
# REGIONAL CC-RESILIENCE RECOMMENDATIONS

ClimEmpower Work Package 4, D4.3, v1

Project ClimEmpower: User Driven Climate Applications Empowering Regional Resilience

Work package 4, Deliverable D4.3

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## Revision history

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## Legal Disclaimer

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# List of Acronyms

| | |
|---|---|
| **BGI** | Blue and Green Infrastructure |
| **CIC** | Climate interaction context |
| **CoP** | Community of Practice |
| **TGM** | Trial Guidance Methodology |
| **WCDS** | Western Costa del Sol |

# Glossary

| | |
|---|---|
| **BGI** | Blue and green infrastructure refers to interconnected networks of natural and semi-natural systems that work together to enhance urban resilience and sustainability. While blue infrastructure focuses on water management through features like rivers, wetlands, and drainage systems, green infrastructure emphasizes the use of plants and green spaces, such as parks, green roofs, and forests, to provide ecosystem services. Together, they manage stormwater, reduce flooding, improve air and water quality, enhance biodiversity, and support climate adaptation in urban environments. |
| **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 (based on IPCC, 2018) |
| **Climate Resilience** | The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions. |
| **Community of Practice** | This deliverable presents the consensus achieved through Community of Practice (CoP) activities, offering both general and region-specific recommendations for decision-makers within and beyond the five ClimEmpower regions. It outlines key insights, best practices, and tailored strategies to enhance resilience and adaptive capacity. By incorporating stakeholder input and regional needs, the document serves as a practical guide for policymakers, providing actionable measures to strengthen climate resilience and sustainable development in diverse contexts |

# Executive summary (publishable)

This report is a first of the two “resilience recommendations” deliverables of the ClimEmpower project. It presents the intermediate consensus on general and region-specific recommendations for decision-makers within and beyond the five ClimEmpower regions.

This consensus has been reached through **Communities of Practice (CoP)** - collaborative platforms where regional authorities, researchers, and stakeholders have engaged in knowledge exchange, shared experiences, and co-developed resilience strategies tailored to specific regional contexts. Through the CoP’s participatory approach, ClimEmpower has facilitated dialogue and joint learning, fostering a shared understanding of resilience challenges and opportunities. The outcomes of this process provide actionable guidance for policymakers, encouraging the adoption of adaptive and sustainable strategies that reflect both scientific knowledge and local realities.

The recommendations outlined in this report address key challenges related to **climate resilience, sustainable resource management, and governance**. These recommendations are structured around critical dimensions, including **ecosystem conservation, infrastructure adaptation, socio-economic resilience, and policy integration**. By aligning with well-established resilience frameworks and leveraging regional expertise, these recommendations ensure practical applicability and relevance across different contexts.

Central to the deliverable is the **concept of resilience** as defined in Work Package 2, and specifically in ClimEmpower D2.2 “Climate Change resilience indicators”. In this context, resilience is understood as the capacity of systems—be they ecological, social, or infrastructural—to absorb disturbances, adapt to changing conditions, and recover from shocks while maintaining essential functions and structures. This definition emphasizes the importance of both adaptive capacity and the ability to build long-term sustainability in the face of climate and environmental stresses.

This document serves as a valuable resource for decision-makers seeking to enhance climate resilience. It offers a **structured methodology and a collection of practical recommendations for identifying priority actions and implementing solutions** that contribute to long-term sustainability and regional development. By strengthening networks and promoting continuous learning through the CoP, the ClimEmpower project supports a more coordinated and informed approach to resilience-building across regions.

# 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).

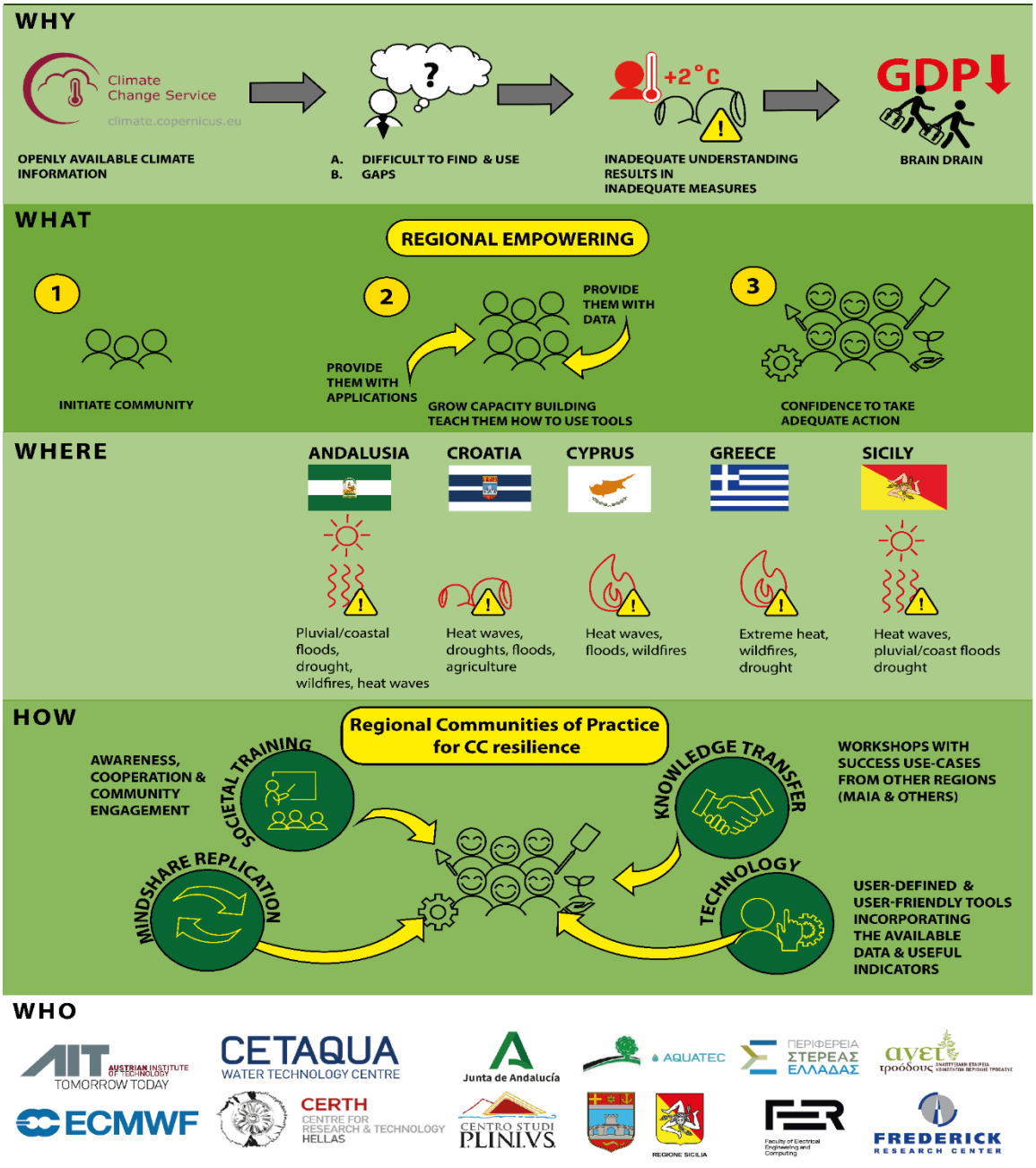
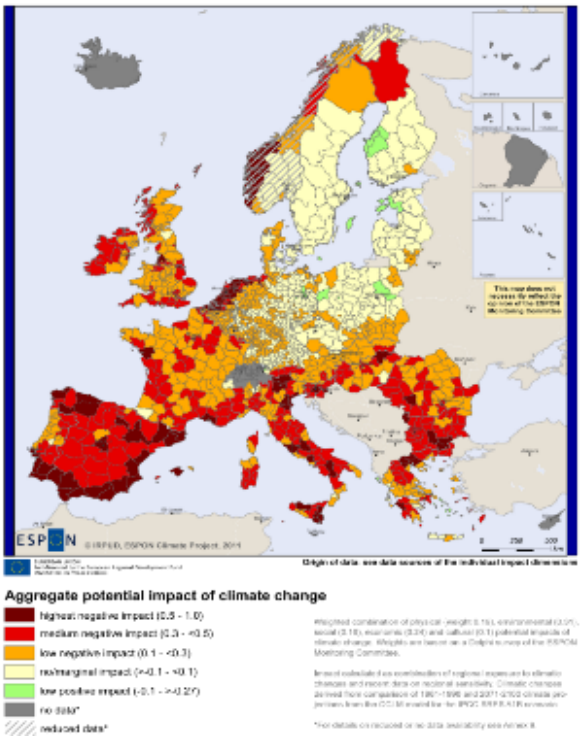
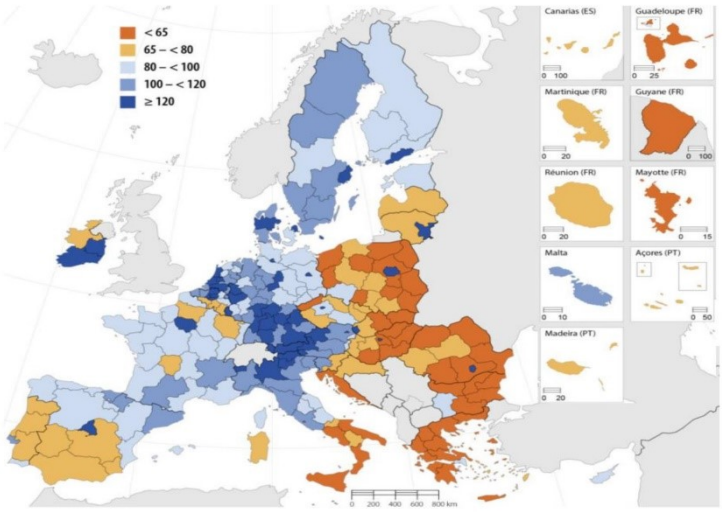



**Figure 1: ClimEmpower at a glance: why, what, where, how and who.**

## 1.1 Project Context

Climate risks result from a combination of a hazard, exposure, and vulnerability (REF). 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




GDP/capita

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, and 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 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.

[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 is a contribution to WP4 'Empowering the Regions,' specifically drawing from Task 4.2. It builds on the foundational work completed in WP1, which focused on establishing the Community of Practice (COP) and implementing a participatory approach. This process identified a set of regional needs, initially outlined in Deliverable D1.2, and further explored during COP meetings held within the scope of WP4. Building upon the work done in WP1, WP2 and WP4, this deliverable aims to provide regional authorities and local stakeholders with practical recommendations designed to enhance local resilience in the face of climate change.

## 2.2 Results and expected impacts

This deliverable provides a set of resilience recommendations for key sectors prioritized by the Communities of Practice (COPs), including:

- New building construction and retrofitting
- Blue and green infrastructure
- Transportation
- Agriculture
- Ecosystem conservation

The recommendations take a systematic approach to resilience, supporting both mitigation and adaptation strategies. They are designed to provide **multi-purpose benefits**, strengthening environmental resilience while also generating socio-economic advantages. By integrating sustainability with economic and social considerations, the deliverable equips regional authorities and local stakeholders with actionable strategies to enhance climate resilience across multiple sectors.

This deliverable directly supports several Specific Objectives (SOs) of the project by providing science-based resilience recommendations tailored on the needs of regional and local authorities.

The deliverable contributes primarily to **SO5 - *Empower the regions to activate and enhance their potential for addressing the climate change challenge*** by providing practical tools and recommendations that strengthen the capacity of stakeholders in ClimEmpower trial regions. By integrating insights from regional Communities of Practice (CoPs) and using a systematic resilience approach, the recommendations enhance the understanding of climate risks and improve regional governance and planning. This enables regions to make informed, data-driven decisions to increase resilience through mitigation and adaptation strategies. Additionally, the deliverable supports **SO4 - *Simplify access to CC data and development of end user application*** by complementing the development of the CC-resilience toolbox. The recommendations, along with climate data and user-friendly decision support applications, help regional and local authorities identify and prioritize climate adaptation measures. By integrating sector-specific resilience strategies into the broader technological framework of WP3, the deliverable improves access to relevant climate data,

visualization tools, and knowledge resources, ensuring that adaptation planning is both data-informed and actionable. In line with **SO6 – *Ensure the use and impact of the ClimEmpower outputs***, this deliverable plays a key role in ensuring that ClimEmpower's outputs are implemented, replicated, and widely adopted. By engaging local and regional stakeholders through a participatory approach, the recommendations facilitate the adoption and scaling of resilience strategies beyond the initial trial regions.

