



CLIMATE CHANGE RESILIENCE: IDENTIFIED DATA, SERVICES, AND GAPS

ClimEmpower Work Package 2, D2.1



Project ClimEmpower: User Driven Climate Applications Empowering Regional Resilience

Work package 2, Deliverable D2.1

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List of Acronyms

AIT	Austrian Institute of Technology GmbH
ANDALUS	Consejería de Sostenibilidad, Medio ambiente y Economía Azul
ANET	Anaptixiaki eteria kinotiton periochis troodoys Ltd.
AQUA	AQUATEC – Proyectos para la gestión del agua
C3S	Copernicus Climate Change Service
CC	Climate Change
CDS	Climate Data Store by Copernicus (part of C3S)
CEMS	Copernicus Emergency Management Service
CERTH	Ethniko kentro erevnas kai technologikis anaptyxis
CET	CETAQUA
CoP	Community of Practice
DMCSEE	Drought Management Centre for South-Eastern Europe
ECMWF	European centre for medium-range weather forecasts
EFFIS	European Forest Fire Information System
FAIR	easily Findable, Accessible, Interoperable and Reusable
FER	Fakultet Elektrotehnike i Racunarstva, Sveučilište Zagreb
FRC	Frederick Research Center
GDP	Gross Domestic Product
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Centre of the European Commission
KISS	Keep It Simple and Stupid
KPI	Key Performance Indicator
MUs	Mission Users
NUTS	Nomenclature of territorial units for statistics
OBZ	Osijek-Baranja County (Osječko-baranjska županija)
PESPA	Regional Climate Change Adaptation Plan (Greek region)
PLINIVS	PLINIVS - Centro Studi per l'Ingegneria Vulcanica Sismica e Idrogeologica

RAs	Regional Authorities
REDIAM	Red de Información Ambiental de Andalucía
PSTE	Region of Central Greece
SICILY	Sicily Region
SMART	Specific, Measurable, Achievable, Reasonable and Time-bound
SO	Strategic Objective
TROODOS	Troodos Mountain Range in Cyprus
WMO	World Meteorological Organization
WP	Work Package

Glossary

Climate impacts	The consequences of realized risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather and climate events), exposure, and vulnerability. Impacts generally refer to effects on lives; livelihoods; health and well-being; ecosystems and species; economic, social and cultural assets; services (including ecosystem services); and infrastructure (based on IPCC, 2018)
Climate risks	Climate risk is the potential for climate change to create adverse consequences for human or ecological systems.
Climate service	A climate service is the provision of climate information to help end-users make climate smart decisions.
Community of Practice	Group of people who share a common interest or concern for a specific activity, practice or topic who engage in a process of collective learning within a shared domain by supporting each other and exchanging information through collaborative activities.
Exposure	Exposure is the situation of people, infrastructure, housing, production capacities and other tangible (human) assets located in hazard-prone areas.
Hazard	Hazards have the potential to cause loss of life, injury or other health impacts, property damage, social and economic disruption, or environmental degradation.
Stakeholder	A person with an interest or concern in something.
Vulnerability	Vulnerability refers to the conditions determined by physical, social, economic, and environmental factors or processes which increase the susceptibility of an individual, a community, assets, or systems to the impacts of hazards.
Reanalysis	A climate reanalysis gives a numerical description of the recent climate, produced by combining models with observations. It usually contains estimates of atmospheric parameters such as air temperature, pressure and wind at different altitudes, and surface parameters such as rainfall or soil moisture content.
ESRI Shapefiles	A shapefile is an Esri vector data storage format for storing the location, shape, and attributes of geographic features. It is stored as a set of related files and contains one feature class.

Executive summary

This Deliverable (D2.1) is part of **WP2 – „Addressing the CC data and knowledge Gaps”** and provides a summary of existing and useful European and region-specific datasets and climate services. In cooperation with WP1 “Regional CC resilience background, challenges and expectations” and WP4 “Empowering the regions” work packages, the team working on D2.1 has compared the available datasets and services with the needs of the regions and identified the data and service gaps to be closed by the project. **The aim of the deliverable is thus to give a comprehensive and tangible overview of datasets, climate services and gaps that are relevant regional climate resilience assessment.**

Deliverable starts with compulsory “summary” and “introduction” Chapters. **Chapter 3 provides an overview on the methodological approach to assess data and services’ availability.** As our central approach relates to the concept of risk assessment, this chapter also elaborates the definition of risk and its components, namely hazard, exposure, and vulnerability. The structure for assessing data and services’ availability adheres to the risk definition of the IPCC and the UNDRR Terminology.

Chapter 3.2 describes the approach applied for reviewing existing data and information, which started with a screening of existing expertise within the WP2 team. Subsequently, information about datasets was collected and the global, European-wide and regionally available datasets related to hazards, exposure, vulnerability, climate, and socio-economic factors were screened systematically. The next step involved engaging with the topic of available climate services. A comprehensive literature review on service typologies was conducted, which delivered a useful typology that was subsequently applied in the survey for analysing the usability of the gathered data for local end-users. The findings from the survey were supplemented by bilateral meetings with each region. Finally, gaps between the collected data and services and the needs of the regional stakeholders were identified and documented.

