Clim
EMPOWER

CLIMEMPOWER SCENARIOS

ClimEmpower Work Package 1, D1.2

Project ClimEmpower: User Driven Climate Applications Empowering Regional Resilience

Work package 1, Deliverable D1.2

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Coordinator:	Denis Havlik, Scientist AIT Austrian Institute of Technology Giefinggasse 4, 1210 Vienna, Austria
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Lead:	Argamasilla, Manuel - CET
Author(s):	Argamasilla, M. (CETAQUA), Spain Molina, P. (AQUATEC), Spain, Solano, F. (ANDALUS), Spain, Tötzer, T. (AIT), Austria Bügelmayer-Blaschek, M. (AIT), Austria Havlik, D. (AIT), Austria Boutsis, S. (PSTE), Greece Forjan, R. (OBZ-AZP), Croatia Vurnek, M. (FER), Croatia Christou, P., Xekalakis, G. (FRC), Cyprus Prisco, M., Pavone, V. (PLINIVS), Italy

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04.06.2024	Final deliverable	Denis Havlik (AIT) → EC	Finalization and upload to Participants portal

Legal Disclaimer

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List of Acronyms

AIT	Austrian Institute of Technology GMBH
ANDALUS	Consejería de Sostenibilidad, Medio ambiente y Economía Azul
ANET	Anaptixiaki eteria kinotiton periochis troodoys ltd
AQUA	AQUATEC – Proyectos para la gestión del agua
CASCADE	CASCADE - Community Safety Action for Supporting Climate Adaptation and Development (European Civil Protection and Humanitarian Aid Operations, 2019-2021; https://www.cascade-bsr.eu/)
CASCADES	CASCADES - CAScading Climate risks: towards ADaptive and resilient European Societies (HORIZON 2020 program, LC-CLA-03-2018, Grant agreement ID: 821010, 2019-2023; https://cordis.europa.eu/project/id/821010)
CC	Climate Change
CER	Critical Entities Resilience Directive
CERTH	Ethniko kentro erevnas kai technologikis anaptyxis
CET	CETAQUA
CLIMAAX	CLIMAAX - CLIMAte risk and vulnerability Assessment framework and toolboX (HORIZON-MISS-2021-CLIMA-02-01, Grant agreement ID: 101093864, 2023-2026; https://cordis.europa.eu/project/id/101093864)
CLIM-RA	ClimEmpower Climate Resilience Assessment
CoP	Community of Practice
CRA	Climate Risk Assessment
CSF	Case Study Facilitator
DRR	Disaster Risk Reduction

ECMWF	European centre for medium-range weather forecasts
ERA	Ecological Risk Assessment
EUCRA	European Climate Risk Assessment
FER	Sveuciliste u Zagrebu Fakultet Elektrotehnike i Racunarstva
FRC	Frederick Research Center
GPD	Gross Domestic Product
ICARIA	ICARIA - Improving ClimAte Resilience of crItical Assets (HORIZON-MISS-2021 program, Grant agreement ID: 101093806, 2023-2025; https://cordis.europa.eu/project/id/101093806)
IPCC	Intergovernmental Panel on Climate Change
KPI	Key Performance Indicator
MUs	Mission Users
OBZ	Osiiek-Baranja County (Osjecko Baranjska Zupanija)
OBZ-AZP	Public Institution Agency for the Management of Protected Natural Values in the Area of Osjensko-Baranja County (Javna Ustanova Agencija Za Upravljanje Zasticenim Prirodnim Vrijednostima na Podrucju Osjensko-Baranjske Zupanije)
PESPA	Regional Climate Change Adaptation Plan (Greek region)
PLINIVS	PLINIVS
PNACC	National Climate Change Adaptation Plan approved by the Italian Government
PSTE	Periferia Stereas Elladas
RAs	Regional Authorities
RESILOC	RESILOC - Resilient Europe and Societies by Innovating Local Communities (HORIZON 2020 program, SU-DRS01-2018-2019-2020, Grant agreement ID: 833671, 2019-2022; https://cordis.europa.eu/project/id/833671)
PSTE	Region of Central Greece
SICILY	Sicily Region
SMART	Specific, Measurable, Achievable, Reasonable and Time-bound
SO	Strategic Objective
SSH	Social Sciences and Humanities
WCDS	Western Costa del Sol
WP	Work Package

Glossary

Climate impacts	The consequences of realized risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather and climate events), exposure, and vulnerability. Impacts generally refer to effects on lives; livelihoods; health and well-being; ecosystems and species; economic, social and cultural assets; services (including ecosystem services); and infrastructure (IPCC, 2022)
Community of Practice	Group of people who share a common interest or concern for a specific activity, practice or topic who engage in a process of collective learning within a shared domain by supporting each other and exchanging information through collaborative activities
Case Study Facilitator	Designated entities in each Case Study that are responsible for maintaining oversight and keeping the WP (Work Package) leaders informed about the progress and development of the CoP (Community of Practice). These entities play a vital role in establishing synergies with other Work Packages and ensure the project activities at local level meet end-users needs.
Quadruple helix model of innovation	Collaborative approach in research and development that involves four key sectors of society: industry, government (public sector), academia and civil society to involve a greater public in innovation processes
Stakeholder	A person with an interest or concern in something

Executive summary (publishable)

This report is a deliverable D1.2 **ClimEmpower scenarios** of the ClimEmpower project. It indicates the progress achieved towards: (i) a **State-of-the-Art (SoA) screening** of different options available to assess climate resilience; (ii) the proposal of regional climate resilience assessment methodology (**CLIM-RA**); (iii) the results from some key **questions for ClimEmpower regions** to identify needs and expectations on expected **climate data services**; and (iv) the strategic vision for **climate resilience pathways**.

Regarding the SoA screening (**section 3**), an analysis of the different standards, approaches, and strategic plans for **Climate Risk Assessment (CRA)** has been conducted (**subsection 3.2.1**). Key inputs to this work were **IPCC Sixth Assessment Report (2022)**, the **European Climate Risk Assessment (EUCRA, 2023)**, the **European Drought Risk Atlas (2023)**, and some **World Bank initiatives** that focussed on countries in Southeast Europe. The EUCRA, following the risk concept of the IPCC AR6, illustrates key impacts on several sectors (ecosystems, forests, water supply, hydropower, energy sector and agriculture). The risk urgency matrix proposed in the EUCRA incorporates an interesting concept called '**Policy readiness**', relying on the social and governance aspects of **climate resilience approach (CLIM-RA),** which will be further explored in upcoming WP2 and WP4-related tasks**.** Moreover, an assessed of related EU-funded projects (**CASCADE, CASCADES, ICARIA and CLIMAAX**) resulted in a portfolio of reviewed risk assessment methods and tools for improving the regional resilience. A regional methodology for climate risk assessment in Junta de Andalucía was analysed, to evaluate its potential replicability and transferability. Other approaches to assess climate resilience have been pointed out, mainly focused on an ecosystem-based risk assessment, Critical Infrastructure Resilience Assessment, Resilience indicators and indices, Early Warning Systems (EWS) and climate hazards observatories, and Social Networks Analysis (Resilience Network Analysis).

Assessment of regional climate resilience (**section 4**), has been performed based on the i) 10 resilience dimensions-based methodology of Schaefer *et al.* (2020) (**subsection 3.1.2**); ii) Key insights gathered from methodological approaches to assess climate risks (**subsection 3.2.1**); iii) Key issues obtained from the deliverable in which the five ClimEmpower "Communities of Practices" were launched (**subsection 4.1**); and iv) "Questions for regions" to identify their main data gaps, local needs, resources, and expectations (four-quadrant graphs in **subsection 4.2**). All five regions scored best in 'Environment', 'Learning and innovation' and 'Information and transparency', and worst in the capacity of adapting and transforming against climate risks at the short and long-terms (Robustness and adaptiveness & Capacity to transform, Table 5).

This report has developed the foundations of the climate resilience scenarios or pathways, which will be further developed in the context of trial design (**WP4**). In parallel, the information on needs and expectations will allow us to start addressing the data gaps in **WP2** and the needs for climate applications/data services in **WP3**. The identified scenarios or pathways to improve climate resilience will be further discussed and developed in the scope of WP4 (D4.5), to ensure full coherence between regional expectations, project objectives, and the capabilities of scientific and technological partners to deliver their results within the time and budget limitation.

1. ClimEmpower summary

ClimEmpower is a Horizon Europe collaborative research project dedicated to addressing the ongoing Climate Crisis in Europe by empowering the regional stakeholders in some of the most vulnerable European regions (Figure 1).
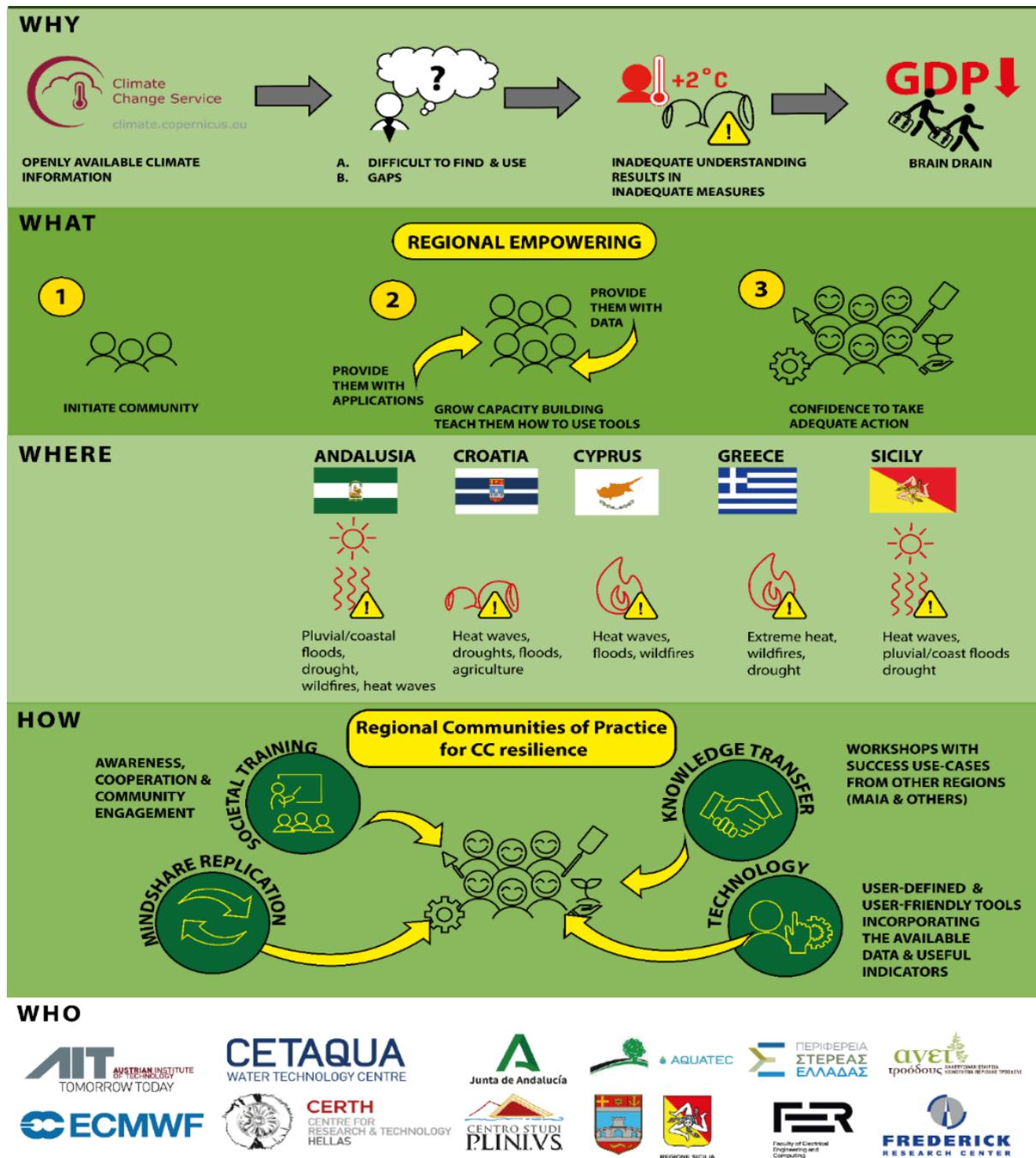
Figure 1: ClimEmpower at a glance: why, what, where, how and who.

1.1 Project Context

Climate risks results from a combination of a hazard, exposure, and vulnerability (IPCC, 2022). Addressing all three aspects is crucial for effective increase of regional resilience. However, exposure, vulnerability, and related aspects, such as adaptive capacity, strongly depend on available knowledge and climate literacy. Consequently, global climate crisis frequently has a higher impact on socioeconomically vulnerable regions, thanks to a higher human and economic potential for addressing the issue in more affluent regions. To maximize its impact, ClimEmpower has therefore chosen to address the EU regions featuring a combination of high potential CC impacts and low and/or stagnant regional GDP/capita. This is mainly the case for regions in South and Southeast Europe (Figure 2).
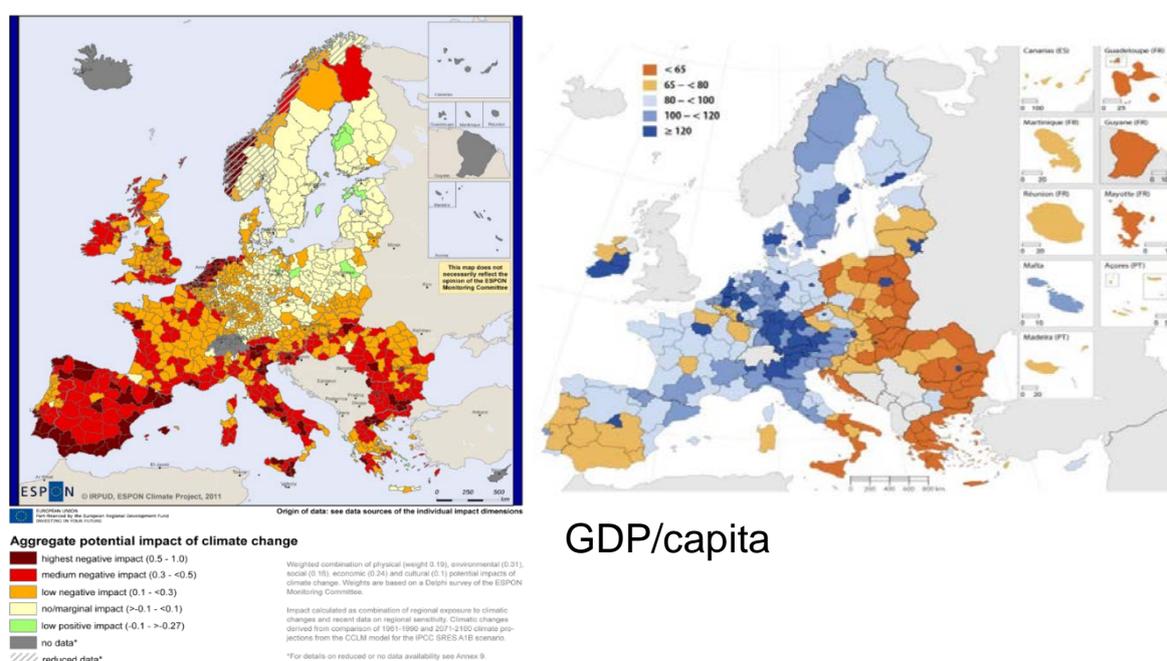
Figure 2: aggregated potential impact of climate change (https://www.espon.eu/climate-2012); GDP/capita (based on https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20210303-1

The context the project addresses is thus one of an ongoing global warming, high regional vulnerability and low coping capacity of the participating regions.

The **overarching strategic objective of ClimEmpower** is to empower the Regional Authorities (RAs) and other Mission Users (MUs) in five EU-regions featuring a combination of exceptionally high climate hazards and exceptionally low coping capacity.

This will be achieved by improving their collective understanding of the Climate Change (CC) hazards, risks and resilient development pathways and supporting their knowledge-based regional planning and development through provision of relevant data, knowledge, and user-defined and user-friendly decision support applications.

1.2 Project Objectives

To achieve this overarching goal, **ClimEmpower has identified six SMART[1] Strategic Objectives (SO)**, each one related to one or several work packages. The SOs have also been classified according to different categories: societal, contributing to improved dialogue, awareness, cooperation and community engagement as highlighted by the European Climate Pact (SO1, SO5); scientific, corresponding to research activities for advances beyond the state of the art (SO2, SO3); technological, suggesting and/or developing novel solutions, integrating state-of-the art and digital advances (SO4); and outreach, aimed at sharing ClimEmpower results to a broader scientific and non-scientific audience, including additional regions and communities, to maximize project impact (SO6).

SO1   Understand regional background, challenges and expectation (WP1, societal)

SO2   Addressing the gaps in availability and usability of CC data and services (WP2 and WP4, scientific)

SO3   Identification, definition, estimating, and communication of climate impact/resilience indicators suitable for local end-users (WP2 and WP4, scientific)

SO4   Simplify access to CC data and development of end user applications (WP3, technological)

SO5   Empower the regions to activate and enhance their potential for addressing the climate change challenge. (WP4, societal)

SO6   Ensure the use and impact of the ClimEmpower outputs (WP4 and WP5, scientific and societal)

> ClimEmpower's key ambition is to **prove beyond doubt that CC-resilience should, and can, be an integral part of regional development everywhere in EU and beyond it**. That is, we anticipate that the regional stakeholders will recognise that CC-resilient development pathways offer multiple benefits to them, including but not limited to higher quality of life and reviving economy, and that these can be understood using available data, tools, and services. Second key ambition of the project is to **help the regions address the CC resilience in key community systems addressed in five ClimEmpower trials**.
>
> Underlying philosophy of the project is to "**help the regions to help themselves**". This will be achieved through various mechanisms, including co-creation and mediation of the regional "**Communities of Practice**", provision of the **Climate Change -resilience training materials**, as well as in provision and training in use of the user-centric data and services – including those that have already been made available through previous research projects and EU initiatives.

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[1] Specific (related to WPs), Measurable (by relevant KPIs), Achievable (the WPs in which they will be achieved are listed), Realistic (since they are referred and explained in the methodology section), and Timebound (each KPI is related to a deliverable and a month of achievement).

2 Introduction

2.1 Deliverable summary

This Deliverable (D1.2) is part of **WP1 – Regional CC-resilience background, challenges, and expectations –** and it reports the different approaches to assess climate change resilience at regional level in the five Case Studies, to develop a better understanding on climate risk and potential adaptation strategies within and beyond the project.

In this regard, WP1 combines approaches from social science and humanities (SSH) domain, promoting methods and tools for interactive knowledge-sharing and co-creation in multi-stakeholder environment to animate cross-cutting Communities of Practice (CoPs). The CoPs provide a mutual learning setting to establish productive relationships between researchers and non-researchers and create actionable research labs where complex problems can be addressed and developed to further actionable research solutions.

The main objectives of WP1 include activating regional stakeholders, building a common understanding and developing regional scenarios. This report is the only public result of WP1 and primarily focuses on the assessment of current state of climate resilience for the ClimEmpower regions (T1.3). It takes advantage of the results from tasks T1.1 and T1.2 (identifying regional stakeholders and establishing CoPs) and makes the key findings of these tasks publicly available[2].

2.2 Results and expected impact

This deliverable is the final result of the WP1. It reports on results of the task 1.3 "Co-create regional CC resilience scenarios" and includes the relevant results of tasks 1.1 "Activate the regional CC stakeholders" and 1.2 "Build a common understanding of regional CC resilience", since these results have not been made public so far. Deliverable provides the following results:

- A catalogue of existing approaches to assess climate resilience.

- 'ClimEmpower approach' (to resilience assessment), to be tested in the five regions.

- Improved understanding of climate resilience, in terms of hazard, vulnerability and exposure assessment, and initial recommendations for improve it.

- Analysis of the replicability of the Andalusian methodology for assessing the climate risk at regional level.