By serving as a valuable input for regional decision-makers, the deliverable supports the integration of resilience strategies into regional development plans.

- In this first version, the emphasis is on recommendations that are applicable to all regions, ensuring broad relevance and scalability.
- In Version 2, the recommendations will be region-specific, tailored to local contexts for practical implementation.

This structure facilitates the reuse and adaptation of best practices across European regions and beyond, amplifying the project's overall impact in fostering resilient and sustainable regional development.

## 2.3 Relation to other work

This deliverable is closely connected to previous, ongoing, and future work within ClimEmpower and beyond. It builds on foundational research, aligns with parallel activities, and provides outputs that will be actively used within the project and by external stakeholders.

The deliverable draws heavily from the work conducted in WP1, where the Communities of Practice (CoPs) were established, and regional needs identified (initially reported in D1.2). Insights from WP4 also played a crucial role, as discussions within regional CoPs helped define sectoral priorities and shaped the structure of the resilience recommendations.

In addition, the resilience framework developed in WP2 provides a systematic approach to understanding and addressing climate risks, which has informed the recommendations. This framework not only helps identify vulnerabilities but also integrates both mitigation and adaptation strategies into the planning process. Furthermore, the deliverable relies on the work done in D2.3, where a set of indicators to measure resilience was defined. These indicators play a key role in assessing the effectiveness of the recommended strategies, providing a way to measure progress and impact over time. The integration of these indicators ensures that the recommendations are not only practical but also measurable, enhancing the ability to track their success in improving climate resilience across the regions.

Finally, the resilience recommendations complement WP3, which focuses on developing the CC-Resilience Toolbox and decision-support applications, ensuring that regional stakeholders have access to the necessary tools to implement these strategies effectively.

In the future, the resilience recommendations will be validated with regional stakeholders and CoP members, within the framework of WP4. Based on their feedback, the recommendations will be further refined. The findings will then be integrated into WP5, supporting dissemination activities to ensure the uptake and implementation of resilience strategies beyond the immediate scope of the project.

Looking ahead, the outputs of this deliverable are expected to play a key role both within ClimEmpower and beyond. Regional authorities and local stakeholders will use the

recommendations to enhance climate resilience planning and integrate them into regional development plans. Additionally, the deliverable will contribute to the broader field of climate adaptation and mitigation, providing valuable insights that can inform future research projects, policy frameworks, and EU-funded initiatives.

## 2.4 Data, security, and ethics

### 2.4.1 Data interoperability

Deliverable 4.3 (D4.3) integrates the initial application of trial guidance methodology, climate resilience assessments, socio-economic impact analyses, and regional adaptation strategies across multiple ClimEmpower case studies.

Some of the data used to write section 4 builds upon previous and ongoing EU-funded projects, such as DRIVER+ (DRiving InnoVation in Crisis Management for European Resilience), BINGO (Bringing INnovation to onGOing water management), ESPREssO (Enhancing Synergies for Disaster Prevention in the European Union), ICARIA (Improving Climate Resilience of Critical Assets), KNOWING (Framework for defining climate mitigation pathways based on understanding and integrated assessment of climate impacts, adaptation strategies and societal transformation), and UP2030 (Urban Planning and design ready for 2030). These projects provided insights, methodologies, and datasets relevant to climate adaptation, resilience planning, and stakeholder engagement.

The tables of outcomes produced in preparation of this deliverable are Excels files with ".xlsx" format that task and work package leaders collaboratively filled based on input from ClimEmpower partners, CoP participants and external experts. Accessing the tables requires either Microsoft Excel or other software capable of displaying ".xlsx" type files, such as Apache OpenOffice or Google Sheets.

### 2.4.2 Data accessibility and reuse:

Primary data sources used in the preparation of the D4.3 deliverable consist of the ClimEmpower deliverables that are quoted in the Table 1:

**Table 1: Data used in preparation of ClimEmpower deliverable D4.3**

| Data set name | For mat | Size | Owner & re-use conditions | Potential Utility within and outside | Unique ID |
|---|---|---|---|---|---|
| Deliverable D1.1 Community of Practice organisation and expectations | PDF | 10,19 MB | Sensitive | Document is available on Projects' document repository, in "Project Outputs" directory. | • On Teams (Project Outputs) |
| Deliverable D1.2 ClimEmpower Scenarios | PDF | 5 MB | Public | Document is available on Projects' document repository, in "Project Outputs" directory.<br>Document will be made available on CORDIS after the M18 (Feb 2025) project review | • On Teams (Project Outputs)<br>CORDIS link N/A yet |

| Data set name | For mat | Size | Owner & re-use conditions | Potential Utility within and outside | Unique ID |
|---|---|---|---|---|---|
| Deliverable D2.1 Climate Change resilience identified data, services, and gaps | PDF | 6,02 MB | Public | Document is available on Projects' document repository, in "Project Outputs" directory. Document will be made available on CORDIS after the M18 (Feb 2025) project review | • On Teams (Project Outputs) CORDIS link N/A yet |
| Deliverable D2.2 Climate Change resilience indicators | PDF | 3,73 MB | Public | Document is available on Projects' document repository, in "Project Outputs" directory. Document will be made available on CORDIS after the M18 (Feb 2025) project review | • On Teams (Project Outputs) CORDIS link N/A yet |
| Deliverable D3.1 ClimEmpower application architecture | PDF | 9,65 MB | Public | Document is available on Projects' document repository, in "Project Outputs" directory. Document will be made available on CORDIS after the M18 (Feb 2025) project review | • On Teams (Project Outputs) CORDIS link N/A yet |
| Deliverable D4.1 Educational materials for increased regional CC resilience v1 | PDF . | 7,75 MB | Public | Document is available on Projects' document repository, in "Project Outputs" directory. Document will be made available on CORDIS after the M18 (Feb 2025) project review | • On Teams (Project Outputs) CORDIS link N/A yet |
| ClimEmpower Climate Change educational resources (Knowledge hubs and educational materials tables) | Micr osoft Exce l (.xlsx ) | 150 KB | Public | Two tables, providing a list of "aggregator pages" with (links to) curated educational materials on climate change adaptation and mitigation and examples of different types of educational materials that are resolving some of the educational needs of the ClimEmpower regional stakeholders. | https://doi.org/10.5281/zenodo.13944851 |
| Deliverable D5.6 Stakeholder engagement plan and events report v1 | PDF | 5,29 MB | Sensitive | Document is available on Projects' document repository, in "Project Outputs" directory. | • On Teams (Project Outputs) |

Main outcome of the ClimEmpower deliverable D4.3 are the resilience recommendations in section 4.2. These recommendations have also been published as a dataset on Zenodo (Table 2).

**Table 2. Data produced in preparation of ClimEmpower deliverable D4.3**

| Data set name | Format | Size | Owner & re-use conditions | Potential Utility within and outside | Unique ID |
|---|---|---|---|---|---|
| ClimEmpower Resilience recommendations | .xlsx | 25.9 KB | ClimEmpower, public | Resilience recommendations suitable for decision makers | 10.5281/zenodo.14945632 |

### 2.4.3 Security and Ethics

Resilience recommendations involve sensitive considerations, as they influence policy, resource allocation, and long-term adaptation strategies. In ClimEmpower, all recommendations have been reviewed through the lens of Just Transition, ensuring that they promote fair, inclusive, and socially equitable climate adaptation measures.

# 3 ClimEmpower Resilience Framework and Needs

## 3.1 Resilience Conceptual Framework

The concept of resilience has become increasingly important in addressing complex socio-environmental challenges, particularly in the contexts of climate change and disaster risk reduction. Within the ClimEmpower project, resilience serves as a foundational principle for understanding and enhancing the adaptive capacities of communities, ecosystems, and infrastructures. This section provides an overview of the resilience concept, its core principles, and its relevance to achieving the objectives of ClimEmpower.

Resilience broadly refers to the capacity of a system, community, or entity to withstand, adapt to, and recover from shocks and stresses while maintaining its essential functions. Initially emerging from disciplines such as ecology (Holling, 1973; Berkes, 2006) and engineering (Schneider and Gane, 1979; Hollnagel et al., 2006) and the concept has evolved into a multidisciplinary framework applied across domains like urban planning, environmental science, and social systems. A key dimension of this evolution is the concept of evolutionary resilience, which integrates elements of both engineering and ecological resilience while emphasizing strategic transformation and adaptability to disturbances. Unlike earlier views that defined resilience as a static state or equilibrium to be maintained, evolutionary resilience recognizes it as an ongoing process of learning and development (Davoudì et al., 2013). This perspective acknowledges that systems are inherently flexible and capable of evolving over time, independently of external disturbances or linear cause-effect relationships (Scheffer, 2009; Davoudi et al., 2013). Within this document and the ClimEmpower project, we adopt the definition provided by the Intergovernmental Panel on Climate Change (IPCC, AR6 WGII SP), which aligns with evolutionary resilience and its principles. The IPCC defines resilience as:

"*The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions. The term describes not just the ability to maintain essential function, identity, and structure, but also the capacity for transformation*." (IPCC AR6, WGII SP)

The broad and complex nature of resilience in its interconnection with climate change, societal and environmental challenges has recently found a wide consensus on a comprehensive definition that connects global and local development priorities with the need for integrated action supporting simultaneously climate mitigation and adaptation, incorporating key principles of sustainable development in the consolidating concept of “Climate Resilient Development” (IPCC, 2022), defined as follows:

“Both the urgency and the complexity of the climate change crisis require actions at a new depth and scale. Our report provides a solutions framework that successfully combines strategies to deal with climate risks (adaptation) with actions to reduce greenhouse gas emissions (mitigation) which result in improvements for nature’s and people’s well-being – for example by reducing poverty and hunger, improving health and livelihoods, providing more people with clean energy and water and safeguarding ecosystems on land, in lakes and rivers and in the ocean. This solutions framework is called Climate Resilient Development (IPCC AR6, WGII)

These definitions are reflected in key principles that enhance a system's ability to adapt and thrive in the face of challenges while addressing simultaneously decarbonization, environmental regeneration and socio-economic development, and these principles are central to the ClimEmpower project. One fundamental principle is systems thinking (Wright et at., 2012), which emphasizes a comprehensive understanding of systems as interconnected and interdependent. In the context of ClimEmpower, this involves recognizing the interplay between environmental, social, and economic factors that influence vulnerability and adaptive capacity. It highlights how various elements of a community or ecosystem are interconnected and how changes in one area can have far-reaching effects on others. The work we are conducting in the project builds on this foundation, striving to integrate interdisciplinary scientific insights and data-driven models (WP2 and WP3) with cooperation and codesign conducted in WP4, enabling a holistic approach to resilience planning. The digital tools will be developed will support multiple key objectives for local climate action allow for simulating and analysing complex scenarios related to climate change, environmental risks, and adaptation and mitigation needs. By integrating simulation models with geospatial databases, it is possible to work on multiple spatial scales, from city-level to neighbourhood, building, and open space scales, enabling informed and strategic planning in highly vulnerable contexts. digital models promote the integration of socio-economic and environmental co-benefits, such as spatial justice, biodiversity, and air quality. This enables the evaluation of how transformation actions can not only reduce climate risks but also improve quality of life, emphasizing inclusive and sustainable policies that support the most vulnerable communities.