Chapter 4 serves as a core section of D2.1, presenting the results. An evaluation of the data availability revealed that almost 70% of the available datasets relate to hazards, in comparison to only about 16% to exposure and 11% to vulnerability. Most of the datasets are either national or European in scope, with only 10% specifically focused on the regions. In chapter 4.2, several examples of available datasets are discussed to offer insights into the extensive collection of information gathered through the factsheets. For **hazard** data, an example from the Copernicus Climate Data Store is discussed, along with the Agro-topoclimatic Atlas of Sicily and the HydroBasins from HydroSHEDSis downscaled for Sicily. In terms of **exposure** data, the open infrastructure map from OpenStreetMap, zoomed in on Cyprus, is discussed, alongside datasets on the REDIAM Golf course placement in Andalusia and the crowdsourced, georeferenced social media data. For **vulnerability** data, the EUROSTAT population dataset and the Italian ISTAT socio economic census data are discussed. Finally, the Historical Analysis of Natural Hazards in Europe (HANZE) is discussed as an example of the **impacts** data base.

Chapter 4.3 is dedicated to the topic of climate services and provides insights from a literature search on success factors for climate services. The chapter results into a **typology of climate services** differentiating between the service types of **Maps & Apps, Expert Analysis,**

Climate-inclusive Consulting, and Sharing Practices. An evaluation of the available climate services is either global or European in scope such as e.g. the Copernicus Climate Data Store providing access to a wide range of climate datasets. Only 18% of the climate services are nationally or regionally available.

As indicated above, only a small part of the data and services that were analysed in preparing this deliverable is discussed in deliverable. Entire list of data sheets for all analysed data and services is available as a separate document and published as Open Data on ClimEmpower Zenodo channel, in accordance with the provisions of the ClimEmpower Data Management Plan (<https://zenodo.org/communities/climempower>).

Chapter 4.4 presents the **results from the gap analysis** conducted for each region. In the Croatian region, the primary requirements are for drought prediction and heatwave forecasting, as no regional tool or model specifically tailored to these needs currently exists. In Central Greece, the analysis revealed a lack of accessible and usable data, tools, and material to support the local authorities in their activities to raise awareness within society. For the Troodos Mountains in Cyprus, the major limitation is the scarcity of available datasets for this island, as Cyprus is often excluded from European datasets. Sicily requires tools, particularly comprehensive reports on flood and drought scenarios, or ideally a „report generator “that ensures climate-proofing for infrastructure projects. Costa del Sol in Andalusia already possesses a wide range of tools and datasets, especially on coastal flooding. However, there are still gaps, particularly in the availability of coupled coastal and pluvial flood models, spatial distribution maps for heatwaves, and integrated tools that combine water scarcity and drought data.

Concluding, with its comprehensive analysis of global/European wide datasets (climate, socio-economic, governance) and climate services, as well as region specific ones, D2.1 provides a basis for the other tasks in WP2. The check of the usability of available datasets for the local end-users revealed gaps which ought to be closed in T2.2 and T2.3 and will need further discussion in the CoPs (WP4).

1. ClimEmpower summary

ClimEmpower is a Horizon Europe collaborative research project dedicated to addressing the ongoing Climate Crisis in Europe by empowering the regional stakeholders in some of the most vulnerable European regions (Figure 1).