2.3 Relation to other work

This deliverable plays a crucial role in establishing the foundation for the subsequent Work Packages. It serves as a starting point for identifying the climate resilience status of the regions

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[2] D1.1 deliverable, which provides detailed information on CoPs is restricted, mainly due to privacy concerns.

according to the main climate hazards and their vulnerability and exposure to the expected impacts. Key relations to other work packages are:

- Define the technical workflow and the interdependencies between related tasks and WPs for future works within the project (climate indicators - WP2 - and integration/visualization in ClimEmpower Platform - WP3).

- Implement a preliminary assessment of climate resilience for the five regions. This information will be vital for WP2, which will conduct more detailed research to define the main hazards, risks, and vulnerabilities.

- Wrap up the WP1 results and hand over the work to WP4, where all future activities related to empowerment of the regional actors to prioritise actions to reduce climate risks and their effects continues after the publication of this deliverable.

2.4 Data, security, and ethics

2.4.1 Data interoperability

This deliverable has generated no inputs relevant to data interoperability.

2.4.2 Data accessibility and reuse

Some of the assessed methodologies, which are introduced in section 3 of this report are based on previous work and lessons learnt in the **RESCCUE** "RESilience to cope with Climate Change in Urban arEas - a multisectoral approach focusing on water"; **ICARIA** "Improving ClimAte Resilience of crItical Assets"); **MAGO** "Mediterranean Water Management Solutions for a Sustainable Agriculture"; **GOTHAM** "Governance tool for sustainable water resources allocation in the Mediterranean through stakeholder's collaboration"; "Deep Demonstration in Regions: Forging Resilience"; and **CRISI-ADAPT-II** projects, among others.

In preparation of the D1.1 deliverable, the project team has performed an initial analysis of the needs, barriers, and expectations of the CoP participants for each of the five regions participating in the project. Since D1.1 is not a public deliverable, relevant findings, have been incorporated in this report.

Preliminary evaluation of climate resilience in ClimEmpower Regions has been published on Zenodo (10.5281/zenodo.11370246).

2.4.3 Security and ethics

This work assesses societal issues and aims to offer benefits to policy and the involved actors. The used information from CoP meetings ensures a participative environment where everyone feels free to express their point of view and safeguards the participants and potential responses.

ClimEmpower project is dedicated to Just and Equitable transition. Consequently, the question of disproportional effects of Climate Change and Climate Action on specific societal groups has, and will be emphasised in all interactions with the CoPs and assessed at the level of recommended actions and pathways.

3 Methodological approaches to assess climate resilience

This section introduces the concept of 'climate resilience' and summarises the results of the "State-of-the-Art" (SoA) screening of different options available to assess climate resilience.

3.1 Climate Resilience Overview

Climate impacts are already here, and risks will continue to increase in the coming decades and beyond due to the inertia of the climate system, even if ambitious global emission cuts reduce the potential damage (COM, 2024). The literature presenting research findings on **climate resilient development (CRD),** pathways and processes for successfully achieving CRD has expanded significantly in the last years since (Shipper *et al.,* 2022). The outlook for Europe is well presented in the first ever **European Climate Risk Assessment (EUCRA)** by the European Environment Agency. In the best-case scenario, where we limit global warming to 1.5 degrees above pre-industrial levels, Europe – which is heating twice the global rate - will have to learn to live with a climate that is 3 degrees warmer, and consequently cope with exponentially more heatwaves and other weather extremes (**Figure 3**).
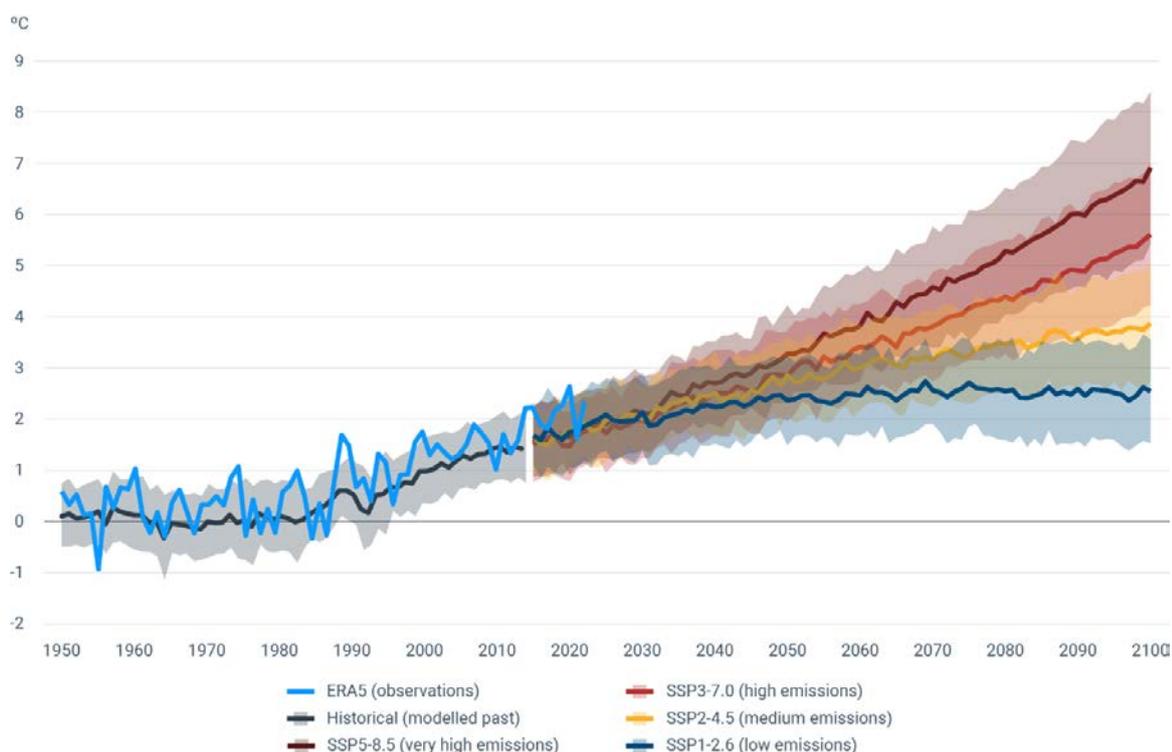
Figure 3 Temperature projections for Europe under four standard global climate scenarios. Source: EUCRA, based on Copernicus Climate Change Service.

77% of the EU public sees climate change as a very serious problem, and 37% already feels personally exposed to climate risks. Both the European Parliament and EU leaders have recognised the urgency of stepping up the response to the climate emergency and **strengthening the EU's resilience**. The **coordination** efforts done by the European Union

are a **powerful mean for building resilience** between regions, seeing what is and isn't working elsewhere (CoPs establishment is crucial at that point), and leading to faster, **more effective action**.

Finally, the EU adds value by developing tools that help citizens, public and private stakeholders build resilience. Considerable investment from the EU budget, notably via cohesion policy, went into climate adaptation and mitigation over the past decade. In 2021-2027, Cohesion investments in this area are foreseen to reach around EUR 118 billion. ClimEmpower will contribute with open access tools to empower stakeholders in developing skills, not only technical but governance and institutional, to reduce the negative effects of climate risks in terms of policy preparedness, having a critical role to play in building resilience.

Another dimension of resilience assessment is related to adapting infrastructure in advance of expected climate impacts. In this regard, the Member States' assessments of risks to critical infrastructure will be carried out by January 2026 under the **Critical Entities Resilience (CER) Directive**. This is an example of climate change unleashing cascading risks and exacerbating environmental degradation and existing drivers of conflict. These complex interlinkages merit specific analysis to inform policy decisions, as reflected in the Communication on the climate and security nexus (JOIN, 2023). In section 3.2.4., some key notes on CER will be explained.

EU Member States have been mandated for the second time to report their national adaptation actions under the Regulation on the Governance of the Energy Union and Climate Action. In October 2023, the European Environment Agency (EEA) published a briefing called "**Is Europe on track towards climate resilience? Status of reported national adaptation actions in 2023**". This briefing is based on a Technical Paper (Leitner *et al.,* 2023), which contains further detailed analysis of the reported information and examples illustrating the observations.

The key messages they arose from such an analysis are the following:

- Heat waves, droughts, floods, heavy precipitation are the most reported observed extreme weather events, while changing temperatures and hydrological variability are the most common chronic hazards. They coincide with hazards to be analysed in the framework of the ClimEmpower project, being also highlighted during the first CoPs meetings.

- Health, agriculture, forestry and biodiversity are the most reported affected sectors, in line with reporting from 2021.

- National climate risk assessments are increasingly used to inform adaptation policy development. The adaptation policy landscape is gradually evolving, and climate laws are increasingly emerging as an instrument to give greater legal power to such policies. In section 3.1.1 a summary of national climate risk assessments in each of the five ClimEmpower regions will be presented.

- Multi-level networks and collaborative mechanisms are reported to be crucial to advancing local adaptation, and governance-related challenges are a persistent barrier to the implementation of adaptation actions. All the efforts dedicated to the constitution and activation of the Communities of Practices (CoPs) are aligned with this key message.

- An indicator-based approach for monitoring, reporting and evaluation (MRE) is often reported, although the indicator types and how they contribute to evaluation purposes are not always clear. Within the ClimEmpower project, several climate risk indicators will be used (WP2) and shown in an open platform (WP3), to give recommendations across regions as much standardised and comparable as possible. The technical paper also points out the importance of ensuring that the different levels of MRE (national, regional and local level) are connected to gain a more comprehensive understanding of what is being monitored, reported and evaluated.

3.1.1 Climate Risk Assessments of the ClimEmpower Regions

The reported information in Leitner *et al.* (2023) demonstrates further progress in assessments of climate-related hazards, vulnerabilities, and risks, confirming that enhancement, expansion, and deepening of the knowledge base on climate risks is a continuous process in many countries. From the 2023 reporting, there emerges a quite balanced ratio between comprehensive multi- or cross-sectoral Climate Risk Assessments (CRAs) and thematically focused or sector-specific assessments, in terms of both number of countries and number of studies.

- **Completion of national multi- or cross-sectoral CRAs or broad climate change assessments** was reported by Austria, **Croatia**, Germany, Finland, **Italy**, **Spain**, **Greece**, Ireland, **Cyprus** and Iceland. Croatia and Finland have conducted new comprehensive national CRAs during preparation of their revised national adaptation policies, while Italy has updated its national risk analysis contained in the National Adaptation Strategy (NAS). Greece has scheduled its update of the national CRA under the LIFE-IP AdaptInGR project for the end of 2024. Cyprus states that update of the national CRA is expected through scientific work done by the 'Cyprus Initiative on Climate Change'. Updating the national CRA in Spain follows statutory revision cycles, e.g., five years. As required under the new Climate Law in Spain, the first report on the evolution of climate change, impacts and risks is scheduled in 2025 and shall inform preparation of the second work program under the NAP.

- **New thematic or sector-specific assessments at national scale** have become available in at least six countries (Denmark, Finland, France, **Greece** -focused on biodiversity and ecosystems-, Hungary, Ireland and Sweden), plus a cost-benefit analysis at the regional level in Flanders (Belgium).

- Seven countries (Belgium, Finland, France, Hungary, **Italy -six cities-**, Poland and Sweden) explicitly mention sub-national CRAs or regional climate projections with mostly multi-sectoral assessment designs. In **Spain**, particularly in the Andalusian region, there is a subnational climate action plan (2021 – 2030) totally aligned with national agenda.

- Several countries highlight progress and substantial achievements in development of CRA-related methodologies (Denmark, Germany, Hungary, Iceland, **Italy -new climate indicators-** and Poland).

Table 1 National and sub-national climate risk assessment in ClimEmpower member countries. Note: in parenthesis the specific ClimEmpower region within the country is noted.

Country	Year	Assessment product
Croatia (OBZ)	2022	National multi-sectoral climate risk assessment
Cyprus (Troodos Mountain)	2022	Cyprus Initiative on Climate Change
Italy (Sicily)	2021	Risk analysis: climate change in six Italian cities (update of climate risk analysis contained in the National Adaptation Strategy, NAS)
	2022	Climate indicators in Italy in 2021
	2023	National Climate Change Adaptation Plan (PNACC)
Greece (Central Region of Greece)	2022	Baseline analysis for climate adaptation of the biodiversity and ecosystem sector (LIFE-IP AdaptInGR)
	2021-2023	National GIS Maps Portal on Climate Change (content enhancement based on climate projection data produced by LIFE-IP AdapInGR)
	2021	Regional Climate Change Adaptation Plan (PESPA)
Spain (Costa del Sol)	2021	Andalusian Climate Action Plan (2021 – 2030)
	2023	Andalusian Methodology for Climate Risk Assessment
	2020	National Climate Adaptation Plan (2021 – 2030)
	2007	Spanish-Climate Change and Clean Energy Strategy. Horizon 2007-2012-2020

3.1.2 Climate Resilience: Differences between risk and resilience assessment

The concept of resilience was first introduced by physical scientists to show the characteristics of a spring to describe the stability of the material and its resilience to external shocks (McEvoy *et al.,* 2012), but later it evolved and was transferred to socio-ecological systems. **Resilience is visualised as the ability to recover after hazard events; so independent of whatever type of extreme events** (Bogardi and Fekete, 2018). In terms of climate change, there is a link between risk assessment and resilience. In the context of risk, resilience can be viewed as a complement and an alternative to conventional risk management (Linkov *et al.,* 2016).

The risk is a function of vulnerability, exposure, and hazard; while resilience is a function of intrinsic resilience, exposure, and hazard (**Figure 4**). The incidence caused by climate change is largely determined by the ability of the community that is related to experience and its participation in the face of disturbance. By assuming a hazard of one value, then the resilience measurement is determined by exposure and intrinsic resilience. Intrinsic resilience itself is an existing condition and is owned by a socio-ecological system in the face of various hazards, and it must be interpreted as survival (non-sensitivity) and adaptive capacity (Subiyanto *et al.,* 2020).

Risk = *func* (Vulnerability, Exposure, Hazard)

Resilience = *func* (Intrinsic Resilience, Exposure, Hazard)
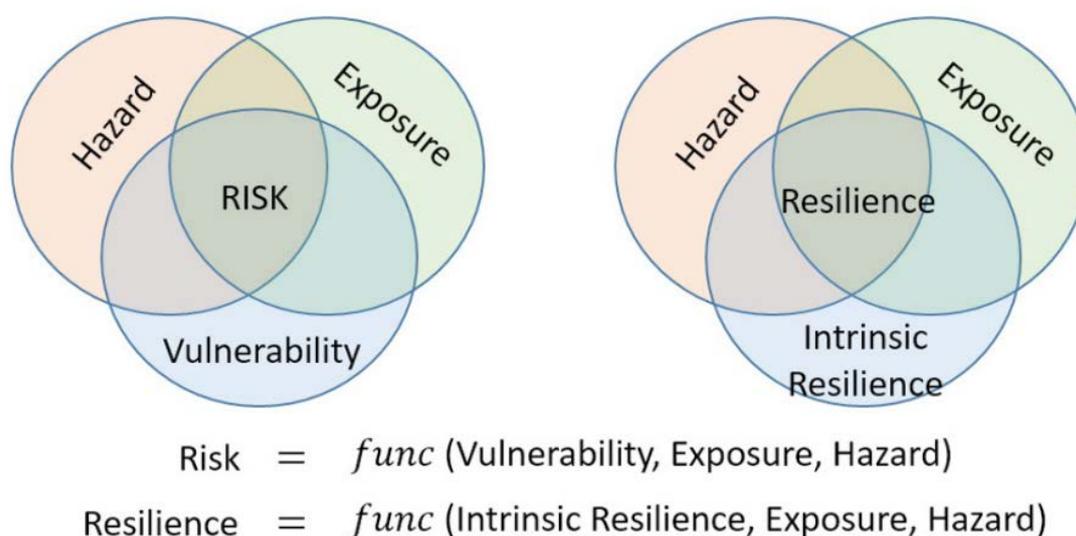
Figure 4 The concept of risk and resilience. Source: Subiyanto et al. (2020)

From the previous figure, the difference between risk and resilience analysis refers to the vulnerability (or intrinsic resilience) assessment approach to be selected. As the vulnerability of the exposed people plays a major role in such assessment, social inequity in health and environmental infrastructure access can even reinforce potential harms through extreme events. It is not intended to further expand the theoretical debate of the resilience concept, as this has been conducted thoroughly in previous studies (Friend *et al.,* 2013).

Drawing on the great amount of existing research articles and reviews, the essential components of climate resilience can be summarised in **Table 2**. In theory, the more pronounced these components are, the more resilient a city/region is to weather related stresses and shocks. The content of table below is an attempt to directly measure climate resilience.

Table 2 Key components of climate resilience definitions. Source: Updated from Schaefer et al. (2020)

Acronym	Explanation	Specific question for the region
R	Robustness and adaptiveness to climate related stresses and shocks	What is the degree of robustness and adaptiveness to climate related stress and shocks in your region?
E	Evaluation and Monitoring: resilience as a process	Is there some public methodology to easily assess climate-related risks and identify potential adaptation measures?
S	Scale (Countries, Regions, Cities, Neighbourhoods, Individual)	What is the level of spatial disaggregation of climate related risks?
I	Interdisciplinarity: resilience as umbrella for different sectors	Are all the critical sectors involved in climate resilience/risk assessment plans and strategies?
L	Learning and innovation	The public administration provides to society free-of-charge resources and materials to learn on expected climate change impacts and potential adaptation measures. Does your region actively participate in R&D projects?
I	Information and transparency: resilience as participation tool	Does your region have some national or sub-national online climate services portal, with information aggregate as climate indicators?
E	Environment (natural and built up)	Do you think that there are enough natural protected areas (NPAs) to buffer the potential impacts of climate change and conserve ecosystem services - e.g, water provisioning?
N	Networked systems and actors (multilevel governance)	Is there good coordination and collaboration between the different stakeholders (public authorities, water utilities, NGOs, SMEs, …) of your region for fostering climate resilience?
C	Capacity to transform after disturbance but maintain self-organisation	What is the "community-level recovery" from extreme weather events?
E	Equity and Justice: resilience measurements must not exclude others	Are climate resilience/risk adaptation measures considering all people? - Leave no one behind approach

This climate resilience assessment is fully aligned with the outputs from **EU CASCADES project**, in which they define resilience as the capacity to absorb shocks, avoid tipping points, navigate surprise and keep options alive, and the ability to innovate and transform in the face of crises and traps (Rockström *et al.,* 2023). This more dynamic understanding implies that European resilience to cascading climate risk is contingent upon:

- the capacity to learn from events and about plausible futures.

- sufficiently diverse sources of inputs and resources.

- diverse ways of achieving its objectives (i.e. avoiding over-reliance on systems that might fail).

- strong links and connectivity with other systems, such as countries, supply chains, markets and ecosystems.

- stores and spare capacity to cope with shocks and surprises.

- the stability of Europe's Neighbourhood (the EU's neighbouring regions, both in the south and in the east).

- the capacity to work with other countries and actors and to learn from and influence them effectively.

- methods for including all of society in decision-making and planning to ensure equity.

3.2 How to assess Climate Resilience?

3.2.1 Climate Risk Assessment (CRA)

The Climate Risk Assessment approach, which is already largely adopted by the public administrations, academia, and industry, it is seen as a part of broader resilience management. This is the reason to include a specific section focused on different CRA at different levels.

3.2.1.1 Standards, approaches and strategic plans for climate risk assessment

Different international, European, and national documents have deepened into the understanding, assessment and monitoring of different climate risks. The international standard is referred to the **IPCC Sixth Assessment Report,** in which the use of the concept of risk has not been fully consistent across Working Groups or between assessment cycles, given that the concept itself and its use by IPCC has continued to evolve. In the context of climate change, risks result from dynamic interactions between climate-related **hazards** with the **exposure** and **vulnerability** of the affected human or ecological system to the hazards. Hazards, exposure and vulnerability may each be subject to uncertainty in terms of magnitude and likelihood of occurrence. The IPCC AR6 poses a conceptual framework for establishing the foundations of risk assessment at global scale, but does not recommend any specific methodology to measure the different components of climate risk. At a European level, it has been recently published the **European Climate Risk Assessment (EUCRA)**. Based on the EUCRA land and marine regions, the five ClimEmpower regions are part the "Southern Europe" zone (**Figure 5**).