Another important principle is adaptive capacity (Scharte, 2024), which refers to the ability to adjust to changing conditions, absorb disturbances, and innovate when necessary. In the ClimEmpower context, promoting adaptive solutions tailored to local circumstances is central, as it allows communities to cope better with climate variability and extremes. A central component of ClimEmpower's approach is the ClimAware "Communities of Practice" (CoPs), which are designed to strengthen regional adaptive and coping capacities. The codesigning activities conducted within WP4 exemplify this principle by fostering the development of locally relevant, context-specific adaptive strategies that empower communities to effectively address their unique challenges.

In addition, resilience requires flexibility and learning. Resilient systems are not static; they evolve through iterative learning and adaptive responses. ClimEmpower fosters this principle by integrating participatory approaches that promote continuous knowledge exchange and capacity building among stakeholders, including community experts (WP4). This collaborative approach not only enables synergy among all participants but also establishes a working method that strengthens their ability to engage in effective resilience planning and better withstand future challenges.

Preparedness and anticipation are equally critical for resilience-building, as proactive planning, impact assessment, and scenario analysis help communities anticipate potential risks and uncertainties. ClimEmpower supports the development of tools and resilience recommendations to enhance preparedness, ensuring that communities are better equipped to respond to future challenges before they arise. By fostering a mindset of anticipation and integrating principles of equity, sustainability, inclusivity, and collaboration, the project strengthens local capacities to mitigate, adapt to, and recover from climate-related impacts, fostering self-reliance and empowerment within communities. This approach helps communities become more capable of navigating climate challenges without over-reliance on external support.

In conclusion, thanks to its broad and multifaceted definition, the concept of resilience has gained significant importance in both literature and practice. However, this widespread adoption also presents challenges, particularly in understanding its inherent complexity and establishing criteria for its measurement and conceptualization in real-world applications. Within ClimEmpower, these crucial aspects have been addressed through the application of general resilience principles following two main approaches.

The first approach involved the close collaboration with regional authorities, allowing the team to precisely identify the specific needs of each territory. This analysis formed the basis for developing tailored resilience recommendations, which will be further elaborated in the next sections.

The second approach, as outlined in Deliverable 2.2 of the ClimEmpower project, focused on developing a set of indicators specifically tailored to the needs of the ClimEmpower regions. To achieve this, the project team conducted a comprehensive review of existing resilience frameworks, drawing insights from the ARUP framework and several key studies (Lavelle et al., 2015; Schipper & Langston, 2015; Patel & Nosal, 2016; Sharifi, 2016; Summers et al., 2016; Tafidis et al., 2016; UN-Habitat, 2018). These studies highlight the multidimensional nature of urban resilience, emphasizing the importance of a multidisciplinary approach and the interconnectedness of urban systems. The City Resilience Framework (CRF) further reinforces this perspective by integrating both physical infrastructure and human behavioural aspects, which are essential in managing economic, social, and environmental disruptions. This literature review forms the foundation for a structured understanding of resilience, encompassing key dimensions such as health and well-being, economy and society, infrastructure and environment, and leadership and strategy, ensuring a holistic and practical approach to resilience assessment.

By aligning with this widely recognized framework, the indicators developed within ClimEmpower ensure both relevance and practical applicability. This alignment facilitates a comprehensive assessment of resilience at the regional level and supports the development of resilience recommendations based on these fundamental dimensions.

## 3.2 Resilience needs in ClimEmpower: insights from the CoPs

The ClimEmpower project establishes Communities of Practice (CoPs) to facilitate stakeholder engagement in addressing climate change challenges. Drawing from the best practices and experiences of previous European projects such as BINGO and ESPREssO, these CoPs aim to unite local authorities, case study facilitators (CSFs), and other relevant parties to collaboratively develop climate solutions.

The project emphasizes stakeholder participation at every stage, ensuring equal involvement throughout the process. Its primary goal is to enhance understanding of climate change impacts, share knowledge, and tackle specific local challenges. The project commenced with the identification and inclusion of stakeholders, supported by the development of a stakeholder database and action plan. Initial meetings of the CoPs in 2023 and 2024 laid the foundation for increased cooperation within the region. These meetings focused on identifying key hazards, such as floods, droughts, and heat waves, and fostering a common understanding of climate change challenges, along with gaps in data and capacity. Key issues identified included data sharing, training needs, and capacity building, with an emphasis on creating user-friendly solutions.

The approach adopted by the project is grounded in the best practices identified from previous EU initiatives and is based on the Trial Guidance Methodology (TGM). The Trial Guidance Methodology (TGM) is a structured framework developed to assess and validate innovative solutions in various fields, including crisis management and climate adaptation. Initially introduced within the DRIVER+ project (DRiving InnoVation in crisis management for European Resilience), TGM provides a systematic approach to designing, executing, and evaluating trials, ensuring that the tested solutions meet the identified challenges in real-world applications fig.

The ClimEmpower project has adopted this methodology to evaluate innovative solutions that enhance climate resilience in five case study regions - Sicily (Italy), Osijek-Baranja County (Croatia), Andalusia (Spain), Troodos Mountain Range (Cyprus), and Central Greece (Greece). The step-by-step design, as outlined in the TGM Handbook (Fonio et al., 2020), ensures that solutions undergo evaluation and continuous improvement.

One of the main strengths of TGM is its emphasis on stakeholder engagement. Since climate resilience strategies require multi-disciplinary and multi-sectoral collaboration, involving stakeholders from government, academia, industry, and civil society ensures that solutions are locally relevant and practically feasible. The methodology also supports iterative learning, allowing solutions to be refined through feedback loops from trial participants. TGM is scalable, meaning that insights from one region can inform resilience strategies in other locations. This characteristic aligns with ClimEmpower's goal of ensuring that tested solutions are adaptable to different socio-political and environmental contexts (for more information about the engagement process see D5.6 and D5.7).

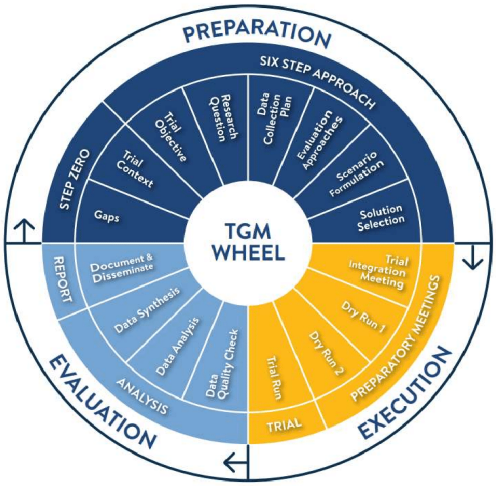



**Figure 3 TGM framework diagram.**

This methodology will be employed in the development, testing, and validation of new climate change solutions. By involving stakeholders throughout all stages—from solution design to testing and validation—the ClimEmpower project aims to ensure that its outcomes are replicable and sustainable, extending beyond the five core case study regions to additional "follower" regions.

Future engagement with the CoPs will include regional workshops and other meetings as needed to maintain stakeholder involvement, address regional priorities, and ensure that project deliverables meet local needs. The CoPs will also contribute to the co-design and testing of tools and services that will enhance regional. The focus of the ClimEmpower project, together with the involvement of CoPs, will be to ensure that solutions are relevant and feasible, leveraging key local knowledge, facilitating knowledge exchange, and promoting capacity building.

### 3.2.1 Italy (Sicily region)

In the Sicily region, the CoP framework has been strategically designed to involve institutional stakeholders, particularly representatives from public entities operating at both regional and

metropolitan levels. This collaborative approach has been instrumental in ensuring that resilience strategies align with the needs and priorities of local governance structures.

The process began with an initial informative meeting, followed by three CoP meetings during 2024, which were co-led by the Department of Public Fund Programming and the Plinius Case Study facilitators. These meetings facilitated engagement with key institutional stakeholders, including representatives from the Department of Civil Protection, the Department of Environment, and metropolitan-level entities from the Functional Urban Areas (FUA) of Catania, Messina, and Palermo (for a more detailed description of the process see D1.1 and D5.7). By bringing together these diverse stakeholders, the CoP meetings provided a platform for knowledge sharing, discussion of critical challenges, and the co-development of strategic resilience priorities.

Among the climate hazards prioritized by CoP stakeholders, **impacts of urban flooding and heat waves emerged as the most critical concerns**. In recent years, Sicily has witnessed increasingly intense rainfall events that have severely impacted urban areas. The island's topographical features, combined with a high prevalence of impermeable surfaces in urban settings, exacerbate the risk of **flash floods**. During periods of heavy rainfall, poorly drained streets and overwhelmed stormwater systems contribute significantly to flood hazards, leading to **disruptions in transportation, economic activities, and public safety**. The impact of climate change in Sicily is multifaceted, presenting a complex interplay of **cascading effects** that permeate various socio-economic dimensions. These challenges exacerbate existing vulnerabilities and create new risks, particularly in sectors such as **tourism, public health, and urban infrastructure**. In the tourism sector, the rising demand for cooling facilities during the summer months places significant **stress on the electrical grid**, often resulting in operational disruptions and economic losses. This, in turn, affects businesses reliant on a consistent energy supply and diminishes the overall attractiveness of Sicily as a tourist destination. Moreover, the public health system faces significant challenges in **maintaining essential health services** during power disruptions. Hospitals and medical facilities, already operating under strained conditions, struggle to ensure service continuity, thereby increasing health risks for vulnerable populations, particularly the elderly and those with pre-existing health conditions.

A critical socio-economic concern in Sicily is the persistent issue of high emigration rates. Over the past two decades, approximately two million people have left the region, leading to a significant loss of human capital and talent. This **ongoing "brain drain"** limits the region's ability to implement sustainable development initiatives and weakens institutional capacities to respond effectively to climate change challenges.

The urgency of developing effective climate change adaptation and mitigation strategies is further underscored by the challenges associated with the multi-scale nature of the issue. At the Functional Urban Area scale, a significant gap exists in the **availability of detailed data and analytical tools necessary for resilience planning**. Addressing this gap requires the development of comprehensive tools that can support the design and implementation of climate-responsive measures for both existing and new infrastructure projects. Public entities, for example, are required to implement **runoff reduction** interventions to mitigate the impacts of infrastructural developments. By adopting the principles of 'urban systemic design,' planners and policymakers can better identify and implement targeted interventions that enhance resilience and sustainability.

From the outset of the CoP engagement process, several key issues were identified. One of the most pressing challenges is the obligation of **climate-proofing for all infrastructure projects eligible for financing under the European Regional Development Fund (ERDF)** Program for 2021-2027. As per Regulation (EU) No. 1060 of 2021, public entities are mandated to ensure the climate resilience of infrastructure investments expected to remain operational for at least five years. However, fulfilling this requirement presents a significant challenge due to the **lack of essential documentation, including climate hazard maps and comprehensive risk scenarios**. This deficiency underscores the urgent need for improved data collection and risk assessment frameworks that can support compliance with climate-proofing requirements and enhance overall resilience planning.

### 3.2.2 Croatia (Osijek-Baranja County)

In Osijek-Baranja County, three CoP meetings were collaboratively organized and led by the Public Institution for Nature Protection of Osijek-Baranja County, the Department of Agriculture of Osijek-Baranja County, and the Faculty of Electrical Engineering and Computing during 2023. / 2024. These meetings engaged key stakeholders representing the quadruple helix model, including civil society organizations (OSPERA), public sector (OBZ, Croatian Water Management, Croatian Agricultural Chamber, Croatian Agency for Agriculture and Food), academia (Faculty of Agrobiotechnical Sciences, Department of Biology, Department of Chemistry), and industry (PPK Valpovo). This collaborative approach has been instrumental in ensuring that resilience strategies align with the needs and priorities of local stakeholders.