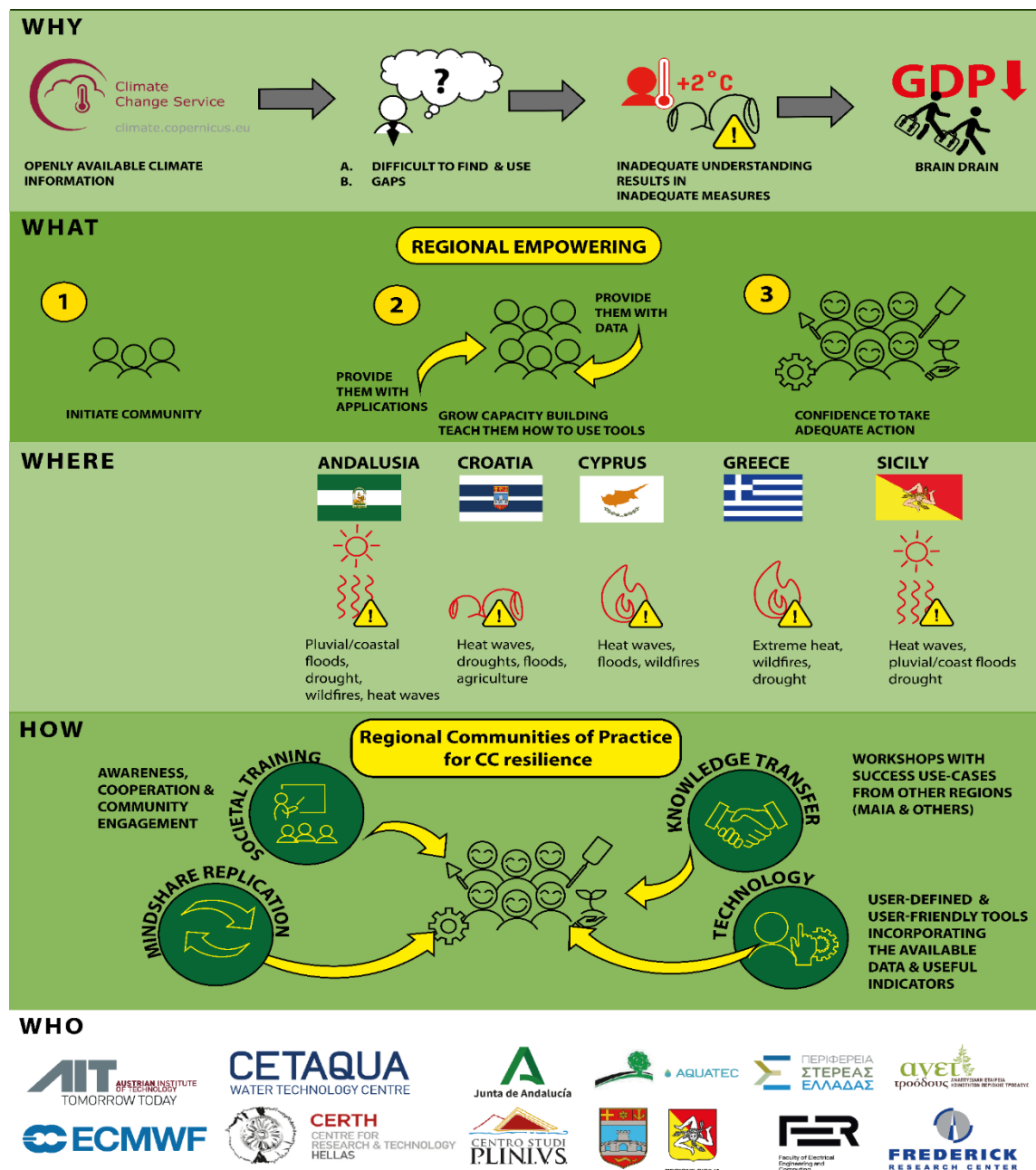


Figure 1: ClimEmpower at a glance: why, what, where how and who.

1.1 Project Context

Climate risks results from a combination of hazard, exposure, and vulnerability (IPCC, 2022). Addressing all three aspects is crucial for effective increase of regional resilience. However, exposure, vulnerability, and related aspects, such as adaptive capacity, strongly depend on available knowledge and climate literacy. Consequently, global climate crisis frequently has a higher impact on socioeconomically vulnerable regions, thanks to a higher human and

economic potential for addressing the issue in more affluent regions. To maximize its impact, ClimEmpower has therefore chosen to address the EU regions featuring a combination of high potential CC impacts and low and/or stagnant regional GDP/capita. This is mainly the case for regions in South and Southeast Europe (Figure 2).

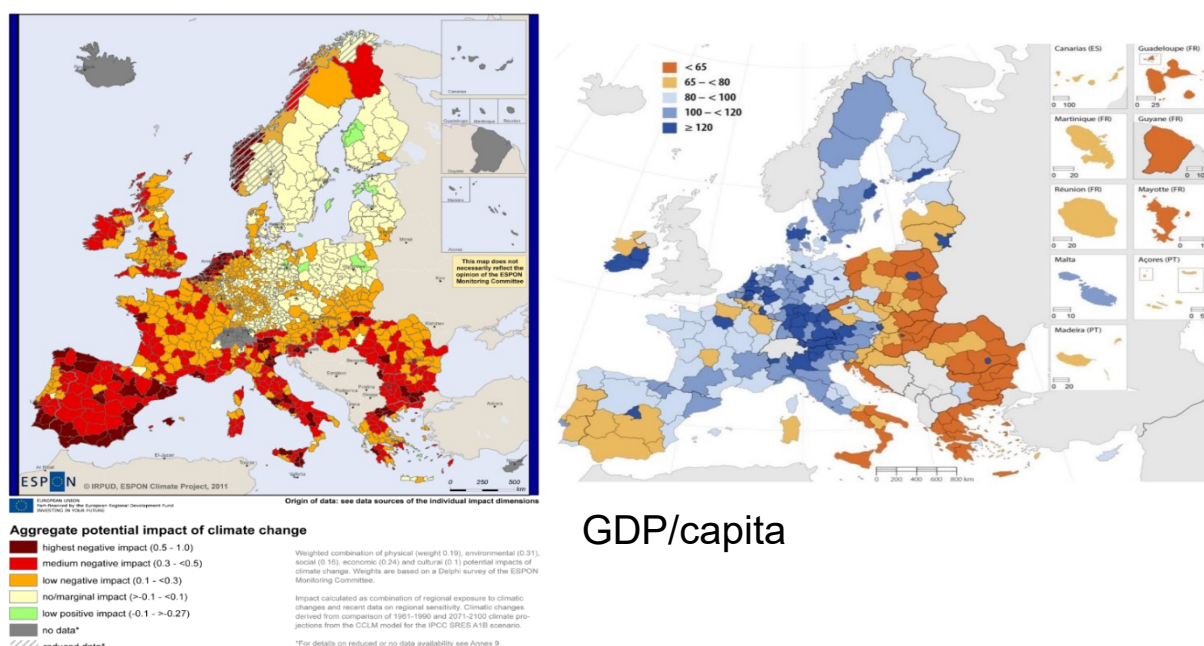


Figure 2: Aggregated potential impact of climate change and GDP/capita; Sources: (Espon, 2012) and (Eurostat, 2021)

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 SMART¹ 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

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).

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.

2 Introduction

2.1 Deliverable summary

This Deliverable (D2.1) is part of **WP2 – „Addressing the CC data and knowledge Gaps”** – and delivers a summary of existing and useful European and region-specific datasets and climate services. D2.1 identifies which datasets and services are available, and in cooperation with WP1 and WP4, what are the needs of the regions and which gaps are still to be closed. Therefore, the aim of the deliverable is to give a comprehensive and tangible overview of datasets and climate services relevant to assess climate resilience of regions, as well as prevailing gaps.

D2.1 is the first deliverable of WP2 which focuses on analysing and mending the data, algorithms, and knowledge gaps, using tangible indicators, and assessing the impact of measures to enable the development of strategies. WP2 is closely linked to WP1, that organized the set-up of CoPs thereby ensuring the inclusion of the regions, WP3 which aims to improve access to climate- and other relevant data and simplify the task of transforming this data in actionable knowledge and WP4 which continues with the CoPs and develops needed training materials.