Figure 5 The EUCRA land and marine regions. Source: modified from https://www.eea.europa.eu/data-and-maps/figures/the-eucra-land-and-marine-regions. Note: the orange one (Southern Europe) corresponds to the ClimEmpower regions

The main climate impacts revealed in the EUCRA are summarised in **Figure 6**. An increasing trend is clearly expected to 'mean temperature', 'heatwave days', 'drought', and 'heavy precipitation' (in both 'low' and 'high' emissions scenarios, except to 'heavy precipitation'), and a robust decreasing pattern for total precipitation (only in future 'high' scenario).

Land regions	Northern Europe			Western Europe			Central-eastern Europe			Southern Europe			European regional seas		Past	Future
	Past	Future		Past	Future		Past	Future		Past	Future					
		Low	High		Low	High		Low	High		Low	High				
Mean temperature	↗	↗	↗	↗	↗	↗	↗	↗	↗	↗	↗	↗	Sea surface temperature		↗	↗
Heatwave days	☐(*)	↗	↗	↗	↗	↗	↗	↗	↗	↗	↗	↗				
Total precipitation	↗	↗	↗	↗	╱	↘	↗	↗	╱	↘	↘	↘	Sea level		↗	↗
Heavy precipitation	↗	↗	↗	↗	↗	↗	↗	↗	↗	↗	↗	↗				
Drought	↗	↘	↘	↗	╱	↗	↗	╱	↗	↗	↗	↗				

Figure 6 Main climate impacts in the EUCRA land and marine regions. Source: https://www.eea.europa.eu/data-and-maps/figures/the-eucra-land-and-marine-regions. Notes: the blurred arrows are referred to projections with high uncertainty; the square is related to not confident projections

EUCRA follows the risk concept of the IPCC AR6, according to which (climate) "risk is defined as the potential for adverse consequences for human or ecological systems … Relevant adverse consequences include those on lives, livelihoods, health and well-being, economic, social and cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species".

Too many geospatial results can be consulted in the EUCRA's report, like the one shown in **Figure** 7, related to the extent of drought at the beginning of August 2022 and its impacts on different sectors. The ability to easily illustrate key impacts on such a several sectors (ecosystems, forests, water supply, hydropower, energy sector and agriculture) is of key importance to effectively empower regions on taking advantage of user driven climate applications, one of the main goals of **ClimEmpower** project. This type of graphical results (focused on the front-end and user interface experience) will be considered in tasks related to **WP3**.
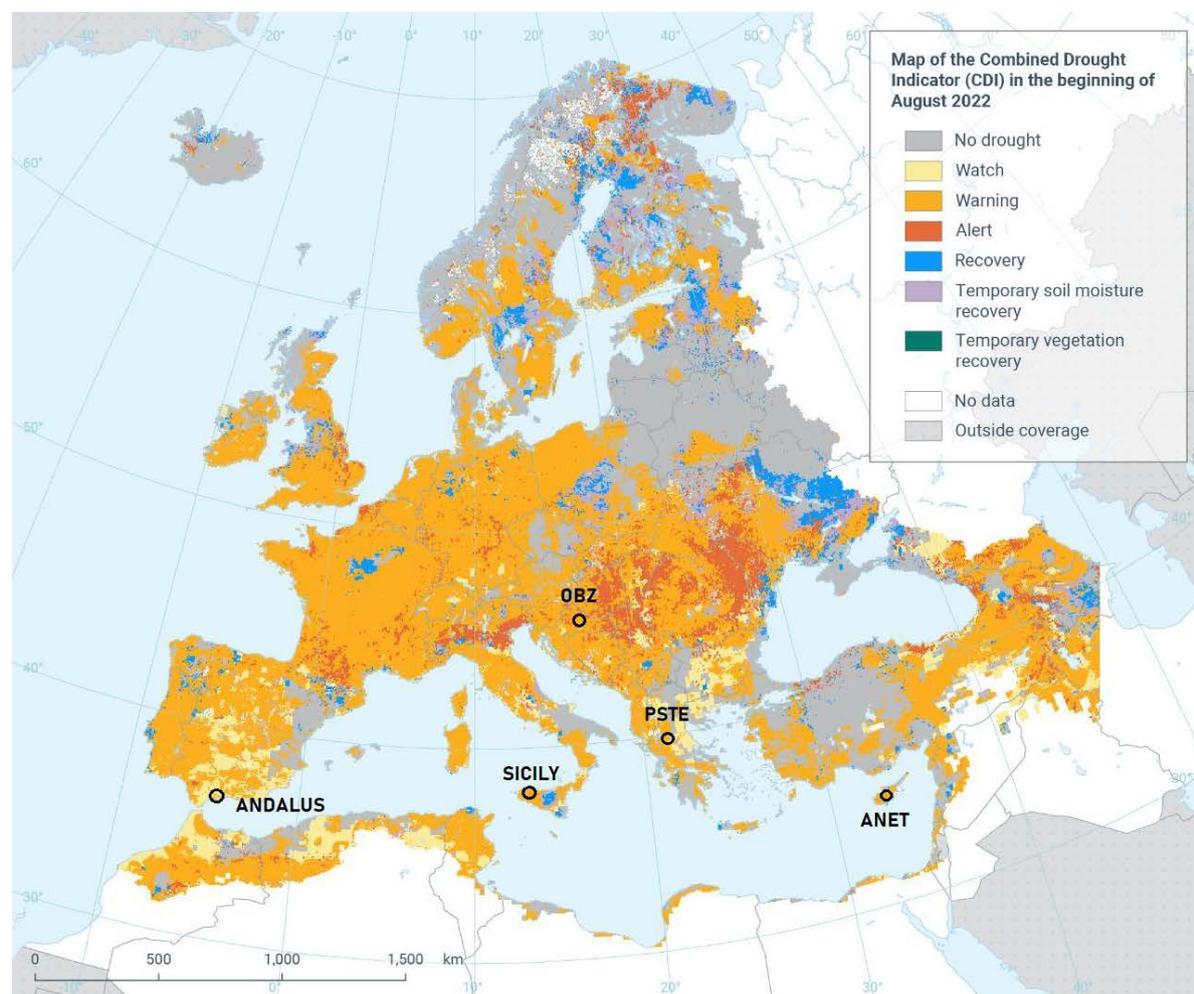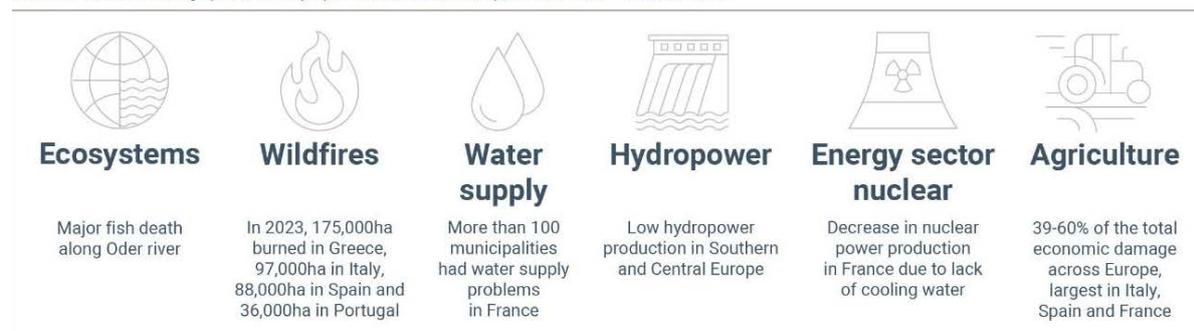
Figure 7 Main climate impacts in the EUCRA land and marine regions. Source: https://www.eea.europa.eu/publications/european-climate-risk-assessment

EUCRA also proposes a "**method for structured risk assessment**". This involved several steps, as shown in **Figure 8**. The risk selection identified major climate risks for Europe based on common criteria. The risk analysis classified these risks according to their potential for severe consequences for Europe; it was complemented by an indicative policy analysis. The risk urgency evaluation determined the urgency for EU action based on the outcomes of the risk and policy analysis. In general, higher risk severity, higher confidence and lower policy readiness increase the urgency and specificity of the recommended policy actions.
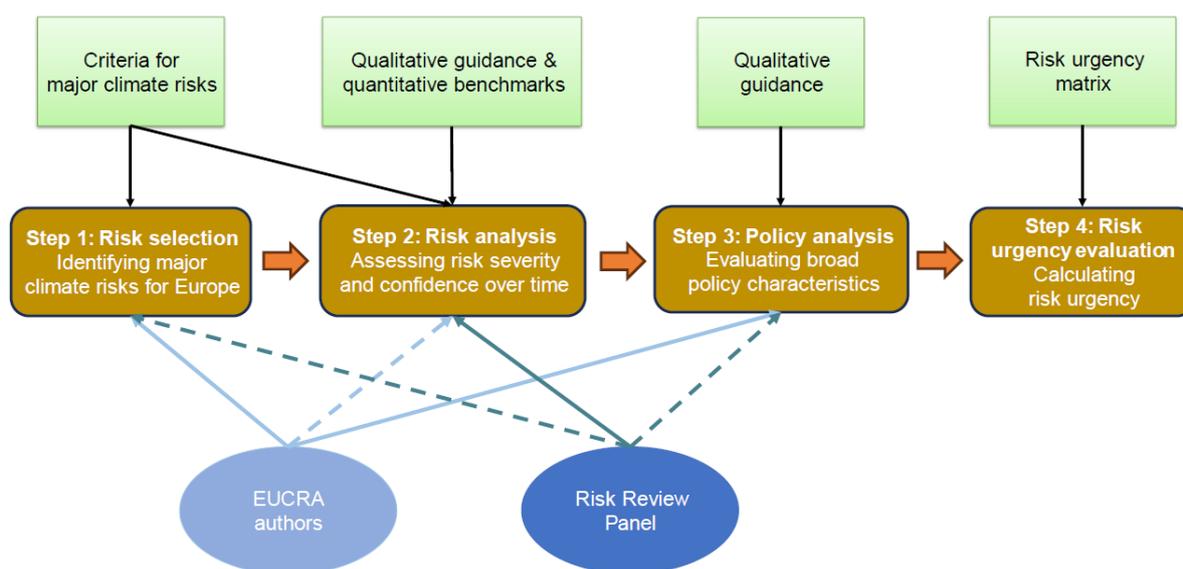
Figure 8 Structured risk assessment in EUCRA. Source: https://www.eea.europa.eu/publications/european-climate-risk-assessment. Note: the strength of the arrows indicates the importance of EUCRA authors vs the risk review panel in the different steps of the structured risk assessmet (solid lines indicate lead role)

The risk urgency evaluation was done algorithmically based on the outputs of the risk analysis and the indicative policy analysis. The key element is a **risk urgency matrix** that considers **risk severity** and **confidence** (for a given period - current, mid-century, or late century - and warming scenario - low or high warming) as well as **policy readiness** (**Table 3**). This matrix builds on experiences from recent national climate risk assessments, which were adapted to the EUCRA framework and objectives.

Table 3 Matrix for determining risk urgency based on risk severity, confidence, and policy readiness. Source: https://www.eea.europa.eu/publications/european-climate-risk-assessment

Risk severity	Confidence	Policy readiness		
		Very advanced	Advanced	Medium/low
Catastrophic	High	More action needed	Urgent action needed	Urgent action needed
	Medium	Further investigation	More action needed	Urgent action needed
	Low	Further investigation	Further investigation	More action needed
Critical	High	Sustain current action	More action needed	Urgent action needed
	Medium	Sustain current action	Further investigation	More action needed
	Low	Sustain current action	Further investigation	Further investigation
Substantial	High	Sustain current action	Sustain current action	More action needed
	Medium	Sustain current action	Sustain current action	Further investigation
	Low	Sustain current action	Sustain current action	Further investigation
Limited	High	Sustain current action	Sustain current action	Watching brief
	Medium	Sustain current action	Sustain current action	Watching brief
	Low	Sustain current action	Sustain current action	Watching brief

The risk urgency matrix incorporates an interesting concept called '**Policy readiness**', but also poses a challenge on how to estimate it. It relies on the social and governance aspects of **climate resilience approach (CLIM-RA)** proposed in the current deliverable (**Table 2**). The EUCRA methodology for the risk urgency evaluation has four categories of policy readiness:

- **Low**: few or no policies, plans, or strategies are in place to reduce the risk.

- **Medium**: policies, plans, strategies, or legislation are in place, but their targets and objectives are vague, or only short-term actions are considered.

- **Advanced**: policies, plans or strategies that manage the risk effectively are partly in place.

- **Very advanced**: policies, plans or strategies are in place with clear objectives and actions to manage the risk. Policies and actions consider short-term risk management as well as long-term risk reduction where relevant.

Considering the limited evidence available regarding policy readiness, in particular, at the national level, only the two central categories were used in practice, with 'medium' being the default choice. **Risk ownership** describes where the lead responsibility to manage a major climate risk lies between the European level and Member State level. EUCRA distinguishes three types of risk ownership:

- **EU**: policy areas where the EU predominantly has the legislative remit and responsibility to act.

- **Co-owned**: policy areas that fall under shared and special competences where the EU could potentially implement policies in accordance with the EU Treaty and intergovernmental agreements, but also in circumstances where actions in more than one policy area is needed and where the level of risk ownership differs.

- **National**: policy areas that are largely under the responsibility of Member States.

EUCRA did not include a comprehensive analysis of risk ownership, which would also have to consider the role of various Directorates-General of the European Commission, subnational governance levels and private actors. This dimension of risk assessment has been included in the preliminary climate resilience assessment of **ClimEmpower**, by adding perceptions on multi-level governance and the European Quality of Government Index.

3.2.1.2 Other strategic climate plans and strategies

Within the European strategy to characterize climate risks in a holistic view, the "**European Drought Risk Atlas (2023)**" characterises how drought hazard, exposure and vulnerability interact and affect different but interconnected systems. It provides for the first time a comprehensive assessment and mapping of drought risks and impacts in the EU for a global warming of 1.5, 2 and 3 degrees. The Atlas is complemented by the European droughts impacts database, which contains data on drought impacts from 1977 to 2022. It will become available to users at a later stage. Both the Atlas and the database have been developed by the JRC and the "**European Drought Observatory for Resilience and Adaptation (EDORA)**" partners, and they will be integrated into the Copernicus European Drought Observatory run by the JRC. During the tasks mainly related to **WP2** and **WP3** the information gathered and analysed from the "European Drought Risk Atlas" will be considered as an input to the expected **risk indicators** and **ClimEmpower Climate Platform**, respectively.

The **World Bank** elaborated programs to decrease the vulnerability of countries in **Southeast Europe** to some climate hazards. These programs are **SEEDRMAP** (Southeastern Europe Disaster Risk Mitigation and Adaptation Programme) and **SEEDRMAI** (Southeastern Europe Disaster Risk Mitigation and Adaptation Initiative). In these programs, risk was assessed at national and subnational levels and there was a wide range of hazards analysed. These programs are especially relevant for Croatian ClimEmpower region (OBZ).

3.2.1.3 EU-related funded projects

There are too many others EU-funded projects related to climate resilience and risk assessment to analyse them all. The projects mentioned below illustrate the main technical and conceptual approaches of relevance for ClimEmpower.

During the **CASCADE project** (*2019 - 2021*), a portfolio of reviewed risk assessment methods and tools was made. This was a comprehensive portfolio of risk management methodologies to improve local level resilience. It collects existing and widely used risk assessment methods and tools. The most interesting approaches are showed below:

1) **A Common Methodology for Risk Assessment and Mapping of Climate Change Related Hazards – Implications for Climate Change Adaptation Policies.** The methodology for risk assessment and mapping of climate change-related hazards considered the definitions described in the EC Guidelines (Papathoma-Köhle *et al.,* 2019), providing flexibility for the user to be able to choose the dimension of the vulnerability and the risk metric that is relevant to the assessment aim.

A questionnaire was prepared by the University of Vienna, the National Directorate General for Disaster Management of Hungary and the SEERISK consortium, and sent to the partners to get information related to:

- Needs and expectations of the individual partners.

- Relevant hazards for each case study area and priorities.

- Legal requirements at the national level.

- Existing products (e.g., risk maps, risk matrices, hazard and vulnerability maps, risk scenarios, etc.).

- Existing data, as well as their availability, quality, format, and scale

This type of information has also been gathered in ClimEmpower for the five project regions and presented in **section 4.2** of this deliverable.

2) **A "three-tier risk assessment process" for climate change adaptation at a local scale (Tonmoy *et al.,* 2019)**. A three-tier climate change risk assessment framework focuses on some of the practical challenges of conducting climate change risk assessment on the ground at a local level.

   a. A **first-pass risk screening** is a rapid and qualitative process which can be carried out without detailed local data to develop a preliminary understanding of the climate change risks faced by an organisation.

   b. A **second-pass risk assessment** is a standard approach based on risk management standards, such as ISO31000 (ISO 2018). This includes conducting a risk workshop with relevant stakeholders to identify and evaluate specific climate change risks, their likelihood and consequences.

   c. A **third-pass risk assessment** focuses on further investigation of prioritised, short-listed and site-specific risks (identified at the second-pass assessment stage).

3) **Adapting to Climate Change: Municipal Adaptation Plans (MAP)**. The principals and goals are quite similar the previous 'three-tier risk assessment process', with a recommended list of 10 steps to implement MAPs. It can be so helpful to the regions in which a regional adaptation plan has been developed but not at municipal scale. It is related to the spatial disaggregation of climate risks (**'Scale: S' dimension of CLIM-RA methodology**).

4) **Comparative Risk Assessment to inform Adaptation Priorities for the Natural Environment**. Another methodology for the climate change risk assessment (CRA) was presented (Brown, 2015), combining the use of a risk assessment procedure and systematic literature review to adopt the methodology for stakeholders and policymakers.

5) **Global Climate Change. Ecological Risk Assessment (ERA) in the context of global climate change**. Landis *et al.* (2019) presented seven principles for improved ERA and management decisions under global climate change. They will be mentioned in the **subsection 3.2.2**.

6) **Regional Risk Assessment for climate change impacts on coastal aquifer**. Multiple sources of hazards (i.e., changes in the precipitation regime, river flow discharge, and groundwater depth and quality) were considered which could influence the status and conditions of coastal groundwater-dependent natural and human systems (Iyalomhe *et al.,* 2015). According to their results, two main impacts on coastal aquifer were analysed:

   a. **Groundwater Level Variation (GLV)**, due to changes in the water table related to the alteration of recharge processes from CC and excessive pumping of groundwater,

b. **Saltwater Intrusion (SI)**, which refers to the subsurface movement of seawater into coastal aquifer. The regional risk matrix identified all elements which contribute to the calculation of risk in the case study area (i.e., stressors, receptors and impacts) and their relationships. It contained two distinct sub-matrixes: the vulnerability matrix and the hazard matrix.

The authors also applied a '**damage assessment framework**', providing the relative estimation of potential social, economic and environmental losses of receptors and areas at risk in the considered region. Related to 'SI' climate impact, a GIS-based methodology for 'seawater risk mapping' is being implemented in the EU project '**MAR2PROTECT**' (developed by CET), and a **potential replication** of it within the **ClimEmpower** will be evaluated.

7) **Wellbeing assessment for climate change**. This approach is directed by the principals of '**Participatory Action Research**', which put emphasis on participants' themselves to provide their experiences, opinions, and worldviews. It follows the principles of best practice for field and community work and ensures that **local communities** are directly involved in the assessment process, guaranteeing that they are active agents in making decisions about their future. This is a very similar procedure compared to the **ClimEmpower approach**, regarding the building of '**Communities of Practices**' in each region (for a summary see the **subsection 4.1**).