Identified hazards were **droughts, floods, heat waves, and hail** as the most pressing climate-related hazards affecting the region. While total annual precipitation remains close to historical averages, **precipitation distribution has become increasingly irregular**. **Heavy rainfall** often occurs within short periods, especially during summer, forming a hard crust on fertile soil, which **restricts crop growth**. This uneven precipitation pattern leads to **extended droughts**, which **severely impact agricultural productivity, employment, and overall economic stability.**

The adverse effects of climate change in Osijek-Baranja County extend beyond agriculture. Droughts and extreme weather conditions reduce crop yields, causing **financial instability for farmers** and threatening food production. Extreme weather also jeopardizes protected wetlands and wildlife, **disrupting conservation efforts and posing risks to biodiversity**. Furthermore, the region, which relies heavily on nature-based tourism, including activities such as hiking, cycling, sport fishing, birdwatching, and boat tours, faces significant challenges. Climate hazards negatively impact these activities, diminishing the region's appeal to tourists and **harming local businesses that depend on eco-tourism and gastronomy, particularly small family farms producing traditional local food**.

The primary challenge identified during the CoP meetings is **adapting to ongoing climate changes while maintaining sustainable farming, food production, and environmental conservation**. Stakeholders noted that while climate adaptation strategies exist, they are largely policy-based, with minimal implementation of technological solutions. As a result, discussions focused on two key areas: **drought prediction and mitigation and flood risk management**. To address drought risks, participants emphasized the need to develop **predictive models that can forecast droughts and minimize their impact**, as well as implement **water optimization strategies to enhance irrigation efficiency**. Regarding flood risk management, stakeholders highlighted the necessity of designing tools and

models to **predict and mitigate excessive flooding**, along with **strategies for managing water levels in agricultural and protected areas** to prevent overflooding.

### 3.2.3 Spain (Andalusia, Costa del Sol)

The Andalusia case study for ClimEmpower focuses on the Western Costa del Sol (WCDS), a region comprising eleven municipalities along the Mediterranean coast in Málaga Province. The region is highly vulnerable to climate change, with increasing risks such as **water scarcity, pluvial and coastal flooding, and wildfires**.

The region's total permanent population of 579,350 inhabitants more than doubles during the summer, reaching 1.2 million people. This **seasonal population influx places additional strain on local water resources**, which rely on a diverse water supply system, including reservoirs, groundwater sources, desalination, and reclaimed water. The variability in water availability, combined with shifting precipitation patterns and extreme weather events, exacerbates local challenges, particularly in urban areas and critical infrastructure. In recent years, **heavy storm events** (e.g., "DANA" (cold drop) episodes) have intensified **pluvial flooding**, while **compound flooding events**, combining storm surges and extreme rainfall, have increased the risk to coastal urban centres. In addition, **wildfires** pose a growing threat, with notable incidents such as the Sierra Bermeja wildfire in 2021, which resulted in the tragic loss of a firefighter's life.

The Western Costa del Sol (WCDS) is facing mounting climate-related challenges. Variability in water quantity and quality has become a critical issue, exacerbated by increasing **competition for water resources** due to **highly seasonal water demand from the tourism industry** and creating socio-economic risks related to water scarcity. The **low storage** capacity of the region's main reservoirs, coupled with the **vulnerability of coastal aquifers** to seawater intrusion, has placed additional pressure on drinking water availability. These factors make WCDS particularly susceptible to global climate change impacts, complicates the operation of water supply systems, and emphasises a need for better coordination between municipal water utilities, users and governance.

A drought-prone climate that is expected to worsen with global warming, resulting in **increased frequency of heatwaves and wildfires** and **negatively affecting human lives and water infrastructure**. Disruptions in rainfall patterns will lead to **increase in flooding events**, exacerbated by rising sea levels and heavy precipitation episodes.

Rapid land-use changes, where the **expansion of urban areas and golf courses** has altered aquifer recharge zones, further complicating water resource management.

CoP Community includes key stakeholders from academia, public administration, industry, and civil society. These included municipal representatives from Torremolinos, Fuengirola, Estepona, Marbella, and Mijas, as well as regional institutions such as the Environment and Water Agency of Andalusia, the Consejería de Sostenibilidad, Medio Ambiente y Economía Azul, and the Consejería de Agricultura, Pesca, Agua y Desarrollo Rural. Water utilities such as Hidralia and Aguas de Torremolinos, along with research organizations like CETAQUA Andalucía and the Farmers' Cooperative of Andalusia (ASAJA).

As part of the CoP framework, the meetings focused on addressing climate change, highlighting key measures and **tools already available**, including **climate risk evaluation guides, municipal climate change plans, climate adaptation project banks, regional**

**climate scenario viewers, carbon footprint assessment tools, and funding mechanisms for municipalities**.

Additional concerns, beyond the risks mentioned above, included **surface and groundwater pollution, loss of biodiversity, spread of invasive species**. **Threats to the water distribution network, urban drainage systems, natural spaces, and wastewater treatment infrastructure have been emphasised as critical vulnerabilities**.

Regarding socioeconomic impacts, **agriculture, health, tourism, and forestry** were identified as the most affected sectors. Specific concerns were raised about the **vulnerability of livestock, the elderly population, insurance markets, energy infrastructure, and emergency services**. There is a need for **more reliable and accessible climate data and improved risk assessment.**

Several barriers were identified to effective climate adaptation. These included the **complexity of existing models**, restricted **access to relevant climate data**, and **limited awareness** among the general public. Concerns were raised regarding the use of **proprietary software for flood modelling**, which may limit accessibility and replicability. Additionally, **data acquisition** was flagged as a major challenge, as municipalities often maintain heterogeneous and outdated datasets that complicate regional assessments.

Andalusian CoP emphasized the importance of **user-friendly, open-access tools for climate risk management.** There was strong consensus on the need for **enhanced stakeholder coordination, improved data-sharing mechanisms, and more robust early warning systems**.

### 3.2.4 Greece (Region of central Greece)

The Region of Central Greece (Perifereia Stereas Elladas - PSTE) is characterized by a varied landscape, consisting of **mountainous, lowland, and semi-mountainous areas**. It plays a key role in Greece's economy, particularly in **manufacturing, metal industries, and agriculture**. Despite its rich potential, the **tourism and service sectors remain underdeveloped**.

To foster broad participation in climate adaptation initiatives, the project actively engaged stakeholders from academia, public administration, industry, and civil society through Communities of Practice (CoP) activities. During these meetings, stakeholders identified several critical climate-related hazards, including **floods, droughts, wildfires, rising temperatures, and water pollution**. These hazards pose significant risks to the region's economy, particularly in **agriculture, health, and tourism**.

Agriculture is particularly vulnerable to climate change, with shifting weather patterns leading to **soil degradation, water scarcity, and declining crop productivity**. Livestock farming is also at risk, as extreme weather conditions affect **animal health and food production**. In the health sector, climate change has increased the prevalence of **vector-borne diseases, particularly mosquito outbreaks in flood-prone areas**. Stakeholders emphasized the urgent need for **predictive and early-warning systems to prevent the spread of malaria and other mosquito-related illnesses**.

Tourism, another important economic sector, is also affected by climate change. Extreme weather conditions make **outdoor recreational activities** less appealing to visitors, while rising temperatures and environmental degradation threaten **historical sites and natural landscapes**, diminishing the region's attractiveness.

Currently, **the region relies on governmental directives, forecasting models, and early warning systems** to address climate risks. However, these systems are **largely dependent on national and European data, rather than localized assessments** managed by regional personnel. Stakeholders stressed the importance of developing region-specific tools and solutions to improve climate resilience.

During the discussions, several key needs emerged. Stakeholders highlighted the importance of better access to climate and hazard-related data, emphasizing that **localized climate data and hazard maps would enhance response planning and predictive capabilities**. They also noted the necessity of **user-friendly technological solutions**, ensuring that climate adaptation tools are accessible and understandable for public agencies. Additionally, stakeholders recognized the need for **public awareness campaigns** to educate local communities on climate risks and adaptation strategies.

Despite the willingness to implement these changes, several challenges remain. Stakeholders identified **limited funding** for climate mitigation projects, **lack of cooperation between public agencies**, **knowledge gaps** in using climate-related technological solutions, and the **absence of a clear strategy for utilizing available climate data and tools** as the main obstacles to effective adaptation.

Several actions have been proposed. Improving data accessibility by **integrating local and regional climate information**, including flood management plans and environmental studies, is a priority. **Expanding stakeholder engagement** by involving additional authorities such as water management agencies and emergency response units will also enhance flood risk response. The development of **technological solutions, including predictive models for floods, droughts, and vector-borne disease outbreaks**, will provide valuable tools for adaptation. Furthermore, **training and capacity-building** programs will be implemented to ensure public sector personnel are well-equipped to manage climate resilience tools effectively.

### 3.2.5 Cyprus (Troodos Mountain Range)

The Troodos Mountain Range, covering approximately 137,000 hectares and spanning across Nicosia, Paphos, and Limassol districts, is a region of significant geological, ecological, and cultural importance. The topography of Troodos plays a critical role in local climate patterns, biodiversity conservation, and water resource management.

During the three CoP meetings held in 2023. and 2024., hazards identified were **wildfires, floods, rising temperatures, Saharan dust, and droughts** as the most pressing climate-related hazards affecting the Troodos region. Climate change poses severe challenges to the region's fragile ecosystem, significantly impacting **water availability, biodiversity, agriculture, and local livelihoods**. Prolonged droughts and rising temperatures have **disrupted rainfall patterns**, leading to more frequent and intense **wildfires**, **loss of biodiversity, and increasing soil degradation**.

The consequences of these climate hazards extend beyond environmental degradation and impact key economic sectors. Agriculture is particularly vulnerable, as **water scarcity and extreme heat reduce crop yields and result in financial losses for farmers**. Changes in precipitation patterns and rising temperatures also disrupt local ecosystems, increasing the **risk of habitat loss and the spread of invasive species**. Tourism, a vital economic activity in the region known for its natural beauty and outdoor attractions, faces significant threats due

to more **frequent wildfires, prolonged droughts, and extreme temperatures, all of which reduce the region's appeal and affect businesses reliant on eco-tourism**.

Cops identified several critical needs and proposed solutions to enhance climate resilience. There is a growing **demand for localized and accessible climate data** to support risk assessment and preparedness. Improved **training programs for public agencies and emergency responders** are necessary to enhance disaster preparedness and response capabilities. The implementation of **predictive models for droughts and floods** is essential for supporting agricultural and infrastructure planning, while strengthening **fire prevention measures** and investing in **early detection** technologies can help mitigate the risk of wildfires. Additionally, targeted plans are needed to reduce the health and environmental impacts of **Saharan dust storms**, which pose **significant risks to both human health and the ecosystem**. **Public awareness campaigns** were also highlighted as important for educating local communities on climate hazards and promoting adaptive strategies.

Despite these challenges, there are significant opportunities to enhance climate adaptation efforts in the region. New technology presents new possibilities for improving risk assessment and mitigation strategies, ultimately contributing to the creation of more resilient communities in the Troodos region.

## 3.3 Climate change impacts prioritizations in the five ClimEmpower regions

The process of listening and engaging in the CoPs has played a fundamental role in identifying and prioritizing the most significant climate risks affecting the five partner regions of the ClimEmpower project. Through this participatory approach, it has become evident that a shared effort is necessary to define and address climate risks that impact three key sectors: the built environment, agriculture, and ecosystem conservation. These sectors, deeply interconnected with both human societies and natural systems, face increasing threats due to climate change, making it imperative to develop targeted strategies for adaptation and resilience.

This section examines the most pressing climate risks that have emerged from the CoP discussions, highlighting their relevance and potential consequences. By analysing these risks, the aim is to establish a clearer understanding of the challenges ahead and lay the groundwork for developing the resilience recommendations Toolkit. This toolkit, which will be further detailed in the next section, is designed to support stakeholders in building climate resilience by providing actionable strategies tailored to these three critical sectors.

### 3.3.1 Climate change impacts on the built environment

A key need identified through the five Communities of Practice (CoP) in WP4 activities is the growing demand to enhance the resilience of urban environments in addressing climate risks. As cities become increasingly vulnerable to extreme weather events, strengthening the resilience of the built environment has become a critical priority. Among the most significant risks, **flooding, heatwaves, and droughts pose serious threats to infrastructure, public health, and socio-economic stability**. This literature review offers a comprehensive analysis of these key climate risks, focusing on their impacts and underlying drivers, while contributing to the broader ClimEmpower objectives of promoting informed decision-making and sustainable urban development.