As D2.1 analyses available data and climate services, it provides a basis for the other tasks in WP2. Thus, a comprehensive analysis of global/European wide datasets (climate, socio-economic, governance) and climate services, as well as region specific ones, has been performed and summarized in factsheets. The available datasets and climate services were and will be checked for their usability for local end-users (CoPs, WP4). Intense work in the CoPs, along with an investigation of available data and a survey conducted with the regional stakeholders revealed the gaps which ought to be closed in T2.2 and T2.3.

2.2 Results and expected impacts

Deliverable 2.1 is the first result of WP2. It provides an overview on existing datasets and climate services and builds a basis for the following tasks and deliverables in this work package as well as input to WP4 and WP3 for setting up the tools for supporting the regions.

In detail, D2.1 has produced the following results:

- **Factsheets of hazard, exposure, and vulnerability datasets** to enable the assessment of risk as defined by the IPCC (see Figure 4)
- Literature review on **typologies of climate services**
- **Factsheets on climate services**
- Analysis of “questions for regions” questionnaire responses.
- **Gap analysis**

This work package primarily addresses the challenges related to SO2 (Addressing the gaps in availability and usability of CC data and services (WP2 and WP4, scientific), by performing a gap-analysis between available data and services and those needed by the regional stakeholders. Through involving the target groups of local and regional authorities (RAs) in bilateral meetings, WP2 aims to guarantee a long-term impact within the case studies. Further,

by comprehensively summarizing all existing data and services, this compilation can be used in future projects and by regions to analyse what is available for them ensuring a widespread impact. Deliverable 2.1 contributes to the scientific result RES-SCI1 by providing an overview of availability and usability of European as well as regional datasets and climate services. It also provides information on existing gaps as well as outcomes from a literature review on service typologies.

2.3 Relation to other work

D2.1 has strong relations to WP1, which organised the first CoP meetings where needs and expectations were gathered. Based on the identified hazards, data specifically suitable for addressing those hazards was looked for. Furthermore, D1.2 “ClimEmpower scenarios” displays an important input for WP2. Consequently, team members of WP2 reviewed the D1.2 report, which described the envisaged ClimEmpower scenarios or pathways, ensuring a common understanding of resilience and a first approach of assessing climate risk at the local level for each of the regions. Additionally, the expected contributions of partners and tasks towards realization of these resilience scenarios or pathways were stated. Regarding WP2, these resilience pathways built a basis for understanding the status quo of resilience in the regions and for exploring their needs and expectations on data and services provided by ClimEmpower. Furthermore, bilateral exchange with Manuel Argamasilla (lead author of D1.2) took place for aligning the work and the two deliverables.

In parallel, WP4 started with Task 4.3 for the co-design of tools and services and with Task 4.2, where the work in the CoPs within WP1 is being continued, ensuring the consistent involvement of regional actors. Thus, a questionnaire for regional actors was set up jointly to clarify their expectations with respect to data and tools being developed within ClimEmpower and bilateral exchange took place for ensuring that the needs stated match what can be provided (e.g. stated need: precipitation data on 10 m spatial resolution; useful spatial resolution: km scale). Since training material on available as well as developed data and services is gathered and will be created within WP4, continuous exchange between WP2 and WP4 is crucial.

The output of D2.1 is expected to be used by regions for gaining a better understanding of which data and services exist and by the ClimEmpower partners, e.g. for setting up the user-centric CC resilience enhancing service in WP3. This aims at reducing gaps between data and services available at European scale and needs of regional actors, thereby empowering vulnerable areas to increase their adaptiveness towards climate change impacts and consequently their resilience.

2.4 Data, security, and ethics

2.4.1 Data interoperability

This deliverable has analysed the availability of climate related datasets relevant for the CoP regions (see Chapter 4).

The most common data formats are **NetCDF4** and **GRIB** for gridded datasets, especially if they are based on information from simulations and projections. However, many exposure and vulnerability related datasets are in the form of point information, either as **georeferenced ESRI shapefile** or simply provided **CSV files** of events or statistics.

Figure 3 provides an overview of the percentage of **gridded datasets** (47 %) and others (53 %), where the most common formats are **tables and statistics**. The usefulness of the data format highly depends on the intended use. Gridded data is especially important when looking at regional aspects and for merging various datasets like population, infrastructure accessibility, zoning information, etc., in order to understand areas especially affected. However, point data is important for localized information and can be used for identifying points of interest, their accessibility and infrastructural quality.