Another interesting climate EU-funded project is called "**CASCADES project** (2019 – 2023)" strives to understand the conditions under which climate risks propagate beyond their geographical and temporal location in ways that may affect European stability and cohesion. It does so via a broad **360° risk assessment** and deeper thematic analyses of trade, value chain, financial and political connections between Europe and the rest of the world. **CASCADES'** ambition was to identify the policy leverage points that can help the EU to adapt and respond to such cascading climate risks. **CASCADES** integrates a wide range of established and innovative methodologies – many of which have not been seriously applied to adaptation questions before – ranging from biophysical climate impact modelling, economic modelling of trade and financial networks, and data integration methods, to qualitative approaches including hotspot case study analysis original social science research and serious games. There are many open resources and materials related to CASCADES implementation (The CASCADES Serious Game, Conceptual framework for cascading climate impacts or a policymakers' toolkit, among others). For the future (beyond may-2024) CoP's and WP1 "follow-up" tasks (mainly concentrated in WP4) is highly recommended to take advantage of them.

Figure 9 shows the 'conceptual framework' of European project 'CASCADES', which includes a set of terms for describing and analysing cascades. The framework distinguishes:

- initial impacts caused by a climate trigger (often within a specific region)

- the 'impact transmission system' through which impacts propagate, often across borders

- the 'response transmission system' through which adaptation responses interact with the impact transmission system.

To help understand cascades, the framework recognizes different types of climate triggers, categories of cross-border impacts, scales and dynamics of impact transmission and the targets and dynamics of responses. The framework also accounts for the current and future socio-economic and environmental context in which cascades occur. The framework can be

used to identify relevant causal relationships, both in retrospect, and proactively. A retrospective approach is useful for learning, while proactive usage can help policymakers plan for, adapt to or potentially prevent cascades. In the absence of resilience and effective mediation, impacts can escalate further.
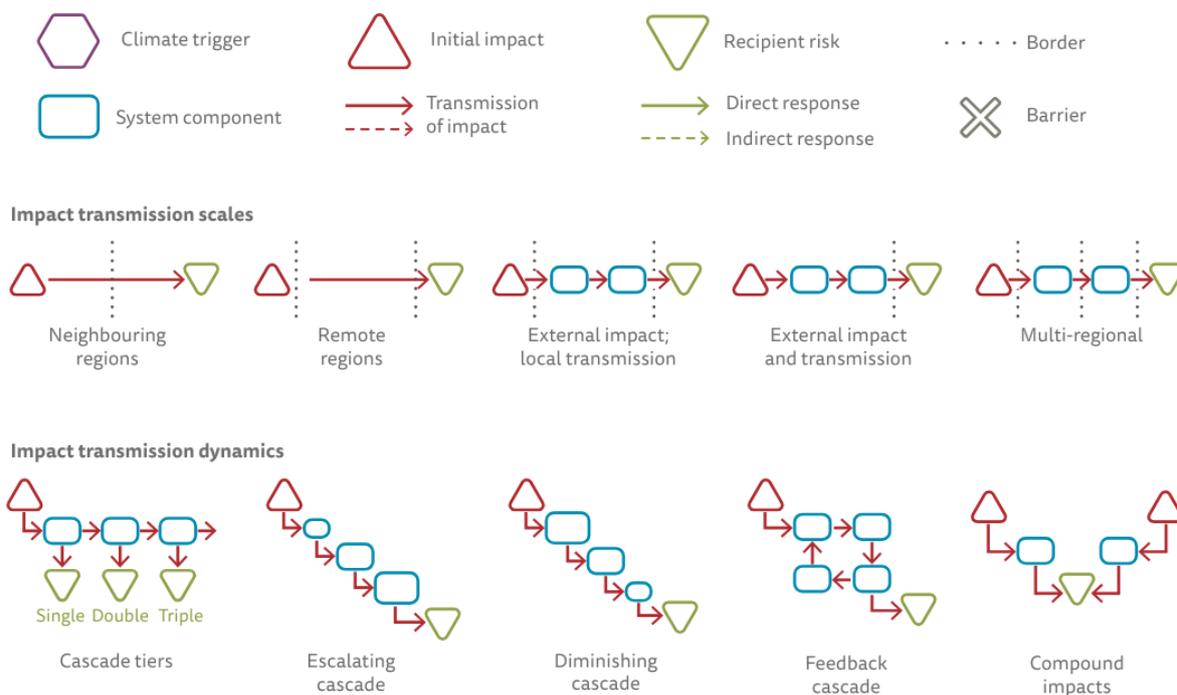
Figure 9 Overarching cascading climate impacts for Europe. Source: Townend et al., 2023.

Through a multi-disciplinary team and a strong background acquired in recent projects, **ICARIA project** (coordinated by AQUATEC with AIT and PLINIVS as a partner, 2023 - 2025) aims to promote the use of asset-level modelling to achieve a better understanding of climate related tangible direct and indirect impacts on critical assets due to complex, cascading, and compound disasters. Furthermore, it considers the related risk reduction provided by suitable, sustainable, and cost-effective adaptation solutions. **ICARIA** focuses on both (i) **critical assets** and services that were not designed for potential climate change-related impacts that can increase the unplanned outages and failures, and (ii) on **housing**, **natural areas**, and **population**. Cutting edge methods regarding climate scenario building, asset-level-coupled models, and multi-risk assessment approaches will be implemented and replicated in three EU regions (Barcelona Metropolitan Area, South Aegean archipelago and Salzburg region), to understand how future climate scenarios might affect critical assets and to provide decision-making support tools to private and public risk owners.

In two recent published deliverables, **ICARIA project** has defined the procedure to achieve a comprehensive risk/impact assessment across different climate-related hazard categories (D1.1), also covering complex interactions characterised by compound events and cascading effects, in the context of climate change. This holistic modelling framework includes the assessment of multi-hazard events, providing a conceptual and methodological approach (D2.1). The focus was put on dynamic assessment between the different risk components: hazard, vulnerability and exposure (**Figure 10**). The combined effects resulting from multi-hazard scenarios are therefore unlikely to be assessed through simple addition of losses, due to the independent effects, and instead require system approaches to understand risk (IPCC, 2022).
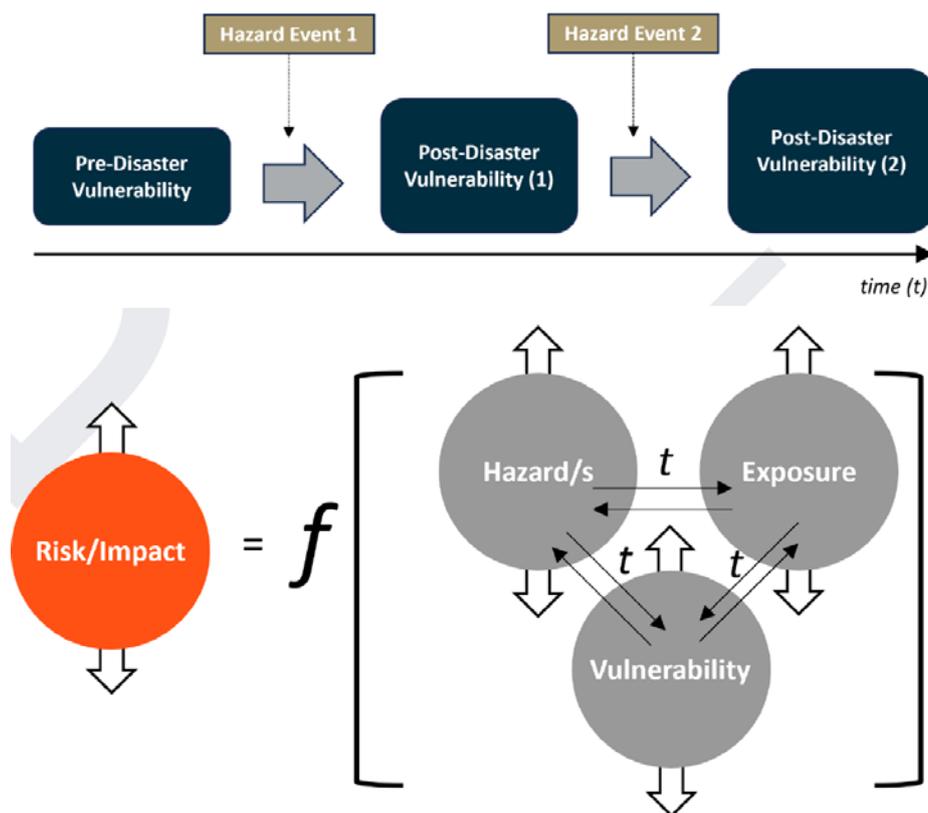
Figure 10 Dynamic changes in vulnerability of exposed assets due to a preceding hazard (upper part), and Dynamic risk equation based on interaction between hazard, exposure and vulnerability over time. Source: Gill et al., 2021.

In the holistic modelling framework of **ICARIA** an elementary brick model (see **Figure 11**) is used to derive the risk/impact assessment for compound and cascading multi-hazard events. The term "**elementary bricks**" refers to model components such as "Hazard", "Exposure", "Vulnerability" etc. Within this approach, the interactions between modelled hazards are captured along with changes in exposure and vulnerability over time and due to prior events via the "Dynamic Vulnerability" functions based on prior work from **EU-FP6 EXPLORIS project** (Zuccaro & De Gregorio, 2013) and **EU-FP7 CRISMA project** (García-Aristizabal *et al.,* 2014). In the current deliverable (D1.2), a special focus has been put on a better understanding and assessment of **climate resilience dimensions** or '**determinants**' (third column of **Figure 11**).

All these conceptual and methodological approaches from ICARIA, will be kept in mind to be used in the development of **ClimEmpower indices** (WP2), **services and products** (WP3), as well as **local and regional climate commitments** (WP4, WP5).
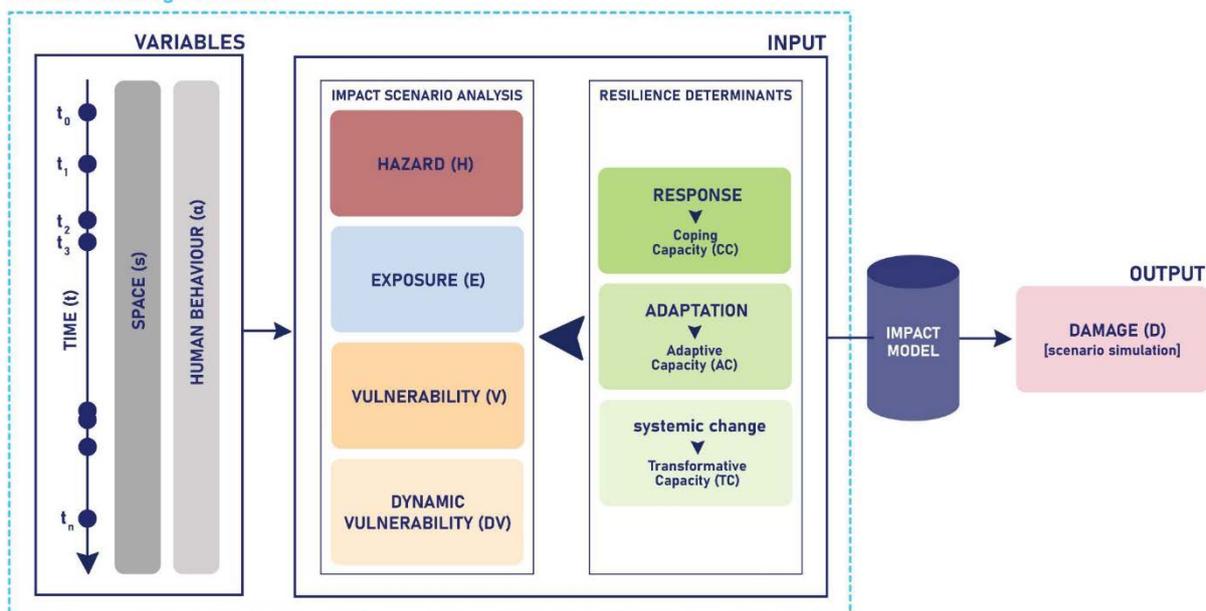
Figure 11 Elementary brick model depicting the holistic modeling framework for risk/impact assessment in ICARIA (modified after Zuccaro et al., 2018 and Russo et al., 2023)

With the aim of harmonization and consolidation of the practice of climate risk assessment (CRA)**,** CLIMAAX project (2023 – 2026) will provide financial, analytical, and practical support to improve regional climate and emergency risk management plans, leaving a legacy for upcoming European initiatives. **CLIMAAX** builds upon existing risk assessment frameworks, methods and tools, and promotes the use of datasets and service platforms for local and regional scale deployment. It will develop a robust and coordinated framework of consistent, harmonised and comparable risk assessments.

This philosophy, based on "not reinventing the wheel", is at the core of **ClimEmpower** project. The fact of being highly aligned and coordinated with CLIMAAX outputs will ensure to be also aligned with other projects and initiatives (**Figure 12**).
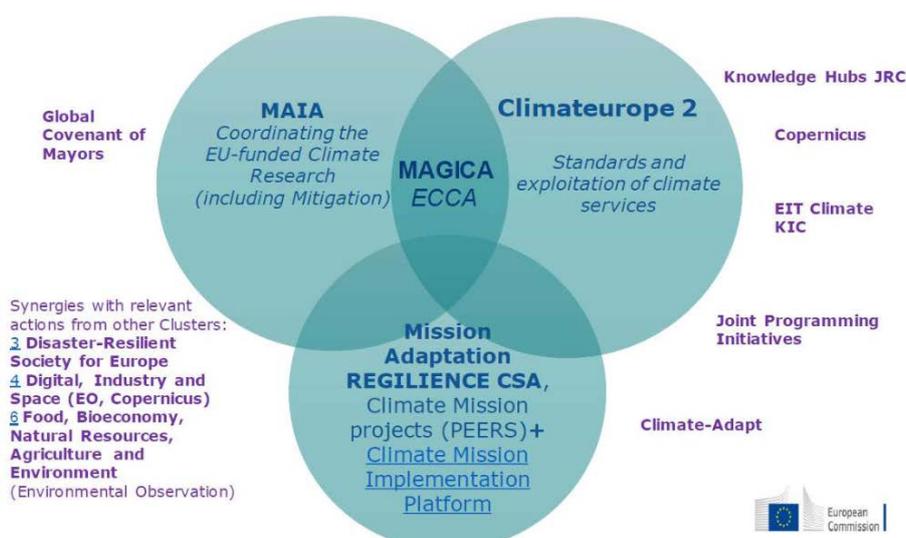
Figure 12 Synergies of CLIMAAX project with coordinating projects and initiatives. Source: https://www.climaax.eu/wp-content/uploads/2023/04/CLIMAAX_general_intro_presentation.pdf

The **CLIMAAX** project has also reviewed several CRA approaches on the deliverable '**D1.2 - Desk review of existing CRA frameworks**'. There is often a tendency to compartmentalize individual risks for analysis and action, overlooking the interactions and interdependencies between risks (Brown and Berry, 2022). Despite the availability of various CRA methodologies, making the risk concept more actionable is still a challenge. Risk compartmentalization is manifested in different ways:

- By **focusing on specific hazards** ignoring other risks that may have serious consequences.

- By **only considering the hazard variability** as climate changes omitting variations in exposure and vulnerability over time.

- By focusing on **assessing multi-risk of various hazards individually** under current conditions or specific scenarios rather than their interactions and feedback over time.

- By **focusing on specific** subsets of systems, such as particular **sectors or communities**, without considering important linkages in risk transmission (e.g., via supply chains).

- By **leaving out** relevant aspects for understanding the risks and impacts such as **the adaptive capacity** (of both nature and humans) **or** key parameters that describe **the system's resilience** and stability under different future climates and socio-economic **pathways**. To better know how the system's resilience is going to behave in the future, it is strictly needed to understand what the current resilience level for a given region is. This is one of the main objectives of **ClimEmpower** deliverable 'D1.2', through the **Climate Resilience Evaluation Table** (results in **subsection 4.3**).

Table 4 summarizes some of the trends driving conceptual and methodological advancements in the CRA field, that were identified from the reviewed literature during **CLIMAAX** project. (Deliverable D1.2).

Table 4 Trends and innovations in Climate Risk Assessment. Source: modified from Deliverable D1.2 - Desk review of existing CRA frameworks (CLIMAAX project – Climate Ready Regions)

Trending issue	Innovation/Development	ClimEmpower Added Value
Spatialization of risk	Identification and aggregation of multiple hazard types at the regional and local scale	During ClimEmpower execution (WP2, WP3), it is expected to develop regional climate services and products (downscaled multispectral data for spatial climate risk assessment: flood, drought, heat waves and forest fires mapping).
	Use of Remote Sensing to identify and rank risk hotspots	
Participation	Integration of local perceptions and risks	Already organised and future events of the 'Communities of Practices' (WP1, WP4) are based on integration of local perceptions. It assures the needed multi-risk component assessment and the inclusion of social aspects on risk and resilience analysis.
	Wider engagement of local stakeholders to assess H, E, and V	
	Exploration of the influence of diverse and evolving societal values (risk tolerance)	
	New forms of engagement (e.g., gamification, serious games, pathways mapping...)	

Trending issue	Innovation/Development	ClimEmpower Added Value
New technologies and sophisticated techniques	Use of Machine Learning to assess multiple risks, focused on predictive methods	Advanced AI-based models and algorithms will be used to predict droughts and water scarcity events (WP3).
	Exploitation of Big Data analytics, and network analysis for identifying emergent patterns of social behaviour and running risk scenarios and cascading uncertainties	The use of 'Polytope' python library (ECMWF) will also ensure the feature extraction for "datacubes" from GRIB climate files, allowing complex climate risk assessments (WP3). Moreover, within WP2 it is expected to define several methodologies for closing data gaps.
Integrated Assessment Models	Hybridization of probabilistic models to reduce uncertainty	A specific methodology will be deployed to assess and model flood risk, based on an ensemble-oriented approach. As mentioned in the previous trending issue, the analytical capabilities of ECMWF can contribute to developing integrated climate models
	Ensembles oriented to model flood risks	
	Combination of models associated to climate change impacts	
Effect of adaptation responses	Integration of the influence of responses in the risk generation	The works and efforts to be done during the execution of WP4, as a continuation of WP1-related tasks, guarantees the integration of user's expectation and needs and the efficient increase on social awareness and climate training. During WP2, indicators to assess impact of adaptation measures will be analysed and defined if needed.
	Prevention of maladaptation	
Validation and calibration of information	Integration of results from top-down and bottom-ups approaches	
	Use of multi-disciplinary and heterogenous sources of information and scenarios	The diversity of technical skills between ClimEmpower partners (AIT, CERTH, AQUA, CET, ECMWF, ...) and the complementarity between the different case studies, will assure the use of such a multi-disciplinarity and heterogenous data sources
Uncertainty handling	Quantification of all type of uncertainties into the final risk	There were no specific developments on this matter (uncertainty), but it will be preliminary analysed by using CLIMAAX Toolbox
	Event-based storyline approach	
	Use of probability density function describing the uncertainty of each risk component	

Regarding new tools for CRA, **CLIMAAX** project pointed out two main tools. Torresan *et al.* (2016) proposed **DESYCO**, a user-friendly GIS-based decision support system tailored for local risk evaluation and management that utilizes a Regional Risk Assessment (RRA) methodology coupled with a Multi-Criteria Decision Analysis (MCDA) model. It integrates hazard, exposure, susceptibility, risk, and damage assessment, with climate scenarios, hydrological simulations, and non-climate vulnerability factors through intuitive interfaces that facilitate risk mapping and result communication.

Additionally, Aznar-Siguan *et al.* (2019) introduced **CLIMADA**, an open-source software specifically designed for CRA, presented in a modular and collaborative design that allows scalable computation. Indeed, open access platforms, such as the CLIMADA toolbox, can

improve CRAs by increasing accessibility to data and foster knowledge exchange among users and stakeholders.