**Urban flooding** is an increasingly significant issue for cities around the world, driven by a combination of climate change, rapid urbanization, and the undersized existing infrastructure. The phenomenon of urban flooding implies the inundation of land that is normally dry, resulting from heavy rainfall, poor drainage systems, or a mixture of both factors. The causes of urban flooding are multifaceted, with the most prominent being the transformation of natural landscapes into built environments that are less permeable. Cities are typically characterized by high concentrations of **impervious surfaces**—such as roads, buildings, and pavements—that prevent the natural absorption of rainfall into the ground. As a result, rainwater runs off more quickly, often overwhelming existing **drainage systems** that were not designed to handle the intensity or volume of water associated with extreme weather events. The effects of climate change on the frequency and intensity of rainfall events have become increasingly apparent, with cities experiencing more frequent and severe flooding because of heavier rainfall (Amaguchi, H., Olsson, J., Kawamura, A., & Imamura, Y., 2024).

The impacts of urban flooding are profound and multifaceted, extending far beyond the immediate damage to property and infrastructure. One of the most significant consequences is the **disruption of essential services and the economic strain** it places on cities. Flooding often results in **costly repairs to damaged infrastructure, including roads, bridges, utilities, and buildings**, which can take months or even years to fully restore. This disruption can severely affect local economies, particularly in flood-prone areas where **businesses may be forced to close or relocate**. The **loss of productivity**, combined with the **costs of rebuilding**, can have long-lasting financial implications (Allaire, 2018). Flooding also poses serious **public health risks**. Stagnant floodwaters can become breeding grounds for **waterborne diseases**, which can quickly spread in densely populated urban environments. The potential for **contamination of drinking water** supplies, combined with the **destruction of sanitation systems**, creates a serious public health emergency in the aftermath of flooding events. Moreover, flooding often results in **injuries or fatalities**, particularly in areas with inadequate flood defences (Allaire, 2018). or in lower-income communities that may lack the resources to mitigate risk. The socio-economic impacts of urban flooding are also felt disproportionately across different communities. **Vulnerable populations**, such as those living in informal settlements, low-lying areas, or on the edges of cities, are often the most affected by flooding. These communities may lack the necessary infrastructure and resources to recover from such events, leading to a cycle of disadvantage. In many cases, these groups are **exposed to greater risks, not only from floods themselves but also from the long-term effects of displacement, loss of livelihoods, and damage to health**. This exacerbates social inequality, making the poorest and most marginalized even more vulnerable to future climate-related shocks (Yadav, 2025). At the same time, the psychological toll of frequent or catastrophic flooding should not be overlooked. The **trauma and anxiety** experienced by individuals and communities living in flood-prone areas can have lasting effects, including **stress, displacement, and the loss of a sense of security**. Communities that face recurrent flooding may experience **diminished trust in local authorities and governance**, further complicating efforts to address the underlying challenges.

**Heatwaves,** defined as prolonged periods of excessively high temperatures, have become a growing concern for urban environments, exacerbated by climate change and urbanization. Cities, with their dense concentration of buildings, roads, and other impervious surfaces, are particularly vulnerable to the effects of extreme heat. The **urban heat island (UHI) effect**, which results from the absorption and **retention of heat by artificial surfaces** such as concrete and asphalt, leads to temperatures in urban areas being significantly higher than

those in surrounding rural areas. This intensified heat is further aggravated by **limited green spaces**, which could otherwise provide natural cooling through evapotranspiration.

The health impacts of heatwaves in urban areas are severe and wide-ranging. High temperatures increase the risk of **heat-related illnesses, including heat exhaustion, heatstroke, and dehydration**, which can lead to fatalities if not addressed. **Vulnerable populations**, such as the elderly, children, individuals with chronic illnesses, and low-income communities, are particularly at risk during heatwaves. Hospitals and emergency services often become overwhelmed during extreme heat events, leading to additional **pressure on public health systems**.

Urban infrastructure also suffers during heatwaves. The combination of high temperatures and increased energy demand for cooling purposes places a **strain on electricity grids**, leading to an elevated **risk of power outages**. In turn, this creates a vicious cycle where people are unable to cool their homes, exacerbating the health risks associated with heat. The socio-economic implications of heatwaves are significant. **Energy costs** often skyrocket as cities struggle to meet the increased demand for cooling, placing a financial burden on residents. Heatwaves can also hinder **economic productivity**, especially in industries reliant on outdoor labour, such as **construction and agriculture**. As temperatures rise, workers may be unable to operate safely, resulting in lower output and potentially dangerous working conditions. Additionally, the strain on urban infrastructure and health services can slow down recovery and exacerbate existing **social inequalities**. The combination of health risks and economic consequences underscores the urgent need for comprehensive adaptation strategies to protect both people and industries from the impacts of heatwaves.

**Droughts**, characterized by extended periods of abnormally low rainfall, represent another major climate challenge for cities. While droughts can affect rural areas and agricultural production, their impact on urban centres is profound, especially in regions already facing water scarcity. Prolonged drought conditions reduce the availability of fresh water, creating immediate challenges for both residents and local governments. As rivers, lakes, and reservoirs dry up, cities are forced to rely on limited water sources, which may not meet the demands of their growing populations. This can lead to **water rationing, higher costs for water**, or the need to implement alternative water sources like **desalination**, which can be **costly and energy intensive**. In addition to the immediate impacts on water availability and food security, droughts can also affect urban ecosystems and biodiversity. Prolonged dry conditions can lead to the **degradation of natural habitats**, threatening local flora and fauna. Droughts also exacerbate the risk of **wildfires** in urban-urban interface areas, as dry vegetation becomes more prone to ignition. These fires, in turn, pose significant **risks to human health, property, and infrastructure**.

Urban areas also face increased strain on their already stretched infrastructure during droughts. In many cities, **water supply networks** are outdated or poorly maintained, which can make it difficult to distribute the limited water available effectively. **Water scarcity** can also lead to the **deterioration of public health**, particularly when sanitation services are disrupted. Inadequate access to clean water during droughts can increase the spread of **waterborne diseases**, affecting vulnerable populations disproportionately. The socio-economic impacts of droughts are similarly felt most acutely by marginalized communities. **Lower-income households** may lack the resources to adapt to water shortages, such as investing in water-efficient technologies or paying higher water costs. These groups are also more likely to live in areas that are at greater risk of the indirect effects of droughts, such as

food insecurity and poor health outcomes. Ultimately, the combined effects of heatwaves and droughts highlight the growing vulnerability of urban areas to climate change. Addressing these challenges requires long-term strategies that prioritize resilience, sustainability, and social equity, ensuring that cities can continue to thrive in a changing environment.

### 3.3.1 Climate change impacts on agriculture

Agriculture is one of the most climate sensitive activities that determines the productivity and profitability of agricultural production. Agricultural production is regulated by a combination of climatic elements such as temperature, rainfall, and weather extremes along with long-term climate fluctuations. Due to accelerating rates of climate change, impacts are being increasingly realized on food security, resource management, and rural economies. This literature review examines key studies on the impact of climate risk to agriculture in terms of **crop yield fluctuations, water resource availability, soil degradation, and economic implications**.

Understanding these risks is important for designing effective adaptation strategies with a view to ensuring long-term sustainability within global agriculture. Water availability is important for agricultural sustainability, while climate change exacerbates **droughts** and disrupts hydrological cycles. According to the Intergovernmental Panel on Climate Change-IPCC, 2019, "Shifting precipitation patterns also contribute to **increased water scarcity**, particularly in arid and semi-arid regions, reducing the reliability of irrigation systems." The changes threaten to compromise the viability of both rain-fed and irrigated agriculture and, consequently, cause water stress among smallholder farmers who have no alternative sources of water. Gleick 2014 states: "As agriculture, industry and urban demands increasingly compete for a scarce supply, **food security** might be seriously jeopardized which already calls for a policy measure on water resource management." Also, **heavy rains** and subsequent **floods** can sweep crops away (as cited by Rosenzweig et al. 2014 in the Proceedings of the National Academy of Sciences). Too much water causes **waterlogging of the soils and** affecting agriculture indirectly.

The unpredictability of rainfall patterns amplifies both **droughts and floods**, both of which affect the **storage of water in the soil and groundwater recharge.** Water stored for long already has been depleted in areas such as the Mediterranean, Sub-Saharan Africa, and parts of the United States due to prolonged droughts. Adaptive strategies like **precision irrigation, rainwater harvesting, and proper watershed management** can counteract this risk. On the other hand, these measures require significant **infrastructural investments** and need to be **supported in both national and international policies**. Weather Variability Effects Fluctuations in the climatic variable mainly include temperature and precipitation, acting directly on yield. From a trend perspective of the global climate since 1980, Lobell et al. (2011) stated that "**rising temperatures are negatively affecting yields of the major staple crops: wheat, maize, and rice.**"

This is more pronounced in the tropics where small increases in temperature depress photosynthesis efficiency and increase water stress. Rosenzweig et al. (2014) estimated that "continued climate shifts will exacerbate crop yield volatility, increasing the need for **climate-resilient crop varieties and improved forecasting models** to support farmer decision-making." Pimentel et al. (2017) published a study in Science indicating that that climate change acts as an **amplifier of agriculture's environmental impacts** by reducing productivity, which may lead to increased land clearing for food production, loss of wildlife habitat, and greater

fertilizer and pesticide use. **Higher temperatures** also alter growing seasons, affecting planting and harvesting schedules. This means **reduced productivity, degraded quality of food, and increased vulnerability to pests and diseases**. Areas dependent on single cycle of cropping that include South Asia and sub-Saharan Africa-are the worst sufferers. For mitigation strategies related to yield variability induced by climate, some of the important strategies are **crop diversification, breeding of heat-tolerant varieties, and improved pest management**. Climate risk leads to **soil degradation through erosion, salinization, and loss of organic matter**. In the words of Lal 2015, "**higher temperatures increase soil evaporation rates, reducing the moisture content and resulting in reduced soil fertility**." This is more precarious in the case of drylands and semi-arid areas, which are already prone to desertification.

As Pimentel et al. (2017) assert, "extreme weather events like **heavy rainfall and storms** enhance the soil erosion and further jeopardize agricultural productivity." Heavy precipitation leads to **loss of topsoil**, especially in hilly and mountainous areas. Reduced carrying capacity decreases land capacity for farming. Changes in climate are **changing soil's microbial composition** and altering their **nutrients-cycling capacity**. Soil **organic matter depletion** reduces the potential for carbon sequestration, thereby increasing the magnitude of climate change. A preprint on arXiv estimates that anthropogenic climate change has lowered global agricultural total factor productivity by around 21% since 1961, with the stronger impacts being observed in the hotter regions of Africa and Latin America (Mendelsohn et al., 2000). It emphasizes adoption of **conservation tillage, agroforestry, and organic amendments** that improve structure and increase retention of water in the soil to counteract soil degradation. Economic analysis shows that **climate change related risks reduce farmer incomes, increase global food prices, and destabilise the global supply chain**. Mendelsohn et al. (2000) realized that "climate variability leads to **higher production costs and reduced profit margins**, particularly for **small-scale farmers in developing countries**." The increased frequency of **extreme weather events** causes the **damage of infrastructure, loss of livestock, and the destruction of stored grains**, hence furthering **economic instability** within rural communities. **Subsistence farmers**, especially, bear severe economic shocks because of a **lack of financial resources** that could help them recover from losses induced by climate change. As Nelson et al. (2014) note, "climate-induced crop failures raise **food price volatility**, and this increases vulnerability to **food insecurity** in poor regions." Since food supply chains are global in nature, climate disruption in one part of the world can have far-reaching impacts on world markets. For example, droughts in major wheat-producing countries like the United States, Australia, and Russia have seen jumps in the price of wheat globally, hence affecting the producers and consumers. Other responses to these challenges include **climate risk insurance, government subsidies, and investment in climate-smart agricultural technologies**. At the same time, most mechanisms of this kind are still lacking in many developing regions, which underlines the need for more **international cooperation** in support of adaptation efforts and enhancement of the resilience of agriculture. According to Nelson et al. (2014), agriculture is one of the major contributors to anthropogenic global warming through **methane and nitrous oxide**. Such reductions might prove important to climate change mitigation in the future. Future research should continue exploring integrated approaches in mitigating climate risks toward the assurance of sustainable agricultural systems facing an increasingly variable climate. Policy makers, researchers, and farmers will need to work in close collaboration to construct comprehensive adaptation strategies to ensure global food security.

