] https://docs.celeryq.dev/en/v5.5.3/index.html#
[10] https://redis.io/
[11] https://www.uvicorn.org/
[12] https://www.docker.com/

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- **Endpoints:** job creation for Flood (Custom), Flood (EU Standard), and Wildfire; status (SSE + polling); results download; and the API documentation UI.
- **Inputs:** uploads are usually a single .zip containing shapefiles (with sidecars) and, where applicable, CSV look-up tables. Flood endpoints expect hazard layers with DEPTH2D/SPEED2D; the EU Standard additionally requires a country code and specific building attributes; Wildfire requires an archive and a receptor selection, with optional bounding box and cost options.
- **Outputs:** a ZIP archive with shapefiles suitable for mapping/analysis. Flood results include aggregated economic loss (e.g., a cost field) over the provided impact areas. Wildfire results include per receptor risk components and a combined risk score. Status is always JSON over SSE/polling.
- **Error handling:** missing required form fields return **422**; malformed archives or processing errors surface as **500**; the download returns **404** until results exist (and after cleanup). SSE streams may drop due to network/interruption; clients should reconnect.
- **Operational notes.** Results archives are temporary and scheduled for cleanup shortly after a successful download (about ten minutes). For Flood (Custom), supply inputs in a projected metric CRS because this method does not perform automatic reprojection. The EU Standard method automatically reprojects inputs to EPSG:3035. Prefer the streaming status feed for responsive user interfaces and fall back to polling where needed.

Summary of endpoints

Pluvial Flood (AMB model method, Path 1)

This endpoint can be used when the project-specific custom methodology for pluvial flood loss estimation is required. Geospatial layers are uploaded as a single ZIP, and a *job_id* and a *task_id* is returned immediately, while processing continues in the background. This method expects a projected metric CRS and project-specific building attributes, making it suitable when curated exposure data and custom cost/permeability tables are already maintained

Table 22: Endpoint Pluvial Flood (AMB model Method, Path1) overview.

Flood (AMB model Method, Path1) endpoint	
URL	http://[HOST]:8050/flood_custom/
Description	Kick off the *custom* flood workflow by uploading the necessary geospatial inputs (supports uploading a ZIP that is extracted server-side). Returns a job identifier and Celery task ID.
Format	• **Request**: multipart/form-data • **Response**: application/json
HTTP METHOD	POST

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For reliable results, the buildings, hazard, and impact layers should be included in the ZIP along with any required CSV lookup tables. Nested ZIPs should be avoided and shapefile “sidecar” files (.dbf, .shx, .prj, .cpg) need to be present. When the upload is accepted, the service immediately schedules a background task and returns identifiers which can be used to monitor the run via the SSE stream or the polling endpoint.

Table 23: Form-data fields of Pluvial Flood (AMB model Method, Path1) endpoint.

Flood (AMB model Method, Path1) request form-data fields			
Name	**Type**	**Required**	**Description**
files	File []	Yes	One or more files. Prefer a single .zip containing all required shapefiles/CSVs (see **ZIP contents & schema**). The server extracts and places files appropriately
callback_url	String (URL)	No	Optional webhook to receive/upload the result upon completion.

Table 24: Response of Pluvial Flood (custom method) endpoint.


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


Errors:

- **422 Unprocessable Entity**: Missing required form parts (files).
- **500 Internal Server Error**: Corrupt/invalid ZIP during extraction, missing required files, or exceptions during upload staging/processing.
- **Async failures**: The POST may succeed but the background job can still fail. Check GET /stream/{job_id} (SSE) or GET /jobs/{job_id}/status?task_id=… — failures return status FAILURE (polling returns **500** with an error message).
- **404 Not Found** (when downloading): Results not ready or already deleted.

If the job later fails during processing, the status endpoints will report FAILURE. In that case, the ZIP contents can be reviewed (schemas, CRS, and field names) to correct any issues, and the job can be resubmitted with the same approach.

Pluvial Flood (Global default values (EU Standard) method, Path 2)

This endpoint can be used when an implementation aligned with EU-standard practice is needed. It accepts a ZIP of inputs like the custom method but relies on a country code to select standardised unit costs and damage curves. Inputs may be in any CRS; they are reprojected internally to EPSG:3035 for area-accurate calculations.