The ECMWF is partner in both projects (**ClimEmpower** and **CLIMAAX**), being responsible, in the latter one, of the upgrade framework and tools, guaranteeing the identification of all potential synergies between these two initiatives, mainly on specific services and products to be developed (ClimEmpower – WP3).

In relation to CRA tools, in the next subsection (**3.2.1.1**) it is presented a regional methodology developed by the public authority (Junta de Andalucía) of the Spanish case study (Costa del Sol).

3.2.1.4 Andalusian methodology for climate risk assessment (ANDALUS)

The Junta de Andalucía (ANDALUS) has published (Nov-2023) a climate risk assessment methodology to evaluate a list of climate impacts at regional scale. In **Figure 13**, a procedure divided into two phases (participative and operational) is shown, very similar to that followed by Junta de Andalucía.
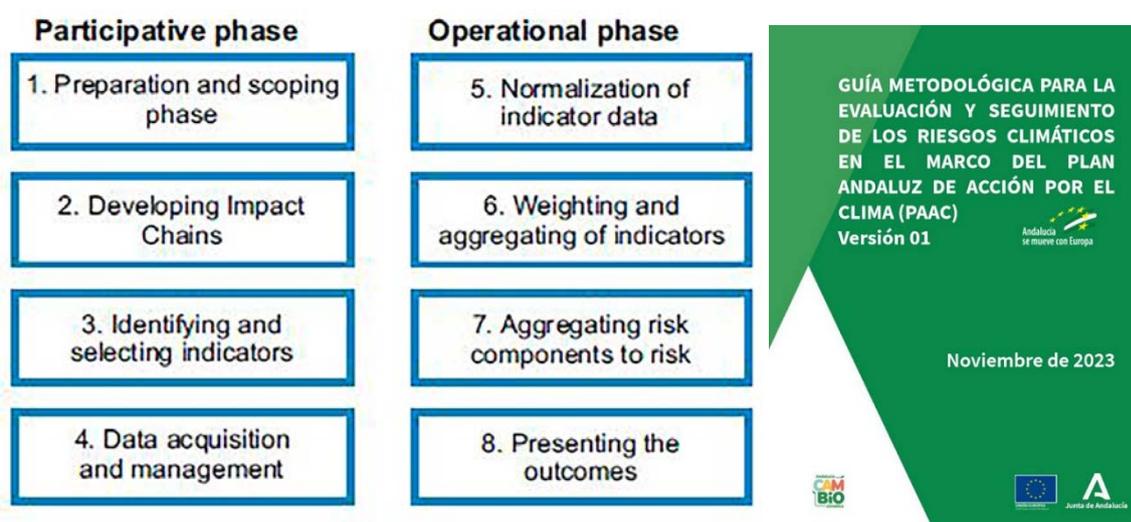
Figure 13 The Vulnerability Sourcebook modules (Menk et al., 2022) and the publication of the Junta de Andalucía risk assessment methodology

The main objective of this regional methodology is to reduce the risk of climate change impacts, minimizing their effects. It is fully aligned with the most important and relevant strategic plans at international, European and national level:

- IPCC Panel (AR6)

- EUCRA

- ClimateADAPT

- Spanish guideline for risk assessment against climate change (2023)

- Technical guidance on the climate proofing of infrastructure in the period 2021 – 2027 (2021/C373/01)

- The three-tier risk assessment process for climate change adaptation at a local scale (Tonmoy *et al.,* 2019), achieving the first two steps **"first-pass risk screening"** and **"second-pass risk assessment"**

An initial template was prepared to initially assess different climate impacts depending on risk evaluation in some strategic areas (Water Resources, Agriculture, Health, Tourism, Biodiversity and ecosystem services, …) (**Figure 14**).
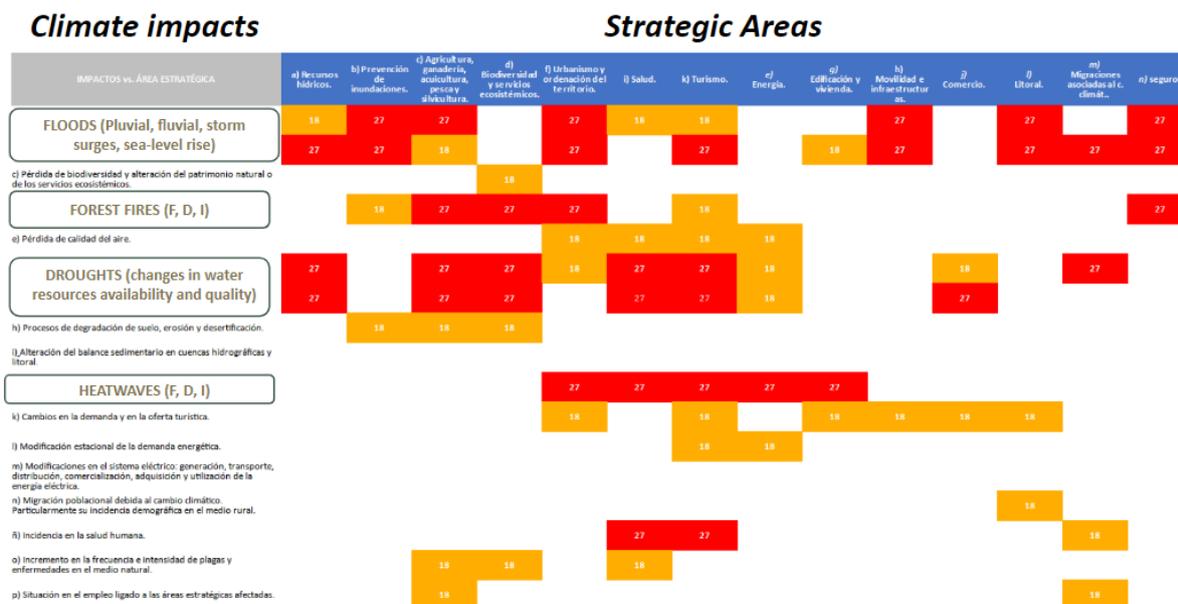
Figure 14 Initial matrix for climate impacts prioritisation in the region of Andalusia. Notes: F = frequency; D = Duration; I = intensity)

Once the preliminary risk screening was made, the climate risk assessment was implemented, focusing on a better understanding of exposure and vulnerability components to improve climate change adaptation capabilities. The key issues of the 'Junta de Andalucía' methodology are:

- Risk assessment is mixed (both quantitative and qualitative) but the result is quantitative.

- Risk value is the result of hazard, exposure and vulnerability estimates (mathematical function), based on a regional catalogue of indicators.

- The vulnerability analysis includes information on sensitivity and adaptive capacity (([sensitivity] + [adaptive capacity]) / 2). Each vulnerability dimension has its own list of indicators.

- Each risk component can be the arithmetic/weighted average of the different considered indicators.

- The indicators are quantitative or qualitative and they're selected based on expert criteria.

- Ranges and thresholds must be established for each indicator, as well as the relationships (weights) between the several indicators used to assess each risk component.

The usefulness of this methodology is guaranteed due to the existence of an automatic tool for climate risk assessment (Excel Spreadsheet, only in Spanish). In each cell of the spreadsheet appear a colour indicating different types of action (**Figure 15**).

The specific procedure to estimate each risk component is detailed in a strategic document called "*Guía metodológica para la evaluación y seguimiento de los riesgos climáticos en el marco del plan andaluz de acción por el clima (PAAC)*".
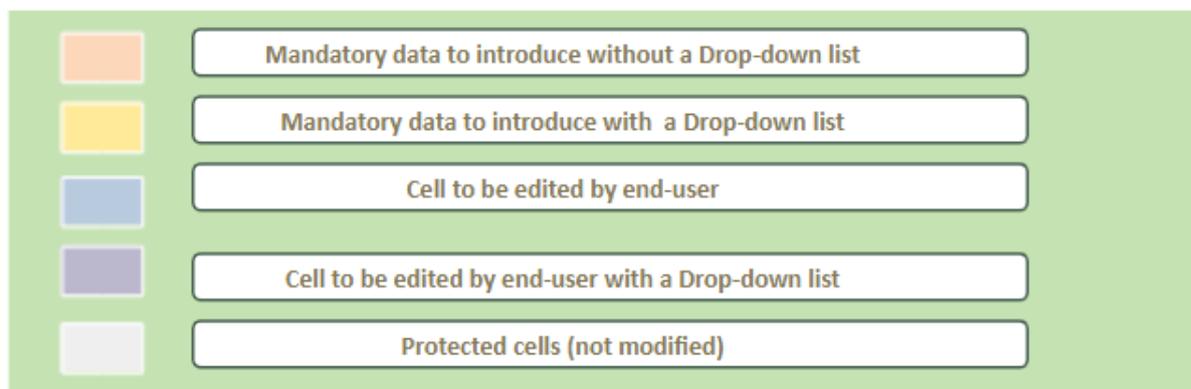
Figure 15 Types of actions to be implemented in the Excel Spreadsheet of the Andalusian methodology

For each climate variable identified to assess the hazard component, it has been defined 2 factors: 1) the magnitude of expected impact, and 2) the temporal analysis of the impact, at short (2015-2040), mid (2041-2070) or long-term (2071-2100).

With all the above-mentioned steps fulfilled, the risk value is calculated. The final risk score is the arithmetic mean of the individual risk values (**Figure 16**). The individual risk values are estimated as follow:

$$\textbf{Risk} = [\text{Hazard}]^{0,2} * [\text{Exposure}]^{0,3} * [\text{Vulnerability}]^{0,5}$$

The coefficients of the previous equation are referred to the relative importance of each risk component, as a function of the expert knowledge considered during the preparation of the methodology. Moreover, it was decided to weigh with a higher coefficient to those risk components (exposure and vulnerability) in which the society (public administration, private companies, NGOs, ...) can influence to some extent (e.g., in terms of CC adaptation strategies).

Figure 16 An example of graphical representation of climate risk assessment (floods and droughts) on water resources dimension. Note: AC = Adaptive Capacity

The existence of this methodology at regional scale has been considered to carry out the baseline climate resilience assessment in **subsection 4.3.** Moreover, in the framework of WP4,

the automatic tool will be translated to be used for all ClimEmpower regions, giving more methodological details on the estimation of each risk component.

3.2.2 Specific approaches to assess climate resilience – beyond the concept of risk

3.2.2.1 Ecosystem Services Assessment

Ecosystem Services Assessment evaluates the capacity of ecosystems to provide services that enhance resilience, such as water purification, flood regulation, and habitat support. Recently, it has been developed some approaches focused on the mapping of ecosystem Services or Nature based Solutions for climate change adaptation (Goodwin et al., 2023), to ease the spatial assessment services enhancing resilience. The authors systematically mapped 216 nature-based solutions (NbS) to climate change adaptation in urban areas from 55 different countries across all United Nations (UN) regions, collected from nine online databases on climate change adaptation and NbS, following the systematic standards of the "**Collaboration for Environmental Evidence**". Another similar approach is to assess the overall health and functionality of ecosystems under climate stress (Ren *et al.,* 2022; Rani *et al.,* 2020).

The **Ecological Risk Assessment (ERA)** in the context of global climate change was analysed in the CASCADE project for Landis *et al.* (2013). They presented seven principles for improved ERA and management decisions under global climate change:

- Consider the importance of GCC-related factors in the ERA process and subsequent management decisions.

- Assessment end points should be expressed as ecosystem services.

- Responses of ecosystem services (end points) can be positive or negative.

- The ERA process requires a multiple stressor approach, and responses may be non-linear.

- Develop conceptual cause–effect diagrams that consider relevant management decisions as well as appropriate spatial and temporal scales to allow consideration of both direct and indirect effects of climate change.

- Determine the major drivers of uncertainty, estimating and bounding stochastic uncertainty spatially and temporally, and continue the process as management activities are implemented.

- Plan for adaptive management to account for changing environmental conditions and consequent changes to ecosystem services.

All previous ecosystem-based approaches are related to the component 'E: Environment' of the 10-dimensions based resilience assessment in **ClimEmpower** project.

3.2.2.2 Critical Infrastructure Resilience Assessment

Risk assessment (or analysis) is a well-researched and even standardised field (e.g., ISO, Citation2018; ISO/IEC, Citation2019). Furthermore, from 2013 onwards, EU member states have already been obliged to conduct national risk assessment based on EU Civil Protection Mechanism legislation also including the CI domain, largely relying on the ISO standards

(Pursiainen and Rød, 2021). By contrast, there is no jointly established, broadly shared or standardised understanding of how to assess and manage critical infrastructure (CI) resilience (Pursiainen and Kytömaa, 2023). This is the challenge of any CIR or Critical Entities Resilience (CER) management. Namely, before one can enhance resilience, one must know how resilient the CI currently is – and in which areas it lags the required resilience level – to enhance resilience in the first place.

The **Critical Entities Resilience (CER)** Directive has created a framework to support Member States in ensuring that critical entities can prevent, resist, absorb and recover from disruptive incidents, including those caused by natural hazards, terrorism, insider threats, sabotage, or public health emergencies. The CER adopted in 2022 provides important opportunities for assessing and improving the resilience of critical entities in Europe, independent of whether they are publicly or privately owned. These opportunities should be utilised to the fullest, including for **resilience to climate change and extremes**. Unless the CER explicitly mentioned resilience in their title, the method for characterise the status of the critical entities is based on the principals of risk management.

Member States will have to identify the critical entities for the sectors set out in the CER Directive by 17 July 2026. They will use this list of essential services to carry out risk assessments and to then identify the critical entities. Once identified, the critical entities will have to take measures to enhance their resilience for the following sectors:

- **Energy sector**, with services such as the electricity production and energy storage.

- **Transport sector**, with services such as management and maintenance of airport or railways infrastructure.

- **Banking sector**, with essential services such as taking deposits and lending.

- **Financial market infrastructure sector**, with services such as the operation of trading venue and of clearing systems.

- **Health sector**, with distribution, manufacturing, provision of healthcare, and medical services.

- **Drinking water sector**, with drinking water supply and drinking water distribution. It includes suppliers and distributors of water intended for human consumption as defined in Article 2, point (1)(a), of Directive (EU) 2020/2184 of the European Parliament and of the Council.

- **Wastewater sector**, with wastewater collection, treatment and disposal services.

- **Digital infrastructure sector**, with services such as the provision and operation of internet exchange point service, domain name system, top-level domain, cloud computing and data centre.

- **Public administration sector services.**

- **Space sector**, with the operation of ground-based infrastructure services.

- **Production, processing and distribution of food sector**, with the large-scale industrial food production and processing, food supply chain services and food wholesale distribution services.

ICARIA EU-funded project is especially devoted to critical assets and infrastructures that are susceptible to climate change, in a sense that its local effects can result in significant increases in cost of potential losses for unplanned outages and failures, as well as maintenance – unless an effort is undertaken in making these assets more resilient. ICARIA aims to understand how future climate might affect life-cycle costs of these assets in the coming decades and to ensure that, where possible, investments in terms of adaptation measures are made up front to face these changes.

ICARIA aims at developing a comprehensive asset level modelling framework to achieve a better understanding about climate related impacts produced by multi-hazard events on critical assets to identify suitable, sustainable, and cost-effective adaptation solutions. This knowledge will be transferred to **ClimEmpower** project due to the coincidence of several partners in both projects.

3.2.2.3 Resilience indicators and indices

Many frameworks have been developed following Holling's work (Holling, 1973) to evaluate resilience, but there is neither an agreed set of variables nor a comprehensive definition (Feldmeyer *et al.,* 2020). Composite indicators have been developed on different scales (e.g., global, country, urban, household, individual) for risk (Birkmann and Welle, 2016, Poljansek *et al.,* 2017), vulnerability (Sorg *et al.,* 2018, Karagiorgos *et al.,* 2016, Jamshed *et al.,* 2019) and resilience (Cutter *et al.,* 2010, Cutter *et al.,* 2014, Suárez *et al.,* 2016, Keating *et al.,* 2014).

More recently, the EU-funded project '**RESILOC** - Resilient Europe and Societies by Innovating Local Communities', will develop a matrix containing a total of 70 indicators and 260 associated proxy measures across 6 resilience dimensions: Disaster Risk Reduction (DRR), Economic, Environmental, Governance, Infrastructure, and Social (**Figure 17**). This 'resilience framework' will be assessed and considered in the on-going tasks related to WP2 (e.g., D2.1).
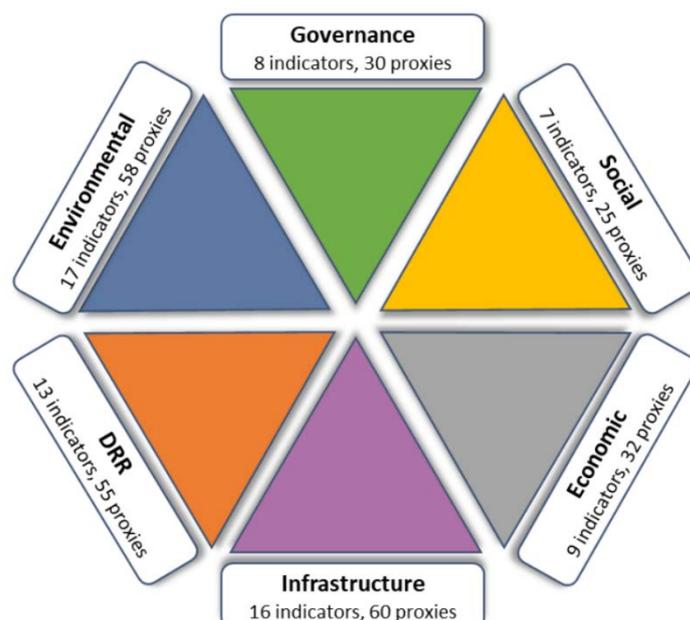
Figure 17 RESILOC dimensions, indicators, and proxies for resilience assessment. Source: https://www.resilocproject.eu/wp-content/uploads/2022/05/RESILOC_D3.1_V7.0.pdf

There are also geospatial approaches for measuring climate resilience, like the one presented by Schaefer *et al.* (2020), although the GIS-based measurement of resilience with indices or

scorecards is nothing new (Renschler *et al.,* 2010; Brunetta & Salata, 2019; among others). Due to the fine resolution of work from Schaefer *et al.* (2020) (**Figure 18**), the results can be implemented in future local climate adaptation plans or serve as an initiator for projects concerning climate resilience and social-ecological disparities. They provided a cost-effective workflow on assessing and visualizing climate resilience to identify potential weaknesses. Nonetheless, the full potential of measured phenomena by indicators only unfolds by investigating how they develop over time. Despite possible monitoring processes that could be carried out in the future, it is the real policy which shapes climate resilience.
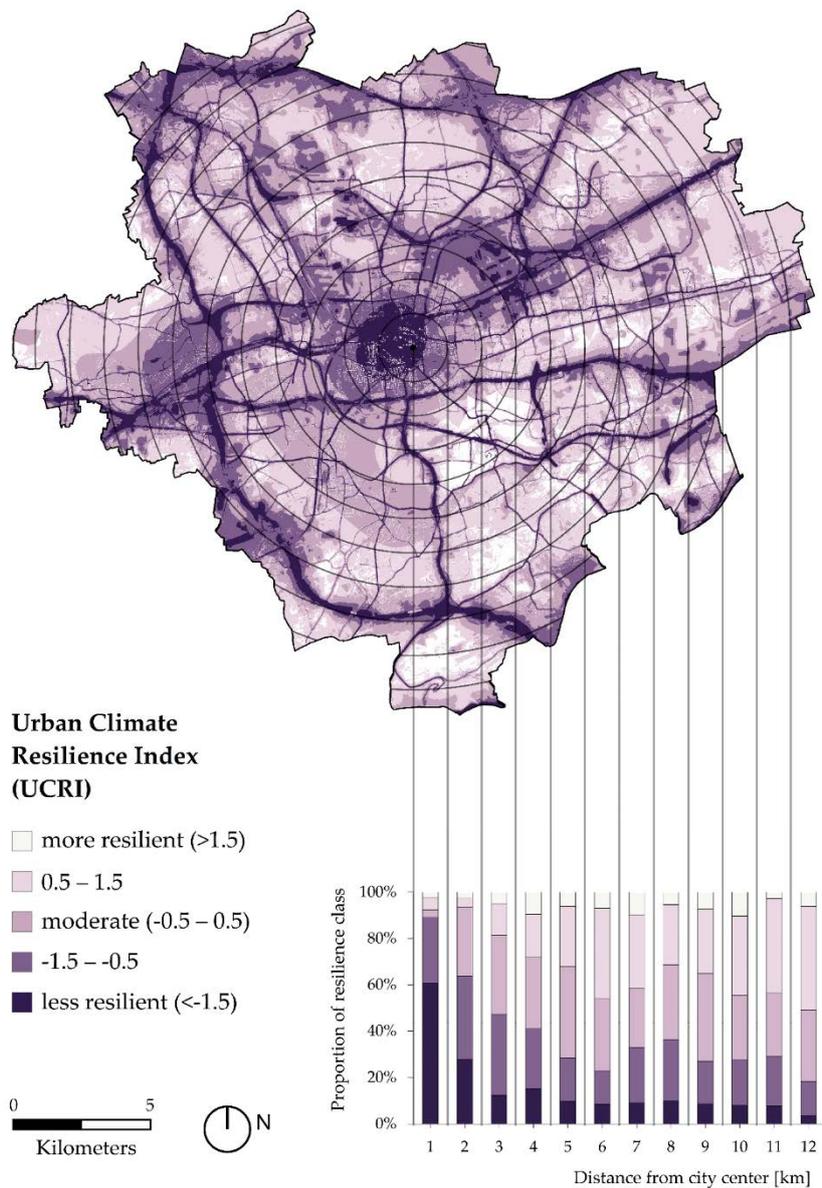
Figure 18 Urban Climate Resilience Index (UCRI) in Dortmund. Source: Schaefer et al. (2020)

3.2.2.4 Early Warning Systems (EWS) and climate hazards observatories

The existence of an early warning system can significantly improve climate resilience in a region by providing timely and actionable information that helps individuals, communities, and governments prepare for and respond to climate-related hazards. Several ways in which early warning systems enhance climate resilience are described below.