### 3.3.2 Climate change impacts on ecosystem conservation

Resilience in ecosystem conservation has become a key focus in efforts to sustain biodiversity, restore ecological functions and adapt to climate change. In the face of increasing pressures from anthropogenic activities and environmental shifts, resilience-based approaches offer a framework for maintaining ecological integrity. This resilience discussion talks about the ways toward **sustaining biodiversity, managing ecosystem services, enhancing connectivity,** and towards developing **sustainable land uses**. Climate change is a massive challenge imposed on ecosystem resilience. Adaptation strategies are geared at enhancing the capacity of ecosystems to absorb or bear changes in their environments. Folke et al. (2010) affirm that the adaptive capacity of ecosystems rests on biodiversity, ecological redundancy, and their resilience to act towards disturbances. Managing ecosystem services such as **regulating water cycles, soil fertility, and carbon sequestration** has become a core part of conservation. **Wetlands restoration**, for instance, has been recognized as an effective measure for flood resilience and the enhancement of water quality. Another important adaptation strategy involves **improving the connectivity of ecosystems**. According to Opdam et al. (2006), ecological networks enhance species dispersal and genetic exchange, decreasing the risk of population decline caused by habitat fragmentation. In European policy on nature conservation, the Natura 2000 network is a large-scale plan that connects habitats in order to maintain biodiversity (European Environment Agency, 2022). It is biodiversity that underpins ecosystem resilience in terms of ensuring functional diversity and redundancy. Elmqvist et al. (2003), for instance, have highlighted response diversity, which means that for species performing similar functions, disturbance responses are different, hence stabilizing ecosystems. Among conservation strategies, **habitat protection, species reintroduction, and ecological restoration** are the most appropriate ways to enhance resilience. Ecological restoration, in particular, **rewilding**, is an emerging activity for restoring degraded landscapes. Indeed, successful European rewilding projects documented by Pereira & Navarro (2015) involve the release of European bison and lynx into their former natural range to restore disrupted trophic interactions. On top of these, **afforestation and reforestation** also offer climate mitigation due to the promotion of carbon sequestration processes, as in the recovery of ecosystem integrity mentioned by Lindenmayer et al. (2012). **Adaptive management** embeds scientific research into flexible decision-making procedures to achieve better conservation outcomes. Similarly, Holling & Meffe (1996) support the adaptive governance models which include **monitoring, stakeholder involvement, and iterative learning**. Examples include the Peatland Action Programme of the UK that utilizes adaptive methods to restore peatlands with enhanced carbon sequestration and better water storage capabilities (Bonn et al., 2014). It looks at **nature-based solutions**, which have recently gained prominence in the pursuit of increased resilience through **co-benefits on biodiversity and human well-being**. Nature-based solutions refer to strategies that address societal challenges with the help of natural processes, as Eggermont et al. (2015) explained. Various case studies included **wetland conservation, agroforestry, and urban green infrastructure** that can be effective to improve resilience through reduced climate vulnerability, as expressed by Raymond et al. 2017. Resilience-based conservation goes beyond ecological systems to include social dimensions. For example, Folke et al. (2016) emphasize the importance of **social capital, institutional flexibility, and participatory governance** in building resilience. In Mediterranean coastal areas, co-management of marine protected areas has enhanced ecosystem resilience while maintaining sustainable fisheries (Gómez-Baggethun et al., 2012). Community engagement and traditional ecological knowledge are also playing very important roles in conservation planning. **Participatory land-use planning** has combined native

knowledge with scientific assessments in an effort to improve climate adaptation efforts in the Alps quite successfully (Plieninger et al., 2015). Such cases prove that effective conservation needs strategies coproduced with local stakeholders to achieve resilience in the longer term. Despite progress in the field of resilience-based conservation, significant challenges remain. The issues of **limited funding, lack of long-term monitoring, and socio-political impediments** are serious deterrents to implementation (Lindenmayer & Likens, 2009). **Balancing economic development with conservation** objectives remains a problem that is always present, especially in highly populated areas. The integration of new technologies, like **remote sensing and artificial intelligence**, into future research will enhance the assessment of resilience and the development of conservation planning (Ullah et al., 2024). Expanding **cross-border conservation initiatives** can also enhance resilience at regional scales. The European Green Deal emphasizes transnational collaboration to tackle climate and biodiversity challenges (European Commission, 2020). It will be important to reinforce international partnerships to address global environmental threats and ensure the sustainability of resilience-based conservation practices. Resilience in the practice of ecosystem conservation is vital for maintaining biodiversity, ensuring continued ecosystem services and responding effectively to climate change. Strategies identified to enhance ecological resilience include, among others, **nature-based solutions, restoration of biodiversity, adaptive management, and socio-ecological resilience frameworks**. However, their full integration into policy, along with continued stakeholder engagement, remains in most cases a significant challenge. Ecosystem conservation requires an interdisciplinary approach with a long-term commitment to sustainability.

# 4 ClimEmpower Resilience Recommendations

## 4.1 Methodological Approach

The methodology adopted for the development of resilience recommendations is rooted in the principles of climate-resilient development as defined by the IPCC (2022). This framework emphasizes the **integration of greenhouse gas emission reduction strategies with adaptation measures aimed at mitigating the impacts of extreme climate events**. Central to this approach is the identification of actions that simultaneously deliver significant social, economic, and environmental co-benefits, fostering more sustainable and equitable outcomes for local communities (Leone et al., 2025).

Recognizing the importance of actionable and context-specific recommendations, the methodology employed focuses on tailoring these principles to the needs and priorities identified through engagement with the Communities of Practice (CoP). The stakeholder consultations provided a platform for understanding local challenges and opportunities, ensuring that the recommendations align with both global best practices and local needs.

Based on insights gathered from the CoP (see paragraph 4.2), five strategic sectors for intervention were identified as critical for advancing resilience goals: **construction of new buildings and renovation of existing buildings, mobility and transport, blue and green infrastructure, agriculture and protected area conservation**. This sectoral focus allowed the recommendations to be more targeted, aligning with specific areas of vulnerability and

potential impact. The sectors were selected for their relevance to key resilience challenges, their potential for transformative change, and their ability to deliver **co-benefits** across multiple dimensions, such as energy efficiency, resource conservation, and enhanced quality of life. In developing the recommendations, special attention was given to the climate risks that most severely impact these sectors—specifically **heatwaves, floods, and droughts**. Each recommendation was crafted to tackle these risks, leveraging solid scientific evidence and established resilience frameworks, ensuring that the proposed measures are both effective and sustainable.

Furthermore, the methodology incorporated principles of integrated and multipurpose planning to maximize synergies between mitigation and adaptation objectives. For instance, recommendations prioritize actions such as the adoption of renewable energy sources, the electrification of energy consumption, and significant improvements in the energy performance of buildings. Simultaneously, they advocate for expanding green and blue infrastructure, strengthening water management systems, and embedding circular economy principles into resource use and capacity-building initiatives This dual focus on addressing immediate climate risks and fostering long-term sustainability reflects the broader objective of transforming both the built and natural environment. Ultimately, the recommendations not only respond to current needs but also provide a foundation for further refinement and adaptation in future versions. This allows for ongoing alignment with emerging challenges, stakeholder feedback, and advancements in climate-resilient practices, ensuring their relevance and effectiveness over time.

## 4.2 Resilience recommendations

This paragraph introduces a set of recommendations designed as a foundational guide for regions embarking on the planning and design of interventions. These recommendations aim to align individual actions with a broader strategic vision, ensuring that even independent initiatives contribute to a cohesive and systemic resilience framework. By establishing this harmonized approach, the recommendations seek to maximize the collective impact of various measures, fostering integrated solutions that address climate challenges while promoting sustainable development. This foundation provides a unified direction, enabling the prioritization of interventions that offer meaningful social, economic, and environmental benefits. The recommendations are presented below in a table that includes five macro-categories of interventions related to the sectors that were prioritized by CoP: New and existing Buildings (Table 3), Blue and Green Infrastructure (Table 5), Transportation (Table 6), Agriculture (Table 4) and Protected Area Conservation (Table 7) along with the corresponding recommendations for each category.

**Table 3. Resilience recommendation for new and existing buildings**

| New and Existing Buildings | |
|---|---|
| **The following recommendations aim to promote the development of buildings that are energy-efficient, climate-resilient, and environmentally sustainable. These recommendations integrate principles from NZEB (Near Zero Energy Building) standards, the Italian CAM (Minimum Environmental Criteria), and international best practices in climate adaptation and mitigation** | |
| Energy Efficiency and Thermal Performance | • Design buildings to NZEB standards with a focus on future-proofing energy requirements for heating and cooling in the face of changing climate conditions. Conduct dynamic simulations to evaluate performance during extreme weather events, such as heatwaves or cold spells. |

| New and Existing Buildings<br>**The following recommendations aim to promote the development of buildings that are energy-efficient, climate-resilient, and environmentally sustainable. These recommendations integrate principles from NZEB (Near Zero Energy Building) standards, the Italian CAM (Minimum Environmental Criteria), and international best practices in climate adaptation and mitigation** | |
|---|---|
| | • Use advanced insulation materials and innovative designs, such as double-skin facades, which provide high thermal inertia and reduce heat gains during summer.<br>• Incorporate smart energy management systems, including sensors and automation, to optimize energy use and monitor building performance in real-time. |
| Passive Design Strategies | • Orient buildings and design layouts to optimize solar gain during winter while minimizing overheating during summer, leveraging natural shading and ventilation.<br>• Install shading systems (e.g., louvers, overhangs) and use glazing with adjustable solar transmittance to ensure adaptability to seasonal variations.<br>• Design roofs, walls, and windows with a high albedo to reflect solar radiation, particularly in urban areas prone to the heat island effect. |
| Climate-Responsive Green and Blue Infrastructure | • Incorporate green roofs, green walls, and urban vegetation as buffers against heat and flooding. Green infrastructure helps mitigate the urban heat island effect and absorbs excess rainwater during extreme precipitation events.<br>• Utilize blue infrastructure, such as rain gardens, bioswales, and permeable pavements, to manage stormwater and reduce the risk of flooding from heavy rainfall |
| Water resources management | • Install greywater recycling systems alongside rainwater harvesting to maximize water reuse for irrigation, cooling, or flushing.<br>• Design landscaping with xerophytic (drought-tolerant) plants to reduce water consumption and ensure resilience during prolonged dry periods. |
| Biodiversity and ecological integration | • Incorporate measures to protect and enhance biodiversity, such as nesting boxes, pollinator-friendly plant species, and connectivity corridors for wildlife.<br>• Restore degraded land or incorporate rooftop habitats to compensate for ecological losses caused by construction. |
| Addressing flood risk | • Elevate building foundations or critical infrastructure in flood-prone areas to reduce vulnerability to storm surges or riverine flooding.<br>• Implement flood barriers, retention basins, and water diversion systems around the site to minimize flood damage.<br>• Use materials resistant to water damage for lower building levels, and design spaces that can be easily restored after flooding (e.g., raised electrical systems, floodproof finishes). |
| Heatwave Preparedness | • Install shading systems such as pergolas, overhangs, or trellises, which reduce solar gain during heatwaves while maintaining natural light.<br>• Use glazing solutions with low solar heat gain coefficients to limit overheating during extreme heat events.<br>• Design outdoor spaces with shaded seating areas and evaporative cooling systems to improve urban comfort during extreme heat. |

| New and Existing Buildings | |
|---|---|
| **The following recommendations aim to promote the development of buildings that are energy-efficient, climate-resilient, and environmentally sustainable. These recommendations integrate principles from NZEB (Near Zero Energy Building) standards, the Italian CAM (Minimum Environmental Criteria), and international best practices in climate adaptation and mitigation** | |
| Renewable Energy System | • Integrate renewable energy systems, such as solar PV, wind turbines, and geothermal heating, to meet or exceed a building's energy demand.<br>• Promote energy-sharing models, such as energy communities, to enhance the resilience and efficiency of energy systems across neighbourhoods. |
| Climate-Adaptive Design Features | • Design multipurpose spaces within buildings that can serve as emergency shelters during climate disasters, such as heatwaves, storms, or flooding.<br>• Include backup systems for water, electricity, and ventilation to ensure buildings remain habitable during extreme climate events.<br>• Establish clear evacuation routes and signage to enhance safety during emergencies. |
| Social and Cultural Resilience | • Design communal spaces within buildings to encourage social interaction, which can enhance community cohesion and resilience during crises.<br>• Ensure accessibility for people of all abilities by following universal design principles, promoting inclusivity in climate-resilient building strategies. |
| Monitoring and Lifecycle Assessment | • Incorporate building performance monitoring systems to ensure ongoing compliance with energy and water efficiency goals.<br>• Conduct lifecycle assessments of materials and systems to minimize the building's overall environmental impact. |
| Education and Stakeholder Engagement | • Engage with stakeholders, including local communities, architects, and policymakers, to ensure the building design aligns with regional resilience goals.<br>• Provide educational materials or signage in buildings to promote awareness of sustainable features and encourage occupants to adopt eco-friendly practices. |