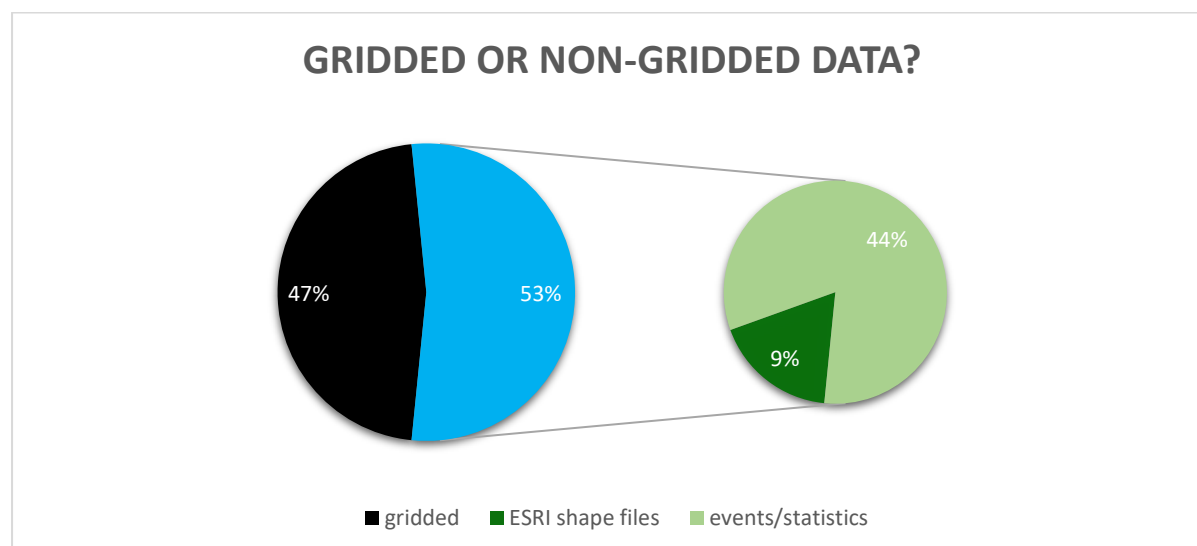


Figure 3: Distribution of gridded datasets; own presentation based on the found datasets (full list in 2.4.2)

Georeferenced formats, like ESRI shapefiles, and gridded data are interoperable, as they allow for easy conversions between formats and can be utilised in GIS-systems. The individual formats of the event-based and statistical datasets vary and georeferencing is often limited to the country as no further data is provided, however within this limits, CSV files and statistics can provide valuable data information, that is easily extractable.

Data factsheets resulting from analysis of this input data are provided as excel sheets and structured in line with the definitions of risk, hazard, exposure, and vulnerability of the IPCC (2022) and on the UNDRR Terminology 2017.

2.4.2 Data accessibility and reuse:

Goal of Task 2.1 was to screen data and climate services available on global, European, national, and regional scale and to compile information on these. Results of this screening have been published on Zenodo, as shown in Table 1.

In preparation of the D2.1 deliverable, the project team has performed a survey among the five CoP regions following the climate service typology (see 4.3.3) and asking them in a structured way what services they need. For gaining a deeper understanding of their needs, bilateral meetings with each region were conducted. Results of the survey and the talks were incorporated in section 0

Gap analysis of this report and a short overview has also been published via Zenodo (Table 1).

Table 1: Data produced in preparation of ClimEmpower deliverable D2.1

Name			Description	Zenodo DOI link
ClimEmpower: Service Needs	Regional	Climate	Results of the CoP surveys for all ClimEmpower regions.	DOI: 10.5281/zenodo.13869395
ClimEmpower: Services for Climate Resilience Assessment	Datasets	and	Tables (*.xlsx) containing datasheets of all collected datasets and climate services.	DOI: 10.5281/zenodo.13868882

2.4.3 Security and Ethics

D2.1 assesses data availability and identifies gaps between availability and needs. This data gap analysis aims to offer benefits to policy and the involved actors. For gaining a better understanding of the regional needs, bilateral meetings and surveys were conducted, where the team aimed to create a participative environment where everyone feels free to express their point of view and safeguards the participants and potential responses.

ClimEmpower project is dedicated to providing useful climate services for a just and equitable transition. Consequently, the question of disproportional effects of Climate Change and Climate Action on specific societal groups such as farmers, companies or specific population groups has been emphasised in the survey and in direct interactions with the regional stakeholders. Gender aspects have been considered in the datasets, especially regarding vulnerability. However, D2.1 mainly analysed data and service availability, whereas the question of ethics will have higher importance in forthcoming WP2 and WP4 tasks, where conclusions and recommendations for suitable services, appropriate data sets, and potential negative impacts of proposed assessment indicators and adaptation measures on specific population groups will be addressed.

3 Methodological approach to assess data and service availability

3.1 Risk definition

WP2 adheres to the (IPCC, 2022) definition of risk, which states that in the context of climate change, risk arises from the dynamic interactions among climate-related hazards, the exposure and vulnerability of affected human and ecological systems. Defining risk is crucial for identifying and considering potential adverse consequences and the uncertainties associated with them. Risk assessment enhances decision-makers' ability to understand and manage these risks effectively (IPCC, 2020).