Risk Awareness and Preparedness:

- **Timely Alerts**: Early warning systems provide advanced notice of impending climate-related hazards. This allows individuals and communities to take preventive actions to protect lives and property.

- **Public Education**: Regular dissemination of information and educational campaigns associated with early warning systems can increase public awareness about climate risks and appropriate response measures.

Effective Emergency Response:

- **Coordinated Efforts**: With early warnings, emergency services can mobilize resources and coordinate their efforts more effectively. This includes evacuation plans, the setup of emergency shelters, and the provision of essential supplies.

Long-term Planning and Adaptation:

- **Risk Assessment**: Data collected from early warning systems can help in assessing climate risks more accurately, aiding in the development of long-term resilience strategies and policies.

- **Infrastructure Planning**: Governments and planners can design infrastructure that is better suited to withstand climate impacts, informed by historical data and predictive models generated by early warning systems.

Community Resilience:

- **Local Empowerment**: Early warning systems can empower local communities by involving them in the monitoring and response processes, fostering a sense of ownership and responsibility towards climate resilience.

Health and Safety:

- **Preventive Health Measures**: Early warnings about extreme weather conditions, such as heatwaves or cold spells, can prompt health advisories and preventive measures to protect vulnerable populations, including the elderly and those with health conditions.

Technological and Scientific Advancements:

- **Innovation**: The development and maintenance of early warning systems drive technological and scientific advancements in meteorology, hydrology, and related fields.

- **Data Utilization**: The extensive data collected by early warning systems can be used for research and development, improving the accuracy and reliability of climate predictions.

At European level, some the EWS focused on drought, forest fires and floods are the 'European Drought Observatory – EDO', the 'European Forest Fire Information System - EFFIS', and the 'European Flood Awareness System – EFAS', respectively. They are components of the Emergency Management Services in the EU Copernicus program.

3.2.2.5 Social Networks Analysis or Resilience Network Analysis

This approach relies on examining social networks to understand the flow of information, resources, and support in the context of climate change impacts. One online tool that can be used with this purpose is "Google Trends", to measure the concept of 'Social Drought' by counting the number of searches for a specific topic.

The analysis of social networks like "X" is other method to assess the human behavioural of society against climate impacts, for example, based on the number of tweets linked to specific climate hazards, such as droughts, floods, among others. In **ClimEmpower** project, it is expected to develop a methodology to extract and analyse posts in social media (crowdsource information).
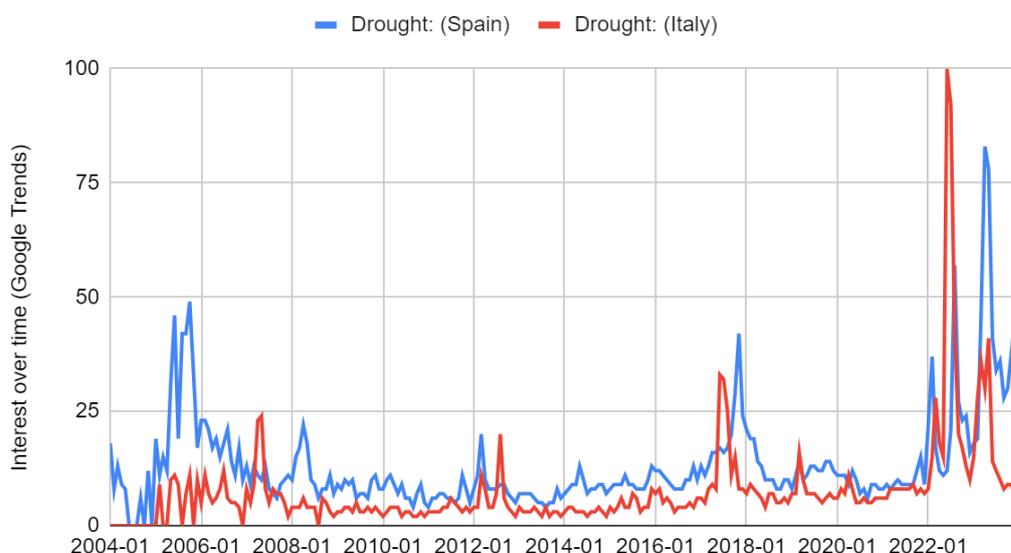
Figure 19 Interest over time in Google Trend of the search 'Drought' from Spain and Italy (national scale).

4 ClimEmpower Climate Resilience Assessment (Clim-RA)

To advance in the line of resilience baseline' assessment for each region, a "**Climate Resilience Evaluation Table**" has been built and fulfilled based on the:

- 10 resilience dimensions-based methodology of Schaefer *et al.* (2020) (**Table 2**).

- Key insights gathered from methodological approaches to assess climate resilience (**subsection 3.2**).

- Key issues obtained from the deliverable in which the five ClimEmpower "Communities of Practices" were launched (D1.1).

- "Questions from regions" to identify their main data gaps, local needs, resources, and expectations (**subsection 4.2**).

The proposed approach has been developed as simply as possible, considering the main dimension of climate resilience and its multiple conceptual and technical definitions. It requires an intermediate knowledge of the main characteristics and features of the region in terms of resilience status, not only focused on robustness and adaptiveness but on social, institutional, environmental and governance capabilities. To get a final climate resilience score, it is needed to assign a value, from 1 (low) to 5 (very high), to each resilience dimension, having the same weight (equal importance), so the maximum score to be obtained is 5. Beyond the interest of getting a final climate resilience score and the associated inter-comparison analysis between the different components and regions, the ultimate goal of this approach is to identify and point out the main resilience strategies to be encouraged and envisaged during the ClimEmpower project.

With respect to the climate resilience classes, they have the following range of values:

- **Low resilience**: [1 - 1,5]
- **Intermediate resilience**: [1,5 - 3]
- **Good foundations on climate resilience**: [3 - 4,5]
- **Very high resilience**: [4,5 - 5]

$$\text{Clim-RA score} = (R + E + S + I + L + I + E + N + C + E) / 10$$

4.1 Expectations coming from CoPs

Communities of Practice (CoPs) were established and launched in all five regions during the development of Task 1.1. Within these CoPs, stakeholders shared their experiences, information, tools, and resources available in their regions, along with the expected solutions based on their specific needs.

Despite regional differences, common hazards emerged in all the Case Studies. Droughts, heat waves, floods, and forest fires were identified as common hazards across all regions.

Vulnerable sectors differ from region to region. Therefore, solutions will need to be adapted to the specific characteristics of each region and the suitability of proposed hazard and

risk/impact models for use in each of the regions assessed in terms of inputs required, resources, expertise, or exploitation.

The main insights for each region are presented hereafter.

4.1.1 Andalusia (Spain)

Andalusia faces several climate-related **hazards**, including a drought-prone climate and an escalation in heavy precipitation events leading to floods. Compounded by rising sea levels, these events can exacerbate the consequences of flooding episodes. Additionally, heatwaves and wildfires pose significant threats to the region, causing substantial damages.

These hazards endanger **critical assets** such as water distribution systems, urban drainage infrastructure, and natural spaces. The sectors most severely impacted are agriculture, healthcare, tourism, and forestry.

While not all **data gaps** have been bridged, the region boasts valuable open climate repositories, climatic data, and prior experience in climate change projects. Consequently, the solutions developed through this initiative are expected to complement and build upon existing efforts, avoiding duplication.

Among the **anticipated outcomes** are models, risk assessments, and impact maps that can be catalogued in regional repositories, master plans, and other reports addressing the primary climate hazards. These resources will support informed decision-making processes. Furthermore, workshops and training activities are planned to enhance governance coordination, raise public awareness, facilitate decision-making, and bridge the gap between scientific findings and end-users.

Envisaged stakeholder **contributions** include climate, hydrogeological data, and sewage network information, enabling the establishment of robust models tailored to the region's specific needs.
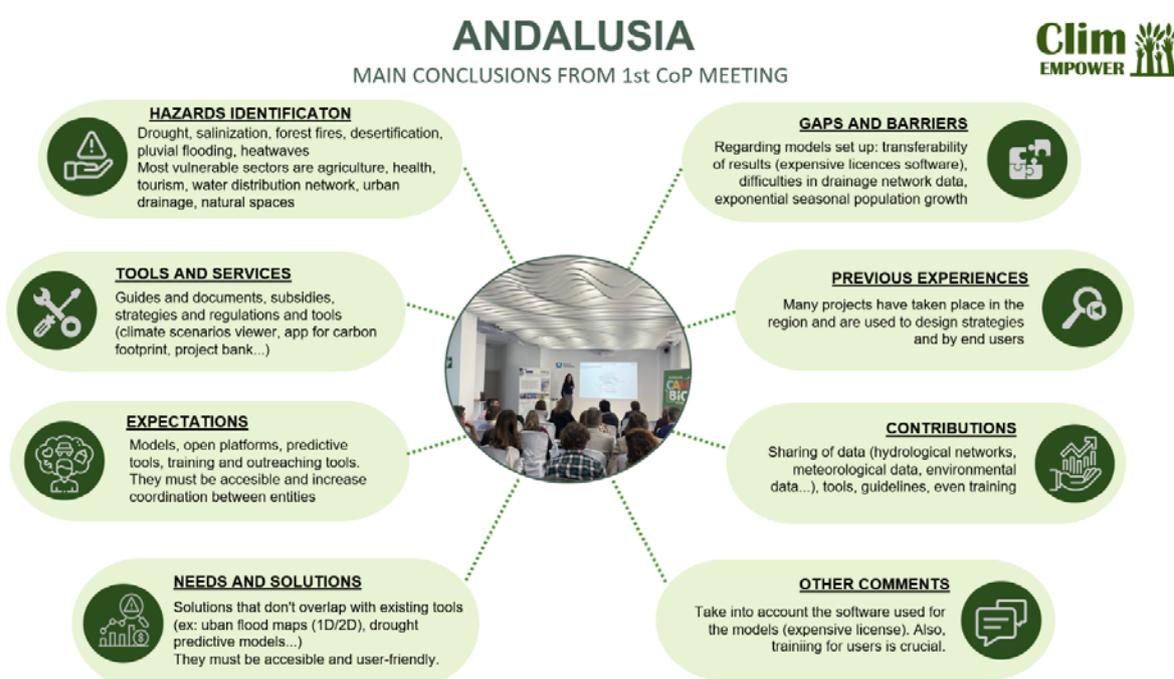
Figure 20: Andalusia: overview of needs and expectations

4.1.2 Central Greece (PSTE, Greece)

The main climate **hazards** affecting this region include floods, wildfires, droughts, rising temperatures, and water pollution. Main **impacts** are on the primary sector, the health and tourism industries.

There is an urgent **need** in the region to assist local agencies in mitigating the effects of climate hazards, educating personnel involved in the planning process, and raising public awareness on these matters. Any **technological solutions** implemented must be user-friendly and accompanied by adequate training.

Tools and needs: while the region already has governmental directives, forecasting models, and early warning systems in place, it is crucial to provide the public with access to climate-related data. Additionally, certain stakeholders have mentioned the availability of private **datasets** based on their projects or commissioned work, such as local hydrological networks (streams), meteorological data (from local meteorological sensors), and environmental data (flooded areas). However, it is a priority to explore the availability of the licensed data and search for other potential sources.

Figure 21: PSTE: overview of needs and expectations

4.1.3 Troodos mountain range (Cyprus)

The **hazards** identified during the CoP are wildfires, floods, increasing temperatures leading to droughts and affecting water availability, and Saharan dust.

Disruptions in meteorological patterns have mainly **impact** on agriculture and biodiversity, which are highly vulnerable to climate change. Wildfires further devastate these habitats, leading to biodiversity loss and disrupting ecological networks. Additionally, tourism is also affected by the consequences of climate change. Saharan dust poses a risk to public health and the environment.

In terms of **tools**, the region relies on governmental directives, forecasting models, and interactive flood risk maps, but these are considered insufficient to address the hazards effectively. Therefore, the region **needs** user-friendly solutions capable of forecasting with a special focus on agricultural production, strategies to mitigate wildfires, improving access to climate and hazard-related data (including vulnerable areas), developing a plan to address Saharan dust, and training personnel.

The region faces **challenges** including limited funding, insufficient cooperation between public agencies, and a lack of understanding of how to effectively implement and maintain technological solutions. However, stakeholders have shown a proactive approach and are willing to share data.

TROODOS MOUNTAIN RANGE
MAIN CONCLUSIONS FROM 1st CoP

HAZARDS IDENTIFICATON
Wildfires, Floods, Increasing of Temperature, Saharan dust and Drought Most vulnerable sectors are Agriculture, biodiveristy and tourism.

TOOLS AND SERVICES
VESSRU (service for fire deprt. assistance), ARI (agricultural research), Civil Defense, WDD (dept. responsible for creating mitigation plans)

EXPECTATIONS
Educational ressources, comprehensive climate change mitigation national strategy

NEEDS AND SOLUTIONS
Difficulties in CC data accesibility, training of personnel, deployment of technological forecasting tools, implementation of strategies and plans (specially saharan dust), raise social awareness about climate-related hazards

GAPS AND BARRIERS
Scarcity of fnding sources, deficiency in cooperation between public agencies and limited understanding of technological solutions

PREVIOUS EXPERIENCES
Involvement in other EU programs are relatively limited

CONTRIBUTIONS
Data sharing (open or private)

OTHER COMMENTS

Figure 22: Troodos: overview of needs and expectations

4.1.4 Osijek-Baranja County (OBZ, Croatia)

The main **hazards** identified during the CoP are drought, followed by floods, heat waves, and hail, which lead to a reduction in food production (locally produced homemade from local farms), desiccation of farmland and wetlands, and natural losses. Main **impacts** are on agricultural productivity and the tourism sector (specifically natural tourism), leading to a decline in social development and economic instability in the region.

Besides the hazards, there are certain **challenges** and barriers or obstacles. Although some public **data** is available (but insufficient to carry studies), valuable data collected and funded from non-EU projects or other sources can exclusively be used within certain institutions, so there is a clear lack of public and accessible data.

The existing **tools** in the region and experiences from other projects are very limited (mainly focused only on strategies on paper). The biggest **challenge** detected is adapting to the current climate changes and searching for alternative ways to continue agricultural farming, food production, and preserving and protecting the remaining wetlands and wildlife in the area.

The developed tools are **expected** to address heat waves or lack of rainfall (such as drought predicting models) and floods, such or flood models or other related tools. Although models could help and seem like a good idea for stakeholders, there are still uncertainties about the set-up, or the data and resources needed.

The stakeholders are willing to contribute in any possible way by sharing the public data that could be useful for the models and the project in general and by participating in climate change-related activities.

OSIJEK-BARANJA COUNTY
MAIN CONCLUSIONS FROM 1st CoP MEETING

HAZARDS IDENTIFICATON
Drought, floods, heat waves, hail
Most vulnerable sectors are agriculture and the environment

TOOLS AND SERVICES
Not much information available. Strategies and plans exist, but only on paper

EXPECTATIONS
Models solutions that will function for the region

NEEDS AND SOLUTIONS
Solutions should focus on drought prediction or aid reducing heat waves and lack of rainfall Adittionally, they should be understandable by the final users

GAPS AND BARRIERS
Maintenance and upgrade of created models

PREVIOUS EXPERIENCES
From other EU projects, only strategies were made, not tools

CONTRIBUTIONS
Participation in data sharing and dissemination of the project through lectures, seminars, workshops and conferences

OTHER COMMENTS
Issues concerning data sharing – most institutions are prohibited from sharing research information

Figure 23: OBZ: overview of needs and expectations

4.1.5 Sicily (Italy)

The main **hazards** detected are flash floods, exacerbated by the island's topography and the increase of impermeable surfaces. Heat waves are also a major problem, worsen by the heat island effect. Main **impacts** are on agriculture, irrigation of green urban areas, and tourism. High temperatures put sectors such as water demand and the functioning of the electrical grid at risk, leading to negative consequences on health and vulnerable populations.

The Italian Government approved the National Climate Change Adaptation Plan (PNACC) in 2023 to address the impacts of climate change on the national territory, and initial actions have been undertaken in terms of strategies and resilience tools.

The main **challenge** for implementing strategies is the obligation of climate-proofing for all infrastructure projects eligible for financing within the ERDF Program 2021-27. Fulfilling this verification requirement necessitates tools and documents currently not available, such as climate hazard maps considering climate change scenarios and risk/impact scenario analyses. In summary, it is essential to develop tools that support the architectural integration of such interventions, ensuring sustainable and resilient design practices. Additionally, it must be highlighted the absence of tools and climate services capable of identifying the origins of extreme events occurring elsewhere but affecting urban areas.

To accomplish this, it has been identified a lack of **data** at higher resolution (currently available maps are 12x12km) to conduct a detailed analysis for city scale.

Stakeholders demonstrate a proactive approach, placing particular emphasis on the exchange of readily available data, including demographic data and the perimeter definition of territorial areas in the Regional ERDF Program. Furthermore, environmental and climate datasets will be collected, underscoring the willingness to enhance the capacity to address complex challenges.

In this regard, two distinct groups of regions were identified: some regions have a clear understanding of the tools and solutions to be tested and developed, while others lack about what kind of tools would be more suitable for the region, and face issues of data availability and implementation strategies.

Most stakeholders agreed on introducing or developing solutions that complement existing regional tools. A major **challenge** across regions is access to climate-related data and the understanding of these tools. Consequently, stakeholders expect that climate change (CC) educational tools and training materials will play a crucial role in empowering them to effectively address CC challenges.