**Table 4 Resilience recommendations in agriculture**

| Agriculture | |
|---|---|
| **The following recommendations in agriculture focus on enhancing the resilience of farming systems to the impacts of climate change. These measures aim to address climate risks such as droughts, floods, heatwaves, and shifts in growing seasons. They also emphasize sustainable resource management, ecosystem conservation, and the adoption of innovative technologies to ensure food security, economic stability, and environmental health.** | |
| Climate-Resilient Crop Management | • Promote crop diversification with drought-resistant, flood-tolerant, and heat-resilient varieties to adapt to variable climate conditions.<br>• Implement intercropping, agroforestry, and crop rotation to improve soil health, enhance biodiversity, and reduce vulnerability to pests and diseases exacerbated by climate change. |

| Agriculture | |
|---|---|
| **The following recommendations in agriculture focus on enhancing the resilience of farming systems to the impacts of climate change. These measures aim to address climate risks such as droughts, floods, heatwaves, and shifts in growing seasons. They also emphasize sustainable resource management, ecosystem conservation, and the adoption of innovative technologies to ensure food security, economic stability, and environmental health.** | |
| | • Adjust planting and harvesting schedules based on seasonal climate forecasts to optimize crop yields and reduce exposure to extreme weather. |
| Water resource management | • Retrofit irrigation systems with water-saving technologies such as drip or micro-sprinkler irrigation to optimize water use and reduce evaporation losses.<br>• Install rainwater harvesting systems on farms to collect and store water for irrigation during dry periods.<br>• Utilize precision farming technologies, such as soil moisture sensors and satellite monitoring, to manage water and nutrient application more effectively. |
| Soil Conservation and Health | • Increase soil organic matter through composting, cover cropping, and reduced tillage to improve soil fertility, water retention, and carbon sequestration.<br>• Implement terracing, buffer strips, and contour farming to minimize soil erosion caused by heavy rains.<br>• Address soil acidity or alkalinity issues through targeted amendments to maintain optimal growing conditions under changing climatic conditions. |
| Biodiversity and Ecosystem Services | • Enhance habitats for pollinators by planting native flowering species around farms and reducing pesticide use.<br>• Create buffer zones and wildlife corridors to preserve biodiversity and support ecosystem balance.<br>• Integrate trees and shrubs into agricultural landscapes to provide shade, improve soil structure, and function as windbreaks, reducing the impact of storms and heatwaves. |
| Mitigating Heat and Drought Risks | • Use organic or synthetic mulch to reduce soil evaporation, moderate soil temperature, and suppress weed growth.<br>• Introduce shade nets or agroforestry systems to protect crops and livestock from heat stress.<br>• Build reservoirs, retention ponds, and underground water storage systems to secure water availability during prolonged dry spells. |
| Enhancing Flood Resilience | • Establish effective drainage networks to prevent waterlogging and root rot in flood-prone areas.<br>• Adopt crop varieties that can survive and thrive in inundated conditions, such as flood-resistant rice strains.<br>• Implement terraced farming or raised planting beds to protect crops from flooding and improve water drainage. |
| Renewable Energy Integration | • Deploy solar panels to power irrigation systems, refrigeration units, and other farm machinery, reducing dependency on fossil fuels.<br>• Utilize agricultural waste to produce biogas, providing renewable energy and reducing waste disposal issues. |

| Agriculture | |
|---|---|
| **The following recommendations in agriculture focus on enhancing the resilience of farming systems to the impacts of climate change. These measures aim to address climate risks such as droughts, floods, heatwaves, and shifts in growing seasons. They also emphasize sustainable resource management, ecosystem conservation, and the adoption of innovative technologies to ensure food security, economic stability, and environmental health.** | |
| | • Explore small-scale wind turbines for energy generation in rural farming areas. |
| Climate Risk Monitoring and Early Warning Systems | • Integrate renewable energy systems, such as solar PV, wind turbines, and geothermal heating, to meet or exceed a building's energy demand.<br>• Promote energy-sharing models, such as energy communities, to enhance the resilience and efficiency of energy systems across neighbourhoods. |
| Adopting Circular Economy Approach | • Promote the use of agricultural waste for composting, bioenergy production, or material recycling to minimize waste and reduce emissions.<br>• Implement practices that recycle nutrients within the farm, such as using livestock manure as fertilizer.<br>• Support local food systems and short supply chains to reduce transportation-related emissions and build community resilience. |
| Education, Training, and Policy Support | • Conduct workshops and training sessions to educate farmers on climate-resilient practices, water management, and sustainable techniques.<br>• Provide financial incentives for farmers to adopt adaptive technologies, renewable energy systems, and sustainable practices.<br>• Align agricultural resilience strategies with national and regional climate adaptation plans and frameworks. |

**Table 5 Resilience recommendation for blue and green infrastructure**

| Blue and green infrastructures | |
|---|---|
| **Blue and green infrastructure are critical strategies for enhancing urban resilience to climate change while promoting environmental, social, and economic co-benefits. By integrating natural elements, such as water bodies (blue infrastructure) and vegetation (green infrastructure), into urban planning and design, cities can mitigate climate impacts, promote biodiversity, and improve the quality of life for residents. Furthermore, BGI plays a vital role as an interface between urban areas and natural ecosystems, enhancing eco-logical connectivity and promoting the seamless integration of human and natural systems.** | |
| Expansion of Green Spaces | • Develop and expand urban green parks, forests, and gardens to provide cooling effects, improve air quality, and offer recreational spaces for communities. These spaces reduce the urban heat island effect by increasing green cover and providing shade.<br>• Integrate vertical gardens, green walls, and green roofs into urban buildings to enhance green coverage, reduce energy consumption, and mitigate the heat island effect.<br>• Promote community gardens as a means of fostering local food production, enhancing food security, and building community resilience. |

| Blue and green infrastructures | |
|---|---|
| **Blue and green infrastructure are critical strategies for enhancing urban resilience to climate change while promoting environmental, social, and economic co-benefits. By integrating natural elements, such as water bodies (blue infrastructure) and vegetation (green infrastructure), into urban planning and design, cities can mitigate climate impacts, promote biodiversity, and improve the quality of life for residents. Furthermore, BGI plays a vital role as an interface between urban areas and natural ecosystems, enhancing eco-logical connectivity and promoting the seamless integration of human and natural systems.** | |
| Rainwater Management and Stormwater Control | • Implement rainwater harvesting systems for buildings, public spaces, and roads to reduce stormwater runoff and conserve water resources. These systems can store water for irrigation, cooling, or domestic use, helping mitigate the impacts of droughts and heatwaves.<br>• Use permeable or semi-permeable materials in urban streets, driveways, and pavements to allow water to infiltrate the ground, reducing surface runoff and helping manage stormwater during heavy rainfall.<br>• Design and restore natural waterways, such as rivers, lakes, wetlands, and ponds, to absorb excess rainfall and reduce flood risks. Construct wetlands and swales to filter stormwater, improve water quality, and provide flood storage capacity. |
| Climate-Resilient Urban Water Systems | • Plan and manage urban water systems to address both water scarcity and excess. Incorporating water-efficient technologies (e.g., low-flow systems, water-saving appliances) and adopting policies to prevent water wastage helps ensure water security under changing climate conditions.<br>• Implement floodplain restoration and design flood control infrastructure (such as levees, dams, and flood retention basins) to protect urban areas from extreme rainfall and rising water levels.<br>• Invest in green infrastructure systems like bioswales, vegetated swales, and rain gardens that manage stormwater naturally, enhancing water infiltration and providing filtration of pollutants before they enter water bodies. |
| Enhancing Biodiversity and Ecosystem Services | • Promote the use of native plant species in urban landscaping and green infrastructure projects to enhance local biodiversity, provide habitat for pollinators, and improve ecological connectivity.<br>• Design urban environments with green corridors and wildlife-friendly spaces that facilitate the movement and survival of local species. This can be achieved by linking parks, forests, and natural reserves with green corridors.<br>• Integrate pollinator habitats, such as flowering plants and wildflower meadows, into urban designs to support bees, butterflies, and other pollinators, which are important for food production and biodiversity. |
| Nature-Based Solutions for Climate Adaptation | • Plant and preserve urban forests and street trees to absorb carbon dioxide, provide shade, and improve air quality. Large canopy trees can reduce the urban heat island effect by lowering temperatures in public spaces.<br>• Restore or create wetlands in urban areas to enhance natural water retention, provide flood mitigation, and support biodiversity. Wetlands also help in reducing pollutants from stormwater runoff and can contribute to carbon sequestration.<br>• In coastal areas, invest in natural coastal protection measures such as mangrove restoration, coral reefs, and dune rehabilitation to protect cities from rising sea levels and storm surges. |

| Blue and green infrastructures | |
|---|---|
| **Blue and green infrastructure are critical strategies for enhancing urban resilience to climate change while promoting environmental, social, and economic co-benefits. By integrating natural elements, such as water bodies (blue infrastructure) and vegetation (green infrastructure), into urban planning and design, cities can mitigate climate impacts, promote biodiversity, and improve the quality of life for residents. Furthermore, BGI plays a vital role as an interface between urban areas and natural ecosystems, enhancing eco-logical connectivity and promoting the seamless integration of human and natural systems.** | |
| Green and Blue Infrastructure Integration into Urban Planning | • Design green infrastructure that serves multiple functions, such as water management, recreation, urban cooling, and biodiversity enhancement. For example, parks can include stormwater retention ponds, and green roofs can offer both aesthetic benefits and energy efficiency.<br>• Use green spaces to create pedestrian and cycling pathways, contributing to sustainable mobility while enhancing green coverage and connecting different parts of the city.<br>• Use green roofs, green walls, and street trees to mitigate the urban heat island effect, particularly in cities with dense built-up areas. Green infrastructure plays an important role in cooling urban environments and improving health outcomes. |
| Community Involvement and Education | • Involve local communities in the planning and maintenance of green and blue infrastructure. By doing so, residents can contribute to environmental stewardship and have a sense of ownership over public spaces.<br>• Promote the benefits of green and blue infrastructure through public awareness campaigns, highlighting how these measures can enhance quality of life, reduce climate risks, and contribute to environmental sustainability.<br>• Provide training and resources to communities and local authorities on the benefits and maintenance of green and blue infrastructure, ensuring that these solutions are well understood and effectively implemented. |
| Blue and Green Infrastructure Monitoring and Evaluation | • Regularly assess the performance of green and blue infrastructure, particularly in terms of water retention, air quality improvement, temperature regulation, and biodiversity enhancement.<br>• Establish adaptive management frameworks to monitor the impacts of climate change on green and blue infrastructure and adjust strategies as needed. This approach ensures that interventions remain effective under changing climate conditions.<br>• Use data from environmental monitoring systems, such as satellite imaging, sensors, and climate models, to guide the planning and development of blue and green infrastructure and to track their performance over time. |
| BGI as an Interface with Natural Ecosystems | • Blue and green infrastructure can serve as an interface between urban spaces and surrounding natural ecosystems, fostering ecological connectivity and facilitating the movement of wildlife. Green corridors, riparian zones, and urban wetlands not only serve human needs but also help maintain and restore critical habitats and biodiversity.<br>• By incorporating blue and green infrastructure into urban planning, cities can harmonize human development with natural processes, utilizing ecosystems to buffer against climate hazards like flooding, heatwaves, and droughts. This integrated approach ensures that urban and natural ecosystems work together to enhance resilience. |

| Blue and green infrastructures | |
|---|---|
| **Blue and green infrastructure are critical strategies for enhancing urban resilience to climate change while promoting environmental, social, and economic co-benefits. By integrating natural elements, such as water bodies (blue infrastructure) and vegetation (green infrastructure), into urban planning and design, cities can mitigate climate impacts, promote biodiversity, and improve the quality of life for residents. Furthermore, BGI plays a vital role as an interface between urban areas and natural ecosystems, enhancing eco-logical connectivity and promoting the seamless integration of human and natural systems.** | |
| | • Green and blue infrastructure can enhance ecosystem services, such as carbon sequestration, air and water purification, and pollination, which are important for adapting to climate change. These services provide benefits not only to human populations but also to the broader natural environment, supporting biodiversity and ecological health. |