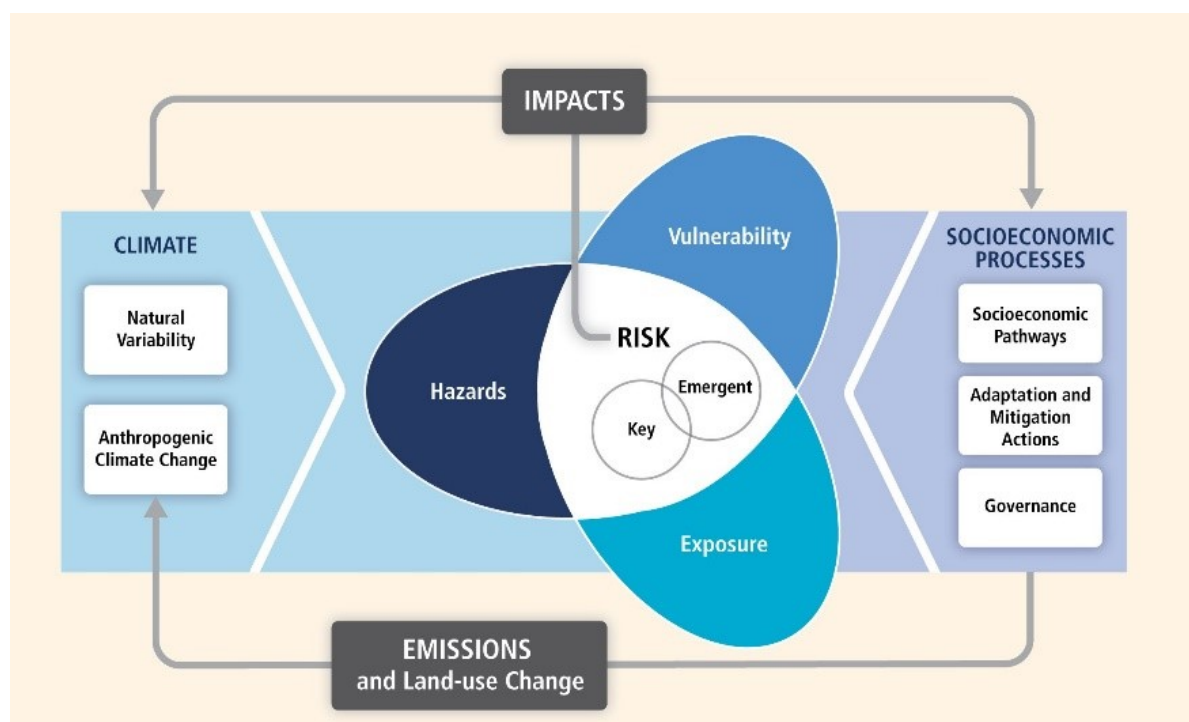


Figure 4: Risk propeller from the IPCC. Source: (IPCC, 2013)

The well-known risk propeller from the IPCC illustrates that risk arises at the intersection of hazard, exposure, and vulnerability. Risk is present only when all three components coexist and always applies to a specific hazard. Figure 5 gives an overview of the individual components of risk which will be describe the in detail in the subsequent sections. In the IPCC definition, risk refers only to negative (“adverse”) consequences.

In the IPCC context, the term hazard usually refers to climate-related physical events or trends or their physical impacts.

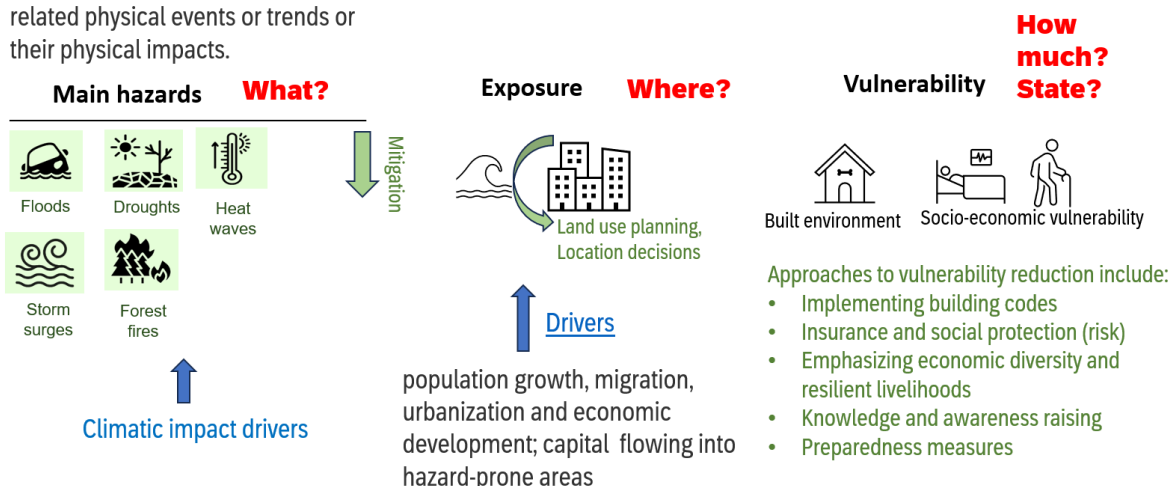


Figure 5: Overview of the three components of risk; own presentation based on definitions from the (IPCC, 2022)

3.1.1 Hazard

Hazards have the potential to cause loss of life, injury or other health impacts, property damage, social and economic disruption, or environmental degradation (UNDRR, 2017). In the IPCC context, the term hazard usually refers to climate-related physical events or trends or their physical impacts. It is defined as the potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources (IPCC, 2022).

Hazard examples: *heat, floods, drought, windstorm.*

3.1.2 Exposure

According to the UNDRR Terminology (UNDRR, 2017) exposure is the situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas. The UNDRR definition is rather neutrally formulated regarding the effects of exposure to the people and their assets. The IPCC (2022) defines exposure very similar as the presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected. Exposure measures may encompass the population count or asset types within a specific area.

Exposure example: *Population and assets (buildings, companies, infrastructure, agricultural areas etc.) along a river are exposed to flooding.*

Exposure is often estimated by combining statistical data (e.g. population density) with the land cover information (e.g. Corine land cover). Crowd-sourcing, which involves gathering information or input from a large number of people typically via the Internet, has emerged as a valuable method for gathering exposure information on a local and regional level (preventionweb.net). Lowering existing exposure is desirable, but often difficult to achieve in the short term, due to vested interest of the asset owners.