Suggested **solutions** aligned with the project include:

- Platforms open to citizens providing climate data

- Information for policy decision-making and drought planning

- Predictive tools and comprehensive reports on flood and drought scenarios

- Models, training, and outreach tools

- Impact assessments and key performance indicators (KPIs)

- Catalogues of models and climate data management applications

- Climate hazard maps and risk scenarios

- Tools supporting sustainable and resilient design practices

It is crucial to avoid complex, restricted, or outdated information, and ensure adequate training to prevent abandonment of these tools. Most regions also face **challenges** such as limited funding, insufficient cooperation between public agencies, and a lack of understanding of how to effectively implement and maintain technological solutions. Data sharing was identified as a common challenge during CoPs, with some regions facing more difficulties than others. Nonetheless, participants exhibited a proactive approach, agreeing to share all feasible data. Stakeholders are committed to contributing by sharing public data useful for the models and the project at large, and by participating in CC-related activities.

SICILY

MAIN CONCLUSIONS FROM 1st CoP MEETING

HAZARDS IDENTIFICATON
Urban flooding, heatwaves, biodiversity loss, wildfires
The most vulnerable sectors are biodiversity, toursim, electric system, health

GAPS AND BARRIERS
Obligaton of climate-proofing for all infrastructure projects, lack of CC-tools and services focused in rural areas, general lack of detailed data and tools

TOOLS AND SERVICES
Socioeconomic data and other environmental and climate datasets (cartography and hidrogeology maps, urban atlas, risk maps, etc)

PREVIOUS EXPERIENCES
Allocation of resources from the EU funds with focus on CCA; Action Plan for Sustainable Energy and Climate (SECAP) and other strategies and tools have been adopted

EXPECTATIONS
Tools that support the integration of CC mitigation strategies within a planning perspective

CONTRIBUTIONS
Stakeholders demonstrate a proactive approach and place emphasis on the exchange of demographic, socioeconomic and technical available data

NEEDS AND SOLUTIONS
Need for operational tools for climate-proofing; services for climate hazard maps; impact and risk models at different scales

OTHER COMMENTS
Stakeholders with diverse backgrounds will be added to future CoPs

Figure 24 Sicily: overview of needs and expectations.

4.2 Results from 'Questions for Regions' questionnaire

In the framework of WP1, in a coordinating way with WP2 and WP3 leaders, some key questions were posed to the regions to reach their main needs and expectations of **ClimEmpower** solutions. For this, a four-quadrant figure (**Figure 21**) has been completed for each region to highlight the main use cases and their relationship with envisaged data services.
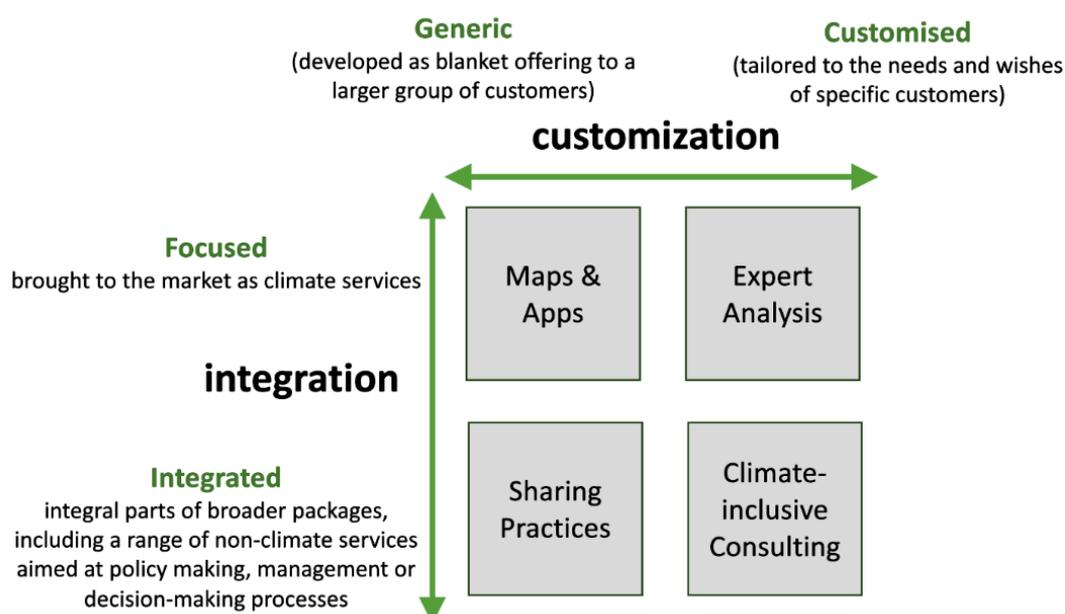
Figure 25 Four-quadrant graph gathering the needs and expectations on ClimEmpower data services.

The 'focused approach' will be the main digital approach of the project (Maps & Apps and Expert Analysis), being the 'integrated' solutions the combination of existing solutions or products.

For all the regions, some feedback has been obtained on the main data gaps (WP2) and climate applications type offer (WP3). They will be mentioned in the corresponding subsection, together with the results coming from the four-quadrant graph.

4.2.1 Andalusia (Spain)

For the Spanish case study, there is a very comprehensive allocation of needs and expectations between types of data services (Figure 26) for Andalusia and specifically for the Western Costa del Sol sub-region. The region would need generic and focused climate applications for assessing several climate hazards, such as wildfires, heatwaves, and drought in a map format. With a more customised approach, an expert analysis has been pointed out based on flood risk assessment models.

The expected integrated solutions are referred to i) the analysis of potential replication of the climate risk assessment methodology (see subsection 3.2.1.3) for empowering other regions, and ii) the implementation of best practices for a future consultation process. The Andalusian methodology provide some advances in the estimation of exposure or vulnerability components of climate risk assessment, contributing to a standardized methodology at European level.

The region has no special needs for downscaled climate prediction data. It is mainly interested in detailed precipitation data, as well as in rainfall event list/photos, for the purpose of calibrating and validating the flood models. The expectations for climate applications are focused on climate risk mapping for droughts, wildfires, and floods, being able to filter key information by districts and visualize associated socio-economic impacts and prioritize actions within several active or future climate adaptation measures.
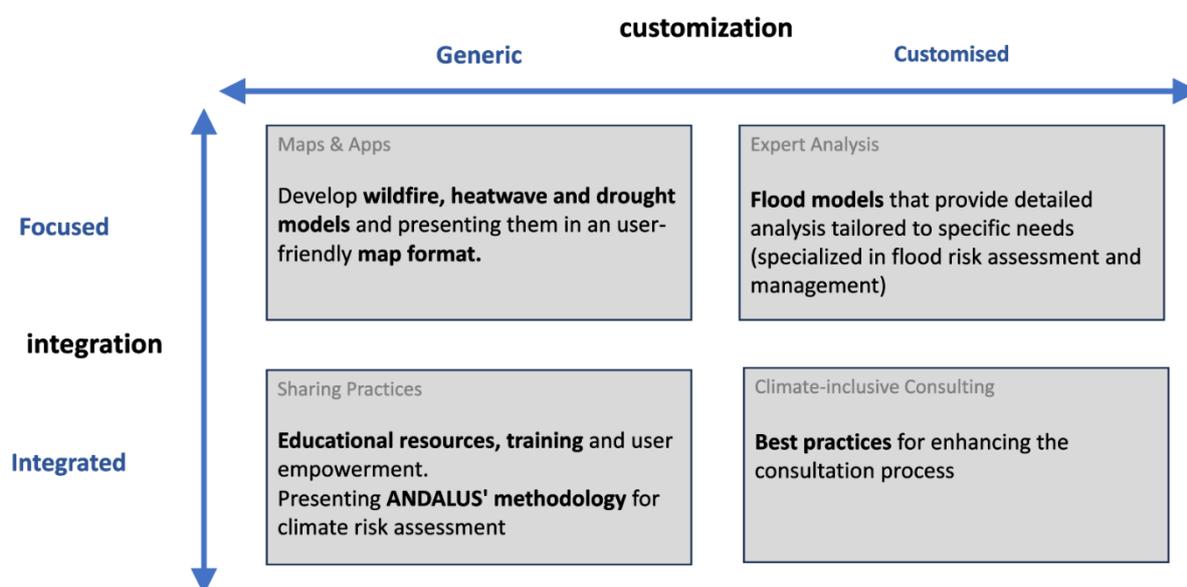
Figure 26 Four-quadrant graph gathering the needs and expectations of Western Costa del Sol on ClimEmpower data services.

4.2.2 Central Greece (PSTE, Greece)

Based on all the information and knowledge from the "**Regional Climate Change Adaptation Plan (PESPA) for the Region of Central Greece**", the Greek case study pointed out its main needs and expectations. The region also pointed out the existence of a web app called "**Oikoskopio**" with reliable and comprehensive information on climate services, but also including geographical information on land covers, distribution species, hydrographic elements, hydrographic network, among others.

The features for expected ClimEmpower applications will depend on their typology:

- **Customized Apps**: Interactivity, real-time data, scalability.

- **Integrated Apps**: Cross-disciplinary integration, user-centric design, compliance, and security.
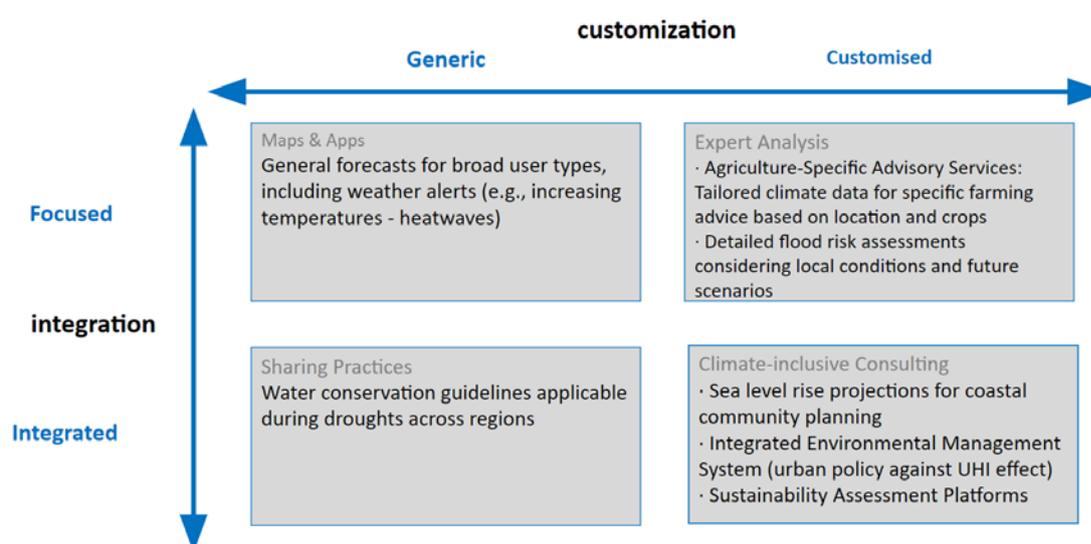
Figure 27 Four-quadrant graph gathering the needs and hopes of Region of Central Greece (PSTE) on ClimEmpower data services.

Regarding data gaps, the Greek region has developed a dataflow for enhancing environmental resilience (**Figure 24**).
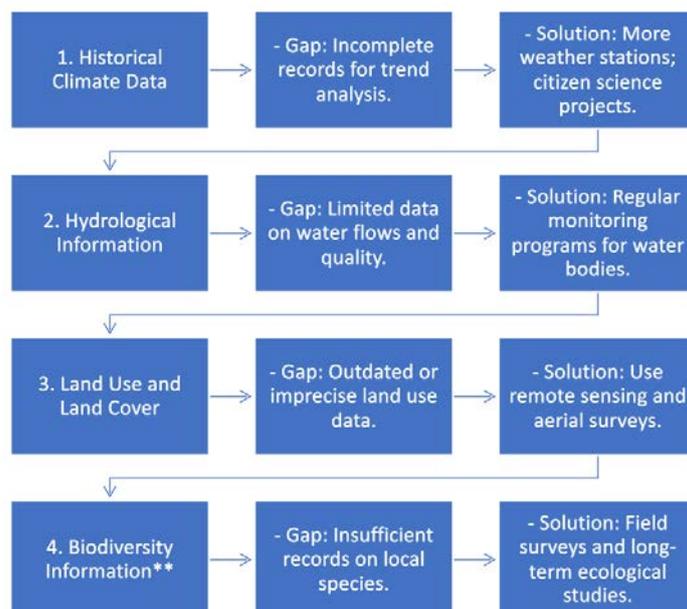
Figure 28 Addressing data gaps in environmental management (Region of Central Greece).

There are other gaps identified for:

- Socio-Economic Data

    o Gap: Limited socio-economic characterisation.

    o Solution: Demographic and economic surveys.

- Infrastructure Resilience Data

    o Gap: Inadequate resilience data of infrastructure.

    o Solution: Regular audits and resilience assessments.

- Pollutant Sources and Loads

    o Gap: Unclear pollutant sources and quantities.

    o Solution: Monitoring stations and pollutant tracing models.

- Community Engagement Levels

    o Gap: Low awareness of environmental issues.

    o Solution: Community outreach and engagement activities.

- Adaptation and Mitigation Measures Efficacy

    o Gap: Uncertain efficacy of climate strategies.

    o Solution: Pilot projects and control sites for evaluation.

4.2.3 Troodos Mountain range (Cyprus)

The four-quadrant graph for this region gives rise the co-existence of several data services that would contribute to the climate resilience of Troodos Mountain. It shows interest (as in all case studies) for a multi-hazard generic and focused data service, including, as something new, the impacts of each hazard on each exposed element or sector (e.g., agriculture, tourism, …).

customization

Generic .... **Customised**

Focused

Maps & Apps
- Fact sheets
- Impacts of each hazard (fires, drought, dust etc.) on each exposed element (agriculture, tourism, biodiversity)

Expert Analysis
Maps of specific areas or communities affected the most under different hazard scenarios and their specific effect on tourism, agriculture and biodiversity.

integration

Integrated

Sharing Practices
Training and educational material
How to deal with:
- Risk of fires
- Increased temperatures
(Response/Action plans)

Climate-inclusive Consulting
Effect of fires/increased temperatures/dust on regional economy including:
- Effect on agriculture, tourism, biodiversity, infrustructures and cultural sites.
- Action plans for decision making in regards to mitigation

Figure 29 Four-quadrant graph gathering the needs and expectations of Cyprus Troodos Mountain region on ClimEmpower data services.

An expert analysis (customised/focused) is highlighted as an evolution of the generic one, looking for maps of the most affected or vulnerable areas or communities. Climate services for wildfires and heatwaves are expected as an integrated solution, as well as the analysis of the effect of these climate impacts on regional economy.

Cyprus regions has pointed out some data gaps to be fulfilled, related to specific datasets, for example, the Land Use and Land Cover (LULC) information, that may not have sufficient resolution. The CSF and regional authorities also mention that the available data (population, weather data, land use, cultural heritage sites and fires) need to be analysed in an integrated manner, to produce any meaningful data. They also put the focus on the importance of combining the concepts of climate hazards with the corresponding exposure component. The region expects a very similar final climate application with respect to the other, focused on mapping, filtering and prioritising functionalities.

4.2.4 Osijek – Baranja county (OBZ, Croatia)

For the Croatian case study, the four-quadrant graph is shown in **Figure 22**. The region needs and expectations are clearly based on a "multi-hazard web app" with information coming from droughts, heatwaves and floods models at a regional scale. In a more customised approach, the region is expecting analytics models to identify trends and patterns on historical climate data and their impacts on several economic sectors. For this, they have proposed the use of crowdsource information and GIS-based approach, respectively.
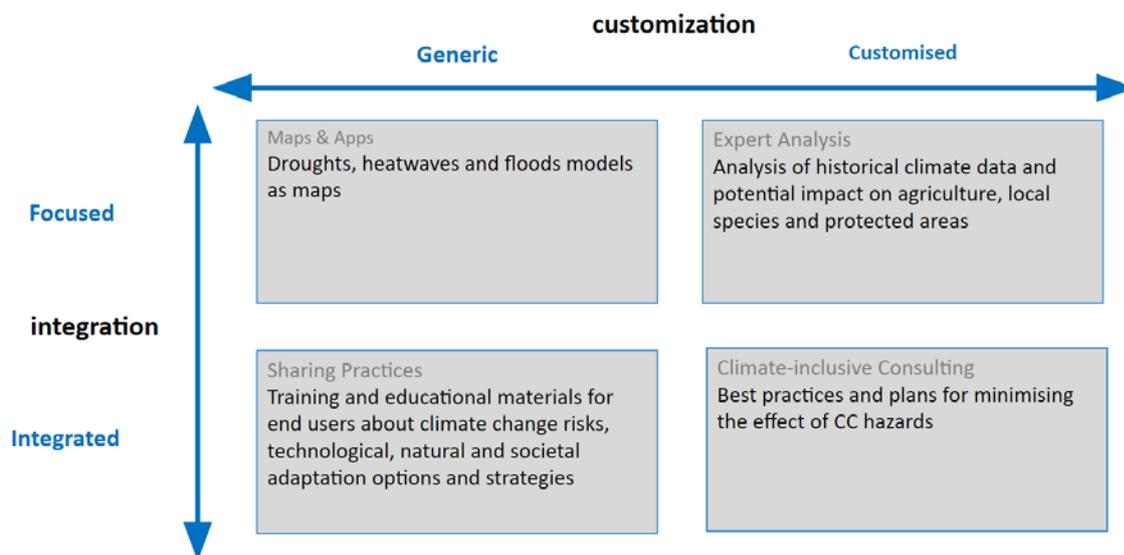
Figure 30 Four-quadrant graph gathering the needs and expectations of OBZ on ClimEmpower data services.

Moreover, the region is interested in integrated solutions that help developing training and educational materials and best practices for a better adaptation of climate change impacts. As the final digital solution, they are thinking on an application capable of:

- Assessing relative importance of various risks (droughts, heatwaves, floods),

- Prioritising different prevention measures based on their expected impact

4.2.5 Sicily (Italy)

The four-quadrant results from Sicily can be observed in **Figure 25**. The case study facilitators highlighted that there is not a sub-national plan for climate change adaptation. The "**National Climate Change Adaptation Plan (PNACC)**" is the reference strategy on climate change aspects, but the geospatial information has got a very coarse resolution (12 x 12 km), so it is clear the need for downscaled climate data (key issue highlighted in **subsection in 4.3**).

Based on the Sicilian analysis of its climate needs and expectation, the region expects from **ClimEmpower** some applications to help developing:

- A "**Regional Climate Framework**" by preparing:

- a set of climate indicators that are reliable and can be populated over time and integrated into the regional context.

- analysis of historical series of climate parameters and an assessment of ongoing changes conducted through trend analysis.

- A "**Regional Climate Risk Assessment**" by preparing:

- mapping of climate risks arising from different hazards for sectors and exposed elements (population, productions, infrastructure, etc.), aimed at understanding the expected local impacts (in the specific zone) in relation to different climate scenarios and identified vulnerabilities.

customization

Generic   **Customised**

Focused

Maps & Apps	Expert Analysis
- a set of **climate indicators/maps** that are reliable and can be populated over time (to assess infrastructural projects and determine their specific contributions to enhancing climate resilience).	- analysis of **historical series of climate parameters and an assessment of ongoing changes conducted through trend analysis**

integration

Integrated

Sharing Practices	Climate-inclusive Consulting
- **roadmaps** for improving infrastructural projects, combining climate/non-climate factors and integrating different aspects (i.e. socio-economic fragilities – census tracts; land uses; characteristics of buildings and open spaces)	- **"Climate Proofing" for infrastructural projects** financed by the ERDF 2021-2027. This verification must be carried out according to the indications provided in the "Technical Guidelines for Climate-Proof Infrastructure for the Period 2021-2027"

Figure 31 Four-quadrant graph gathering the needs and expectations of Sicily on ClimEmpower data services.

In terms of data gaps, the Italian region has required high-resolution climate data for regional and local analyses (e.g., for infrastructural projects in urban areas) for enhancing stakeholders' involvement in climate adaptation strategies. It is interested in historical and observational data on climate parameters, as well as in indicators and metrics to monitor and evaluate the adaptation progress, including the Integration and harmonization of data across different sources and sectors.