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Table 25: Endpoint Pluvial Flood (EU standard method) overview.

Flood (EU Standard Method) endpoint	
URL	http://[HOST]:8050/flood_eu_standard /
Description	Kick off the *EU-standard* flood workflow by uploading the required inputs and specifying the target country (ISO code). Returns a job identifier and Celery task ID.
Format	• **Request**: multipart/form-data • **Response**: application/json
HTTP METHOD	POST

Attention must be paid to building attribute names: the shapefile column for residential must be RESIDENTIA (ten-character limit). An unknown or misspelt country code will surface as a processing error. Once a request is accepted, a *job_id* and *task_id* is received and progress can be tracked via SSE or polling just like the custom method.

Table 26: Form-data fields of Pluvial Flood (EU standard method) endpoint.

Flood (EU Standard Method) request form-data fields			
Name	**Type**	**Required**	**Description**
files	File []	Yes	One or more files. Prefer a single .zip containing all required shapefiles (see **ZIP contents & schema**).
country	String	Yes	ISO country code used to look up unit costs from internal tables. Must exist in the server's country mapping; otherwise processing fails.
callback_url	String (URL)	No	Optional webhook to receive/upload the result upon completion.

Table 27: Response of Pluvial Flood (EU standard method) endpoint.


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


Errors:

- **422 Unprocessable Entity**: Missing required form parts (files, country).

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- **500 Internal Server Error**: Corrupt/invalid ZIP during extraction, missing required files, or unknown country in the internal mapping.
- **Async failures**: The POST may succeed but the background job can still fail. Check GET /stream/{job_id} (SSE) or GET /jobs/{job_id}/status?task_id=... — failures return status FAILURE (polling returns **500** with an error message).
- **404 Not Found** (when downloading): Results not ready or already deleted.

FAILURE on status endpoints are caused by missing mandatory columns, non-numeric hazard attributes, or a country code not present in the server's cost tables. Once the input is fixed another attempt can be made.

Wildfires (EU Standard Method)

This endpoint can be used to run the wildfire impact workflow. A single ZIP archive is submitted together with analysis options describing the receptor of interest and, optionally, a bounding box. The service produces per-receptor risk layers and a combined risk score that can be mapped together.

Table 28: Endpoint wildfires overview.

Wildfires (EU Standard Method) endpoint	
URL	http://[HOST]:8050/fire/
Description	Run the wildfire workflow by uploading a ZIP archive containing all required layers and specifying analysis options (receptor, bounding box, costs). Returns a job identifier and Celery task ID.
Format	• **Request**: multipart/form-data • **Response**: application/json
HTTP METHOD	POST

The receptor flag determines the primary lens—natural assets, people, or properties. For properties, a cost mode must be chosen as well as cost_per_sqm for per-square-meter costing. If a CORINE land-cover layer is included in the ZIP, use_corine_shp=true shoud be set. Providing a bounding box usually speeds up processing by clipping the analysis to the area of interest.

Table 29: Form-data fields of wildfires endpoint.

Wildfires (EU Standard Method) request form-data fields			
Name	**Type**	**Required**	**Description**
archive	File	Yes	A .zip containing all layers (FWI and optional Population/ Buildings/*corine_areas*). Extracted server-side.

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receptor	String	Yes	Target asset-of-interest. Choose: **"natural"** (ecological habitats / land cover), **"people"** (population exposure & density), or **"properties"** (buildings & infrastructure). All runs produce eco_risk, pop_risk, econ_risk and a combined risk_score; this flag declares the primary lens and enables cost options for "properties" (see cost_mode / cost_per_sqm).
use_corine_shp	Bollean	No	If true, use the provided CORINE land-cover layer contained in the ZIP.
min_lon	Float	No	Bounding box minimum longitude.
min_lat	Float	No	Bounding box minimum latitude.
max_lon	Float	No	Bounding box maximum longitude.
max_lat	Float	No	Bounding box maximum latitude.
cost_mode	String	No	Cost mode for buildings when receptor = properties: **per_sqm** (default) or **per_feature.**
cost_per_sqm	Float	Conditional	**Required if** cost_mode = per_sqm and receptor = properties.
callback_url	String (URL)	No	Optional webhook to receive/upload the result upon completion.