3.1.3 Vulnerability

The IPCC (2022) defines vulnerability as the propensity or predisposition to be adversely affected and encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt. The United Nations Office for Disaster Risk Reduction (UNDRR, 2015) describes vulnerability as the conditions determined by physical, social, economic, and environmental factors or processes which increase the susceptibility of an individual, a community, assets, or systems to the impacts of hazards (www.undrr.org). In both definitions susceptibility to harm plays a decisive role. Thus, vulnerability expresses the limits of people, communities, and assets to cope with the impact of hazard (preventionweb.net). Vulnerability relates to (preventionweb.net):

- physical factors (e.g. poor design and construction of buildings, crop type),
- social factors (e.g. poverty, inequality, age),
- economic factors (e.g. dependence on single industries, globalization of business and supply chain, loss of work force),
- environmental factors (e.g. poor environmental management, overconsumption of natural resources).

The climate risks Europe is facing aren't only driven by increases in climate hazards, but also by level of societal preparedness (EEA 2024-report on European Climate Risk Assessment). The extent to which exposed people or economic assets are actually at risk is generally determined by how vulnerable they are, as it is possible to be exposed but not vulnerable (preventionweb.net). The Global Assessment Report on Disaster Risk Reduction (UNISDR, 2015) states that there is growing evidence that there are four interlinked global drivers that increase the risk to unsustainable level: increasing hazard exposure, high levels of inequality, rapid urban development, and environmental degradation. In the case of extreme hazards the degree of disaster risk is a consequence of exposure more than it is a result of vulnerability (UNISDR, 2015).

Vulnerability Example: *very young and elderly people are more likely to suffer from and thus more vulnerable towards heat than young or middle-aged people.*

Measuring vulnerability is a complex process with no single standardized method; it is typically divided into assessments of physical (or built environment) vulnerability and socio-economic vulnerability. Enhancing coping capacity is a positive factor that improves the ability of populations to manage and respond to hazards effectively.

3.2 Assessment workflow of data set collection

To achieve a comprehensive review of existing data and information, the following approach has been applied: Expertise Assessment, Dataset Collection, Local Data Integration, and Identification and Evaluation of Climate Services. The following explains each step in more detail:

- 1) **Expertise Assessment:** Initially, a thorough screening was conducted to identify the existing expertise within the WP2 team. The assessment was structured around the risk components of hazards, exposure, and vulnerability. The expertise was differentiated between expertise with indicators and expertise with data within these

fields. This provided a comprehensive overview across the expertise available in the various domains.

- 2) **Dataset Collection:** Subsequently, global and European-wide datasets related to hazards, exposure, vulnerability, climate, and socio-economic factors were screened systematically. The main information from these datasets was collected in a structured manner. Templates for factsheets were developed to request specific information on the following aspects:
 - a. Author and Date,
 - b. Name of dataset,
 - c. Source,
 - d. Access to data / link (if available),
 - e. Assigned to the topic of climate, socio-economic, governance,
 - f. Content,
 - g. Data format,
 - h. Resolution, spatial extension,
 - i. Timeframe covered.
- 3) **Local Data Integration:** In addition to the global and European-wide datasets, local datasets were incorporated which were obtained from CoPs. The local datasets are important as they display what data is already gathered, used, at which resolution and by whom and therefore helps to identify existing gaps.
- 4) **Climate services:** As task 2.1 encompasses both data identification and the evaluation of climate services and gaps, the next step involved engaging with the topic of available climate services. To gain a comprehensive overview, a thorough screening of available climate services relating to different economic sectors was conducted. Additionally, all partners contributed information on the services they were already familiar with, and an additional screening was conducted. To streamline this process, a template was provided to gather specific details on the identified services as follows:
 - a. Author and Date,
 - b. Name of Service,
 - c. Website, Link,
 - d. Provider,
 - e. Status of provider (public, private, other),
 - f. Origin (name of country/international),
 - g. Thematic focus,
 - h. Target group,
 - i. Service description of website,

- j. Screenshot of services/products,
 - k. Type of service offered (data, consulting, specific product),
 - l. Source of the data displayed/used.
- 5) Given the extensive variety of climate services, the initial collection did not yield the desired insights. Consequently, a comprehensive literature review on service typologies (see 4.3.3 Services typologies) was conducted to derive an approach for structuring these services. The literature revealed a typology based on two dimensions: 1) Customization (generic vs. customised) and 2) Integration (focused vs. integrated), which can be seen in Figure 6: A typology framework of Climate Services. This typological framework was subsequently applied in the survey for the usability analysis.