The abovementioned "**Regional climate framework**" would include:

- Climate indicators customised over time,

- Analysis of historical series and trends,

- Mapping of climate risks and impacts.

The most relevant information regarding WP3 application type offer is referred to the interest on a "**Report generator**" for a defined area for specific layers/scenarios (with maps, graphs, tables, etc.), giving an overview of the potential climate hazards.

4.3 Regional climate Resilience assessment

The results of climate resilience assessment for all the five regions are shown in **Figure 29**. The main objective of this analysis is not to implement a comparative analysis between regions (e.g., putting the focus on the absolute vales of the resilience dimensions), but point out key strengths and weaknesses of the demo sites to help drawing the resilience pathways to be implement during the project lifetime.
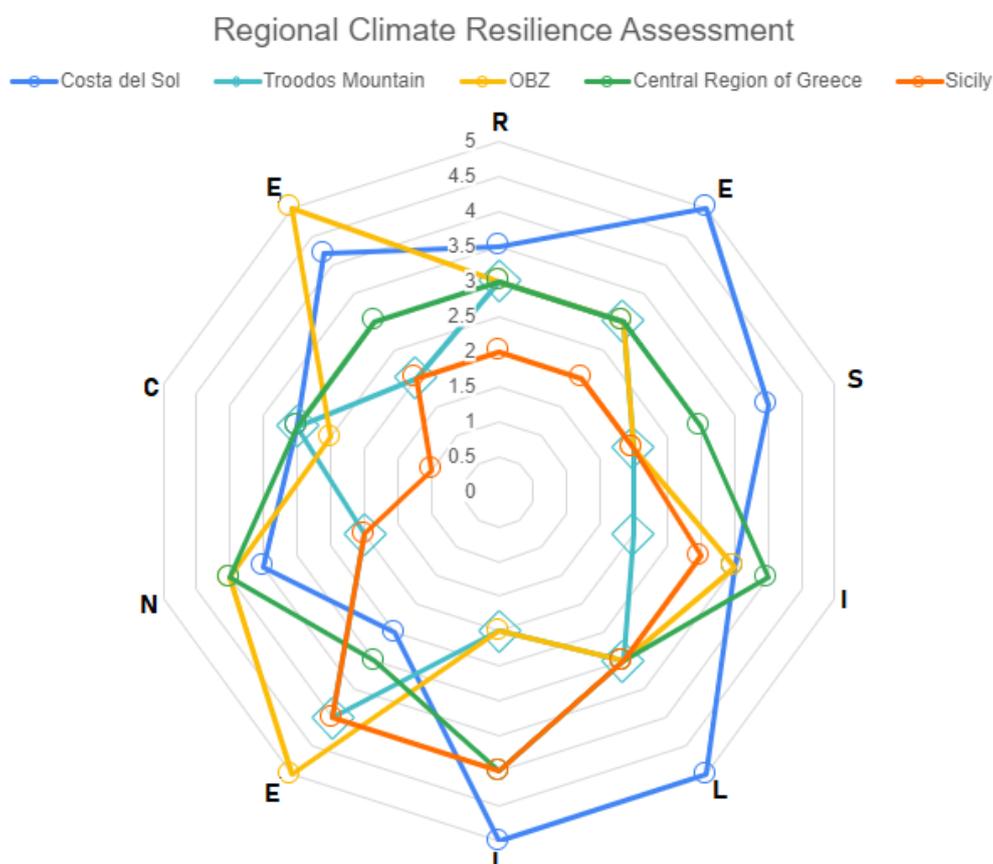

Figure 32 Regional climate resilience evaluation results from the Spanish region. Notes: R = Robustness and adaptiveness to climate related stresses and shocks; E = Evaluation and Monitoring: resilience as a process; S = Scale (Countries, Regions, Cities, Neighbourhoods, Individual); I = Interdisciplinarity: resilience as umbrella for different sectors; L = Learning and innovation; I = Information and transparency: resilience as participation tool; E = Environment (natural and built up); N = Networked systems and actors (multilevel governance); C = Capacity to transform after disturbance but maintain self-organisation; E = Equity and Justice: resilience measurements must not exclude others

On average, the highest top 3 scores are obtained in 'Environment', 'Learning and innovation' and 'Information and transparency', and the lowest ones on the capacity of adapting and transforming against climate risks at the short and long-terms (Robustness and adaptiveness & Capacity to transform). Moreover, there is an opportunity to build resilience pathways improving the level of spatial disaggregation (e.g., downscaled climate projections and indicators) of climate related risks for all the ClimEmpower regions ('Scale' dimension), with an average score of 2,6. In the framework of WP2 and WP3 it is expected to produce this kind of 'regionalized' data, so there is a clear match between needs/expectations and climate services to be developed.

Regarding adapting and transforming dimensions of resilience, ClimEmpower tailored-made applications will enhance the robustness of the regions by providing focused and customised services and products, as can be seen in subsection 4.2.

Comparing the individual scores between regions (Table 5), the highest score is referred to Spanish case study (Costa del Sol), with a value of 3,9. This region shows high resilience values regarding its evaluation and monitoring processes (E), due to an **existing and specific methodology to quantify climate risks** (see subsection 3.2.1.1 for more details), the learning and innovation dimensions (L), as well as the perception of resilience as a participation tool (I). Related to the learning and innovation spheres, through the "**Andalusian Portal on Climate Change**" the region shares with the citizens, private sector, and local public administration all type of information regarding climate change impacts and potential adaptation measures. Moreover, the region actively participates in national and European public funded R&D projects (Forging Resilience – ClimateKic, Interreg FIREPOCTEP and CILIFO projects (wildfires), POCTEFEX PRAVEMA or FLOOD CBA#2 (floods), among others). The 'Costa del Sol' region has the lowest scores related to the environment protection status (E) and the "community-level recovery" from extreme weather events (C). The latter, in addition to being one of the most difficult to quantify, manifests complex synergies and trade-offs with other resilience dimensions. The **ClimEmpower** solutions must help the regions learning from previous extreme climate events, to be better prepare and recover to and from future climate impacts.

Table 5 Regional climate resilience evaluation results (individual scores) by dimensions and regions. Legend: Es = Costa del Sol sub-region, Andalusia, Spain; Cy = Troodos mountains, Cyprus, Hr = OBZ, Croatia, Gr = PSTE, Greece, and It = Sicily, italy

Acronym	Explanation	Specific question for the region	Climate Resilience Evaluation					Average value
			Es	Cy	Hr	Gr	It	
R	Robustness and adaptiveness to climate related stresses and shocks	What is the degree of robustness and adaptiveness to climate related stress and shocks in your region?	3.5	3	3	3	2	**2.90**
E	Evaluation and Monitoring: resilience as a process	Is there some public methodology to easily assess climate-related risks and identify potential adaptation measures?	5	3	3	3	2	**3.20**
S	Scale (Countries, Regions, Cities, Neighbourhoods, Individual)	What is the level of spatial disaggregation of climate related risks?	4	2	2	3	2	**2.60**
I	Interdisciplinarity: resilience as umbrella for different sectors	Are all the critical sectors involved in climate resilience/risk assessment plans and strategies?	3.5	2	3.5	4	3	**3.20**
L	Learning and innovation	The public administration provides to society free-of-charge resources and materials to learn on expected climate change impacts and potential adaptation measures. Does your region actively participate in R&D projects?	5	3	3	3	3	**3.40**
I	Information and transparency: resilience as participation tool [it's linked to "L" score]	Does your region have some national or sub-national online climate services portal, with information aggregate as climate indicators?	5	2	2	4	4	**3.40**

Acronym	Explanation	Specific question for the region	Climate Resilience Evaluation					Average value
			Es	Cy	Hr	Gr	It	
E	Environment (natural and built up)	Do you think that there are enough natural protected areas (NPAs) to buffer the potential impacts of climate change and conserve ecosystem services - e.g, water provisioning?	2.5	4	5	3	4	3.70
N	Networked systems and actors (multilevel governance)	Is there good coordination and collaboration between the different stakeholders (public authorities, water utilities, NGOs, SMEs, …) of your region for fostering climate resilience?	3.5	2	4	4	2	3.10
C	Capacity to transform after disturbance but maintain self-organisation (it is linked to "R" dimension)	What is the "community-level recovery" from extreme weather events?	3	3	2.5	3	1	2.50
E	Equity and Justice: resilience measurements must not exclude others	Are climate resilience/risk adaptation measures taking into account all people? - Leave no one behind approach	4.2	2	5	3	2	3.24
			3.9	2.6	3.3	3.3	2.5	

OBZ (Croatia) and Central Region of Greece. OBZ region have the same score of 3.3. These regions pointed out the potential of regional environmental systems to buffer the expected climate impacts (the protected areas in the region have their own 'Conservation and Management' Plans) and the existence of robust and sound efforts to promote equity and justice during the implementation of climate resilience plans and strategies (involving stakeholders from all the critical sectors). The most important climate document, the "**National Strategy of the Republic of Croatia**", which breaks down to plans according to the needs of the regions, can contribute to **ClimEmpower** goals once the main risks are detected and assessed. In the Croatian region, there is not an official climate service or product already on-going, so a gap to be filled has been identified.

In the region of central Greece (PSTE), the highest scores were awarded to "Interdisciplinarity", "Information and Transparency", and "Networked systems and actors" dimensions. Their climate resilience and risk assessment plans involve multiple critical sectors, reflecting an interdisciplinary approach. Key sectors include agriculture (drought-resistant crops, sustainable farming), water resources (managing supply and quality), energy (renewable sources, infrastructure resilience), urban planning (climate-resilient infrastructure), health (addressing climate impacts), environment (biodiversity conservation), transportation (resilient networks), economy and tourism (sustainable practices), and community and education (awareness and engagement). This comprehensive strategy ensures that all aspects of society are prepared for and resilient to climate-related stresses and shocks. Central Greece also utilizes several online climate services that provide aggregated climate information and indicators. The "**National Observatory of Athens (NOA)**" and the "**Hellenic National Meteorological Service (HNMS)**" offer comprehensive portals with climate data, weather forecasts, and long-term trends. Some regional government websites also provide local climate data and adaptation plans. These online portals enhance transparency and encourage public participation in climate resilience efforts. Regarding multilevel governance, fostering climate resilience involves multiple stakeholders, including public authorities, water utilities,

NGOs, SMEs, and local communities. While there are established frameworks for coordination, and NGOs play a vital role in advocacy and education, the effectiveness of collaboration varies. Strengths include existing coordination frameworks and active NGO involvement. However, challenges such as resource constraints, coordination gaps, and inconsistent public engagement remain. Overall, improving multi-level governance and consistent stakeholder collaboration are essential for building robust climate resilience in the region.

The last group of two regions are made up by 'Troodos Mountain: 2,6' and 'Sicily: 2,5'. The Cyprus region highlights the contribution of environment dimension to climate resilience, due the presence of **Troodos National Forest Park** (NATURA 2000), in which a specific EU funded project was developed (iLIFE-TROODOS) to increase public awareness of its natural values and the ecosystem services it provides. However, these natural protected areas are also highly vulnerable to effects of climate change (e.g. wildfires) and hence subsequently on tourism/biodiversity, etc. At national level, the "**Cyprus Climate Change Risk Assessment**" has been developed (Contract No. 22/2014), providing an overview of potential risks and opportunities of climate change for Cyprus to the end of the 21st century. Its findings, particularly related to those risks that require early action, informed the development of adaptation plans by the Government and the Competent Authorities. It has been identified a weakness to be overcome during **ClimEmpower** in terms of 'Interdisciplinarity' and 'Equity and Justice', due to not all key sectors are adequately integrated into climate plans and strategies, which could include sectors like agriculture, water resources, health, and infrastructure. The existing plans and strategies do not comprehensively cover all necessary aspects of climate resilience and climate risks and adaptation measures is not easily accessible to everyone, due to language barriers, technological limitations, or lack of outreach in certain areas. Fragmentation of jurisdictions and responsibilities is one of the most important issues in Cyprus (low multilevel governance score).

Regarding Sicily, it points out two main resilience dimensions in which the regions has got a higher status are 'Information and transparency' and 'Environment'. Related to the former resilience dimension, it has been identified the following web apps:

- **Regional level**: the SIAS SIT portal (https://www.sitagro.it/jml/) offers an agro-topoclimatic atlas which also contains climate indices and indicators.

- **National level**: ISPRA portal (https://www.isprambiente.gov.it/it) on climate indicators and the Climate Changes section contains many useful indicators (https://indicatoriambientali.isprambiente.it/framework/cambiamenti-climatici

The score of 'Environment' is justified by a geospatial analysis made comparing the area under natural protected zones and the total surface of the region. The worst resilience dimensions are motivated by the existing of the "**National Plan for Adaptation and Mitigation to Climate Change**" but not adapted at regional level. Moreover, there are not services that allow to consult data at different scales. The different actors and stakeholders in Sicily use the climate data reported in the National Plan. Nowadays, the issue of climate change adaptation is still considered by single sectors. The region is currently drafting the "**Regional Adaptation Plan**", under the responsibility of the Regional Environment Department and the participation of representatives of other regional departments, being the level participation of private or public sectors is still undefined.

5 Strategic vision for climate resilience pathways

In this section, the main conclusions gathered for the previous analysis (section 4) and results are presented as **bullet points**:

- The deliverable '**D1.2**' has served as an overview of regions' from **ClimEmpower** expected solutions, built upon the existing (**D1.1** - CoPs) and new gathered insights (Regional Climate Resilience Assessment: CLIM-RA).

- The abovementioned deliverable has been more focused on a planning perspective, developing the foundations of the final resilience scenarios or pathways to be produced, mainly, in further **WP4** tasks.

- During the project execution, these resilience pathways will be feed with the inputs gathered from the regions regarding their needs and expectations on data gaps (**WP2**) and climate applications/data services (**WP3**) to be addressed.

- In next deliverable '**WP2 - D2.1**', a link between the 10-resilience dimensions (CLIM-RA) and climate risk indicators will be proposed and defined, to polish the preliminary obtained scores.

- The conceptual and methodological advancements in the CRA field have analysed, pointing out the added value of ClimEmpower solutions (see **Table 4** for more details) and the synergies between work packages.

- The **ClimEmpower** digital solutions (**WP3**) must help the regions learning from previous extreme climate events, to be better prepare and recover to and from future climate impacts.

- The estimation of exposure and vulnerability components within climate risk assessment must be standardized to some extent (to be done during **WP2 – D2.2**), to ease the inter-comparison analysis between regions, contributing to a common methodology at European level.

- There is an opportunity to build resilience pathways improving the level of spatial disaggregation (e.g., downscaled climate projections and indicators) of climate related risks for all the ClimEmpower regions.

- ClimEmpower tailor-made applications (**WP3**) will enhance the climate resilience fostering robustness of the regions through focused and customised services and products.

For a more regional point of view:

- Most of the regions are interested in multi-hazard web applications (generic/focused).

- The **common attributes** of **expected climate applications** between regions are referred to three main functionalities: i) risk mapping, ii) data filtering (by areas of interest, climate impacts, ...) and iii) prioritisation of measures (adaptation measure Nº1 vs adaptation measure Nº2).

- A "**Regional Climate Framework**" is needed for most of the regions, more specifically gave rise for **Sicily**. The Italian CSF mentioned that all help and support received from ClimEmpower to start developing such a framework will be very welcomed.

- Related to the previous issue, the **Spanish region (Costa del Sol - Andalusia)** can serve as an 'early adopter' of such a regional climate framework, due to the existence of a **climate risk assessment methodology** with a high potential to be replicated in the other regions.

- The **Region of Central Greece** has highlighted some integrated data services to be developed, such an "Integrated Environmental Management Systems", combining data for comprehensive urban and policy planning, or "Sustainability Assessment Platforms", helping businesses integrate climate considerations into operations.

- For the **Greek region**, improved multi-level governance and consistent stakeholder collaboration are essential for building robust climate resilience in the region. This is clearly aligned with the objectives and expectations from WP4-related tasks.

- The "**National Strategy of the Republic of Croatia**" can contribute to **ClimEmpower** goals, once the main risks are detected and assessed. In the Croatian region, there is not an official climate service or product already on-going, so a gap to be filled has been identified.

- The Cyprus region has highlighted the contribution of environment dimension to climate resilience, due the presence of **Troodos National Forest Park** (NATURA 2000). It has also pointed out a weakness to be overcome during ClimEmpower in terms of 'Interdisciplinarity' and 'Equity and Justice', due to not all key sectors are adequately integrated into climate plans and strategies. To implement an effective stakeholder's engagement strategy is a key issue.

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Annex I: Guideline for regions to complete climate resilience assessment

In this annex, some resources, insights, and recommendations for regional climate resilience assessment are briefly described below.

- **[R] Robustness and adaptiveness to climate related stresses and shocks:**

    o Redundancy in infrastructure in different sectors (water, energy, ...) can provide a higher value of this resilience dimension.

    o The robustness is referred to short-term response skills (e.g., operational Early Warning Systems).

    o The adaptiveness is more focused on mid/long term response skills (e.g., multisectoral regional climate action plan, including diverse strategic areas: water resources; flood prevention; Agriculture/Fishery/; Urbanism; Tourism; Energy; among others).

- **[E] Evaluation and Monitoring:** resilience as a process: the existing of a robust, tested and validated national or regional methodology to assess (quantitatively or semi-quantitatively) climate risks and their contributions on building resilience.

- **[S] Scale (Countries, Regions, Cities, Neighbourhoods, Individual):** Does the region have some climate service or product in which you can filter climate risks projections at different spatial scales - Basin, municipality/city, region/province, boundary box/...?

- **[I] Interdisciplinarity**: resilience as umbrella for different sectors: to investigate the level of participation (including diversity) of public/private sectors and stakeholders during the preparation of existing climate strategic plans, strategies and methodologies.

- **[L] Learning and innovation:**

    o Learning from past experiences at government and politician scales is also a significance point of view.

    o Learning from 'failures' must be a mandatory issue.

    o How on-going/finished/planned R&D projects can contribute to regional climate goals?

- **[I] Information and transparency - resilience as participation tool:** to make a catalogue of existing climate platforms and services in each region can be a good proxy to evaluate this dimension.

- **[E] Environment (natural and built-up):** based on the number of natural protected areas (NPAs) in the region:

- o the percentage of land cover referred as NPA with respect to total area

- o Resource (NATURA 2000 DATA - the European network of protected sites): https://www.eea.europa.eu/en/datahub/datahubitem-view/6fc8ad2d-195d-40f4-bdec-576e7d1268e4

A complementary approach to evaluate this dimension is referred to the number of Nature-Based Solutions (NBS) already implemented or projected in the short-term (not assessed in the current version of the methodology).

- **[N] Networked systems and actors (multilevel governance)**: one recommended proxy can be the "**Regional Authority Indicator (RAI)**" - a scale ranging between 1 and 30 - for each region or regional tier. It measures the authority in self-rule and shared rule exercised by regional governments. **Self-rule** refers to autonomy and hence the extent to which sub-national units (Länder, cantons, States, provinces, autonomous communities, etc.) are free in deciding, financing and implementing their own policies. **Shared rule** defines it as the extent to which sub-national units can participate in decisions that concern the whole political community and not just their region.

  - o Resources

    - ▪ RAI-MLG: https://garymarks.web.unc.edu/data/regional-authority-2/

    - ▪ Causes and Consequences of Multilevel Governance: https://cordis.europa.eu/project/id/249543/de

- **[C] Capacity to transform after disturbance but maintain self-organisation:**

  - o Skills to anticipate the impact (Indicator-based management)

  - o Maintaining self-organisation = governance capabilities (EQI - Data)

  - o Resource: European Quality of Government Index (EQI): https://eqi-map.qog.gu.se/

- **[E] Equity and Justice: resilience measurements must not exclude others**: the equity and justice score must be coherent with those related to climate resilience dimensions "Scale", "Interdisciplinarity", "Learning", "Information & transparency", "Networked systems".