Table 30: Response of Wildfire endpoint.

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

Errors:

- 400 Bad Request if the uploaded archive is not a valid ZIP.
- 422 Unprocessable Entity for invalid combinations (e.g., missing *cost_per_sqm* when required; invalid receptor value).

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Invalid ZIP files return an immediate 400, while missing or inconsistent options return 422. If a long-running job fails, the status feed will switch to FAILURE; corrections to options and data layers should be made in order to submit a new job.

Stream Job Status

The streaming status endpoint is the preferred way to monitor jobs in real time. It keeps a single HTTP connection open and pushes compact JSON messages as the backend updates the job state. This is ideal for dashboards and interactive UIs.

Table 31: Stream Job Status (SSE) endpoint information.

Stream Job Status (SSE) endpoint	
URL	http://[HOST]:8050/stream/{job_id}
Description	Server-Sent Events (SSE) stream that pushes job status updates as text/event-stream. Each message data: line is a JSON object with *job_id* and status (SUCCESS or FAILURE).
Format	• **Response:** text/event-stream (messages with JSON payloads)
HTTP METHOD	GET

Most browsers support SSE via the EventSource API, and command-line tools like curl can consume the stream as well. If a proxy or network device closes idle connections, it is possible to reconnect with a short back-off. Streaming is read-only: jobs cannot be cancelled here - orchestration tools should be used for that.

Table 32: Response of Stream Job Status.

```
{
"job_id": "<uuid>",
"status": "SUCCESS"
}
```

Notes:

- The connection remains open until the client disconnects.
- If *job_id* is unknown, the stream still opens but no messages will arrive.

Errors

- **500 Internal Server Error**: Backend messaging (Redis) unavailable or subscription fails; the connection may close immediately.
- **Network disconnects**: Clients should implement reconnection/backoff (standard EventSource behavior).

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Poll Job Status (Polling Feedback)

Polling can be used when streaming is not feasible (for example, in environments where long-lived connections are blocked). The endpoint returns a simple JSON status for the provided *job_id* and *task_id*.

Table 33: Polling Endpoint for Celery Task Status by Job ID.

Poll Job Status (Polling Fallback) endpoint	
URL	http://[HOST]:8050/jobs/{job_id}/status?task_id=<celery_task_id>
Description	Returns the Celery task state (PENDING, STARTED, SUCCESS) for the specified *task_id* associated with *job_id*.
Format	• **Response:** application/json
HTTP METHOD	GET

Table 34: Response for Pol Job Status.

```
{
"job_id": "<uuid>",
"status": " PENDING|STARTED|SUCCESS "
}
```

Errors:

- **500** (Failure or revoked): { "job_id": "...", "status": "FAILURE", "error": "..." }

A practical polling cadence is every five to fifteen seconds. Any 500 responses can be treated as a failure signal from the background task. After logging the accompanying error message for diagnostics, it is possible to decide whether to resubmit.

Download results

When a job reaches SUCCESS, the outputs can be retrieved as a single ZIP archive. The archive contains GIS-ready layers with standard shapefile sidecars, available to open with GIS tools.

Table 35: Download results endpoint.

Download results endpoint	
URL	http://[HOST]:8050/jobs/{job_id}/download

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Description	Downloads the generated results ZIP for the given job. If results are not yet available, returns 404. After a successful download, the ZIP is scheduled for deletion ~10 minutes later.
Format	• **Response:** application/zip
HTTP METHOD	GET

Table 25: Download results endpoint.

Errors

- **404 Not Found**: Results are not ready or have been deleted.

Where there is a 404 response, the results are not yet available or were already cleaned up after a previous download. In automated clients, SUCCESS via SSE or polling must be confirmed before calling the download endpoint; the ZIP can be then stored in one's own persistence layer.

API Documentation UI

The built-in Swagger UI offers an interactive way to explore the API, upload files, and try out requests without writing code. It mirrors the behavior of the live endpoints, making it useful for quick smoke tests and for sharing reproducible examples with collaborators.

Table 36: API Documentation UI information.