**Table 6 Resilience Recommendations on transportation**

| Transportation | |
|---|---|
| **The following recommendations aim to promote the development of transportation systems that are energy-efficient, climate-resilient, and environmentally sustainable. These recommendations integrate principles from low-carbon mobility strategies and sustainable infrastructure standards in climate adaptation and mitigation** | |
| Promote Multi-Modal and Flexible Transport Solutions | • the connection between buses, trains, bikes, car-sharing, and pedestrian pathways to ensure seamless mobility.<br>• transport hubs that allow smooth transitions between different modes of transport (e.g., bike-to-train, park-and-ride systems).<br>• Use AI-driven demand forecasting and real-time traffic management to adjust transport routes dynamically in case of disruptions.<br>• Expand micro-mobility services (e-scooters, bike-sharing) and pedestrian-friendly urban designs |
| Build a Socially Sensitive Transport System | • Improve transport facilities for people with disabilities, elderly passengers, and low-income communities.<br>• Offer subsidies for public transport and shared mobility services in underserved areas.<br>• Implement better lighting, surveillance, and emergency response mechanisms in public transport to improve passenger security.<br>• Include citizens in transport planning to design systems that meet diverse mobility needs. |
| Enhance Practical and Resilient Infrastructure | • Upgrade and Maintain Critical Transport Assets: Invest in high-quality roads, bridges, railways, and public transport fleets resistant to climate and operational stress.<br>• Develop Emergency Backup Systems: Ensure alternative routes, backup fuel supplies, and emergency transit plans are in place for disruptions.<br>• Implement Smart Infrastructure: Use IoT sensors, AI-based monitoring, and predictive maintenance to reduce breakdown risks and optimize performance.<br>• Encourage Modular and Scalable Solutions: Build adaptable transport networks that can quickly respond to population growth or changing travel patterns |
| Foster Environmental Sustainability in Transport | • Invest in electric buses, trains, and vehicles with a robust charging infrastructure. |

| Transportation | |
|---|---|
| **The following recommendations aim to promote the development of transportation systems that are energy-efficient, climate-resilient, and environmentally sustainable. These recommendations integrate principles from low-carbon mobility strategies and sustainable infrastructure standards in climate adaptation and mitigation** | |
| | • Expand bike lanes, pedestrian-friendly areas, and car-free zones in urban centres.<br>• Encourage biofuels, hydrogen, and hybrid transport solutions to reduce dependence on fossil fuels.<br>• Use permeable pavements, urban forests, and renewable energy-powered transit stations to minimize environmental impact. |
| Improve Crisis Preparedness and Adaptability | • Implement real-time alert systems and emergency protocols for natural disasters, strikes, and infrastructure failures.<br>• Avoid over-reliance on single transport hubs by creating multiple transit centres and alternative supply chain routes.<br>• Design transport systems that can withstand extreme weather, including flood-resistant roads and heatproof rail tracks. |

**Table 7 Resilience Recommendation on protected areas conservation**

| Protected Areas Conservation | |
|---|---|
| **The following recommendations aim to promote the conservation of protected areas in a way that is ecologically sustainable, climate-resilient, and supportive of biodiversity. These recommendations integrate principles from ecosystem-based adaptation strategies, sustainable land management practices, and conservation policies to enhance resilience and mitigate climate impacts.** | |
| Habitat Protection and Restoration | • Connect protected areas to allow species migration and adapt to environmental changes.<br>• Focus on rehabilitating degraded areas such as wetlands, mangroves, and forests to enhance biodiversity.<br>• Identify and protect areas likely to function as refuges under changing climate conditions, such as high-altitude regions or areas with stable microclimates. |
| Ecosystem Monitoring and Adaptive Management | • Regularly monitor ecosystem indicators (e.g., keystone species or coral reefs) to detect early signs of stress.<br>• Continuously update management plans based on monitoring results and emerging environmental data, such as changes in wildfire risk or vegetation health |
| Invasive Species and Human Impact Management | • Implement strategies to eradicate or control invasive species that threaten native biodiversity, such as predators on islands or invasive plants in forests.<br>• Regulate activities like logging, fishing, and tourism to prevent overexploitation within protected areas.<br>• Establish buffer zones around protected areas to mitigate external pressures, such as agricultural runoff or urban expansion. |
| Community and Indigenous Engagement | • Involve local and Indigenous communities in conservation efforts, incorporating traditional ecological practices (e.g., fire management or sustainable hunting). |

| Protected Areas Conservation | |
|---|---|
| **The following recommendations aim to promote the conservation of protected areas in a way that is ecologically sustainable, climate-resilient, and supportive of biodiversity. These recommendations integrate principles from ecosystem-based adaptation strategies, sustainable land management practices, and conservation policies to enhance resilience and mitigate climate impacts.** | |
| | • Support community-led conservation, where local stakeholders help manage natural resources, such as co-managing a marine protected area for sustainable fish stocks. |
| Cross-Border and Transboundary Conservation | • Work across borders with neighbouring countries on joint conservation efforts, especially for migratory species or large ecosystems. |
| Financial and Policy Support | • Secure long-term funding for protected areas, such as biodiversity credits, eco-tourism fees, or trust funds.<br>• Empower local communities through involvement in decision-making, providing resources and authority for management, such as community patrols. |

# 5 Conclusions

Resilience recommendations presented in this document are directly informed by the major issues raised by the community of practice (CoP), with particular attention given to the **unique challenges of both urban and agricultural sectors**. Throughout the process, input from CoP stakeholders has been instrumental in shaping the recommendations, ensuring they align with the specific needs, priorities, and vulnerabilities identified by the communities involved. These concerns include a range of climate risks such as **extreme heat, flooding, drought, and soil degradation**, as well as the increasing **demand for sustainable agricultural practices, improved water management, and resilient infrastructure in both urban and rural settings**.

The recommendations emphasize the importance of a tailored approach that integrates **local knowledge**, fosters **community participation**, and ensures that interventions are context-sensitive and responsive to the distinct circumstances of each locality. Whether addressing the agricultural sector's need for climate-resilient crop management or enhancing the resilience of urban infrastructure, these recommendations **prioritize solutions that can be adapted to local realities**. By embedding local knowledge and community-driven solutions, we ensure that interventions are not only relevant but also effective in enhancing resilience across sectors. While these strategies are informed by global best practices, their true value lies in their adaptability and scalability to different local contexts, which makes them practical and actionable for communities of all sizes.

The document also highlights the **importance of addressing both immediate and long-term challenges**. By focusing on scalable and flexible interventions, such as promoting climate-resilient agricultural techniques, integrating blue and green infrastructure, and fostering sustainable mobility options, the recommendations offer a comprehensive framework for addressing climate risks. These actions are designed to enhance the resilience of both the agricultural and built environments, ensuring that communities can better withstand the impacts of climate change while simultaneously improving social, environmental, and economic outcomes.

Furthermore, these recommendations aim to **bridge the gap between urban development and agricultural practices**, recognizing the interconnectedness between them. For example, integrating sustainable agricultural practices with urban planning, including the use of **green spaces, water management systems, and energy-efficient technologies**, provides opportunities for enhancing **ecosystem services** and mitigating climate risks such as flooding and heatwaves. This integrated approach creates **synergies between human and natural systems**, fostering long-term resilience in both urban and rural landscapes.

Lastly, the **replicability** of these recommendations is a key consideration. The flexibility of the proposed interventions means they can be adapted and replicated across various local settings, both urban and agricultural, contributing to the broader goal of building a resilient, sustainable future. By developing strategies that are scalable and customizable to different environments, these recommendations offer a **pathway for creating climate-resilient communities**, where agricultural productivity, urban development, and environmental sustainability can coexist and thrive, ensuring a more sustainable and resilient future for both people and nature.

# 6 Next Steps

The second version of this deliverable (D4.4, scheduled for May 2026) will provide concrete recommendations for resilient development in the five ClimEmpower regions, along with a general framework for their application in other regions. In the next phase of the project, WP4 will focus on co-developing resilience recommendations with regional stakeholders, ensuring they address more specific regional challenges and intervention practices. This process will follow the ClimEmpower collaborative approach that integrates scientific insights with local expertise to develop actionable and context-specific strategies.

As the project progresses, several key challenges must be considered to ensure that resilience recommendations are meaningful and relevant to stakeholders. One major challenge is **aligning these recommendations with existing regional and national policy frameworks**. Ensuring they resonate with ongoing policy discussions will enhance their value to decision-makers. Another critical aspect is **financial feasibility**; identifying potential funding mechanisms and understanding economic constraints will help stakeholders assess the practicality of various adaptation approaches. Additionally, effective engagement and coordination among regional authorities, local communities, and other key actors will be essential. The impact of these recommendations depends on their ability to reflect diverse perspectives and priorities, fostering a shared understanding of regional resilience challenges. Finally, the **accessibility and usability of knowledge** remain significant concerns. Climate data and adaptation strategies can be complex, and without clear interpretation and contextualization, they risk being overlooked or misunderstood by those who could benefit from them.

To address these challenges, the next steps will focus on developing resilience recommendations that serve as inspiration and strategically relevant resources for stakeholders. As part of WP4, regional partners will play a central role in refining these recommendations through **collaborative discussions**, engaging CoP stakeholders in **scenario analysis, serious roleplaying games and storytelling exercises**. These activities will help frame resilience recommendations in ways that are engaging, regionally specific, and reflective of real-world complexities. In terms of helping the CoPs with knowledge, data and software, ClimEmpower foresees two possibilities: (1) helping the CoPs to re-use of the already existing knowledge, data and services, and (2) development of specific data (WP2), knowledge (WP2, WP3, T4.1) and services (WP3) covering (some of) the needs of the regional stakeholders that aren't satisfactory resolved by existing offers. This support includes **contextualization of climate indicators and baseline data** (WP2), development of **microlearning materials** to enhance understanding (T4.1), facilitating the **co-design of digital tools and services** (T4.3) and implementing these tools and services (WP3).

Ultimately, the emphasis will be on fostering meaningful dialogue and collaboration among stakeholders. Workshops, discussions, and targeted engagement activities within T4.2 and T4.3 will ensure that regional authorities, CoP stakeholders, and other actors find the recommendations relevant, engaging, and useful for their own strategic planning. By taking this approach, the project aims to create a framework that stimulates discussion, supports capacity building, and provides stakeholders with valuable insights into resilience planning.

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