API Documentation UI	
URL	http://[HOST]:8050/api-docs
Description	Serves the bundled Swagger UI for interactive exploration of the API.
HTTP METHOD	GET

The Swagger UI is grouped by resource: **flood** (POST /flood_custom/, POST /flood_eu_standard/), **fire** (POST /fire/), and **system** utilities (GET /stream/{job_id}, GET /jobs/{job_id}/status, GET /jobs/{job_id}/download) and the **Schemas** panel lists JobCreated, StatusResponse, and Error. This UI lets users expand each operation to view parameters, try requests with sample payloads, and see live responses, which makes it ideal for quick smoke-tests and onboarding. Labels and descriptions are

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localised (Greek in this example), but the underlying endpoints and behaviour are identical across environments.

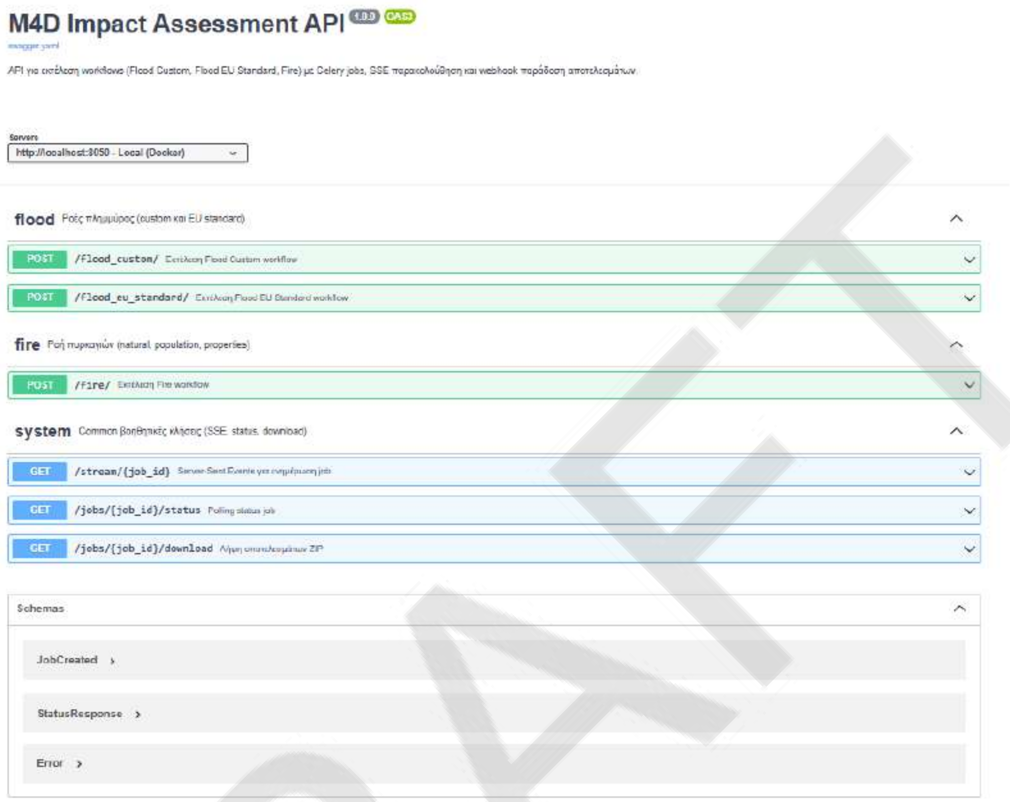

Figure 77: API Documentation UI.

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Appendix 8: Data Management Statement

Table 37: Data used in preparation of ICARIA DSS (version 1).

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	-
Adaptation measures (T3.3)	API	N/A	ICARIA Consortium	Use inside the DSS	www.icariastrategies.eu/measures

Table 38: Data produced in preparation of ICARIA DSS (version 1).

Dataset name	Format	Size	Owner and re-use conditions	Potential Utility within and outside ICARIA	Unique ID
Impact assessment results	shp	Depends on input data	Results are only available to authorised users with appropriate permissions to each	Downloadable geospatial files generated by users inside the DSS to be used as they see fit	N/A

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			generated result. There is currently no limitation for reuse.		

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

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