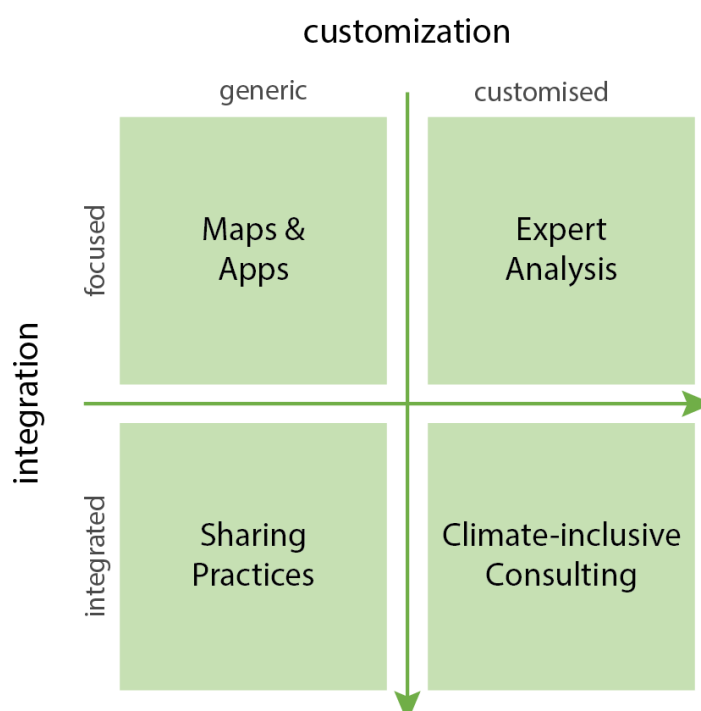


Figure 6: A typology framework of Climate Services

- 6) **Usability Analysis:** A key objective of WP2 is to identify needs of regional actors for taking decisions and planning towards climate resilience. To achieve this, we engaged in discussions with regional stakeholders through tight links to WP1. To assess the usability of the gathered data for local end-users, a survey was designed based on the typological framework identified in the literature review. The objective was to gain deeper insights into the climate data and services that are genuinely useful versus those that are considered “nice-but-impractical”. The survey was given to the CoP representatives who asked the regional partners for input and helped them to answer the survey questions. The survey results were analysed and provided initial insights into the needs of the regions. For a deeper understanding and more detailed insights, bilateral online meetings were conducted with each region to discuss their survey responses in greater detail and its meaning for T2.1, T2.2.
- 7) **Gap Analysis:** Finally, gaps between the collected data and services and the needs of the regional stakeholders were identified and documented.

4 Results

4.1 Overview of data availability

When WP2 started, all WP2 partners were asked to provide input to the data collection in order to get a comprehensive overview from all experts and CoPs. The following results show the status quo of information obtained. However, the factsheets are living documents and can still be further completed if new datasets or services are found.

Based on the described approach 126 relevant datasets were identified. From this total number, 80 % are related to climate data and 20 % focus on socio-economic aspects, as can be seen in Figure 7 left panel. Although Governance related data was asked for in the factsheet, no information in the form of a dataset has been collected.

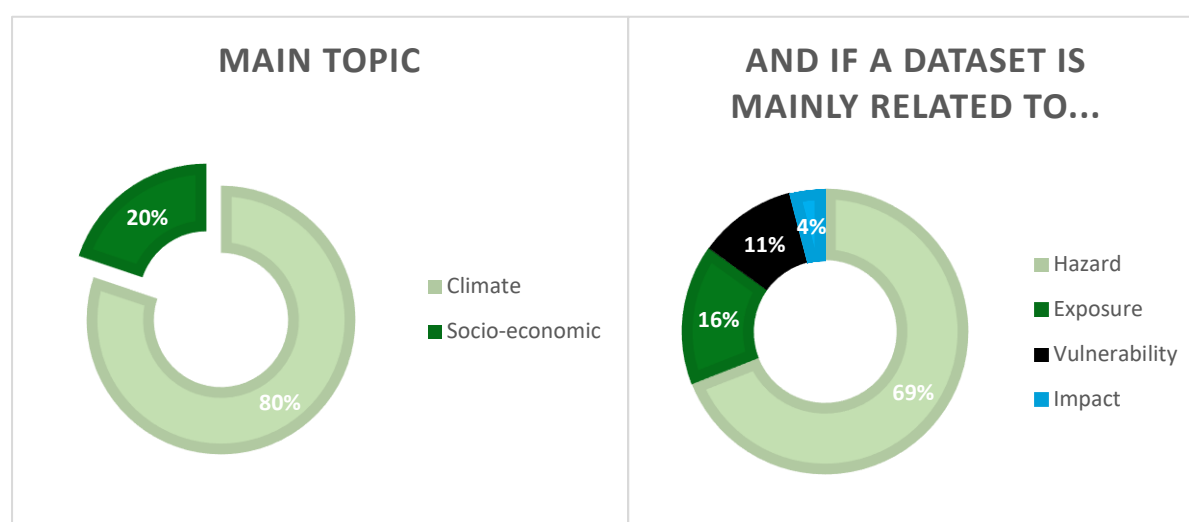


Figure 7: Main topic distribution of the available datasets, own presentation based on the found datasets (link in 2.4.2)

Following the classification described in 3.1, the datasets were separated into hazard, vulnerability, and exposure related data. Many datasets are not direct information on e.g. hazard but serve as input data for hazard calculation. Thus, those data have been labelled 'hazard related'. If a dataset is mostly related to hazard, vulnerability or exposure is always dependent on the asset, for which the risk analysis is performed. An asset can be the exposed element itself: humans, nature parks, critical infrastructure, or buildings for example. Figure 7 (right panel) shows the datasets separated by their most relevant relation and reveals that most datasets exist on hazards (69 %), followed by exposure and lastly vulnerability related data. Regarding the impacts of hazards, only a few datasets have been found.

Most of the available datasets (68 %) contain data on a country or European scale, as shown in Figure 8. National and European scale are shown in the same category, as they usually exist on similar resolutions, are not specific to a ClimEmpower region and might not cover all ClimEmpower regions. Many European datasets for example do not cover Cyprus due to its geographic location. Only 10 % region specific data exist, for example a regional rainfall anomaly prognosis provided specifically for Sicily. Even if datasets are country-specific, they might not cover the region's individual needs, as for example OBZ and coastal Croatia are very distinct regions and therefore different climate parameters might be of interest. The distribution of datasets specific to the ClimEmpower regions and their respective nation can

be seen on the right panel. Although in many cases, country- or European-wide datasets are available, the individual information specifically tailored to the ClimEmpower regions is often not available and often contains the data either averaged over specified regions or as point data, which is important for localized information, while gridded data is useful when looking at regional differences, to understand areas especially affected.

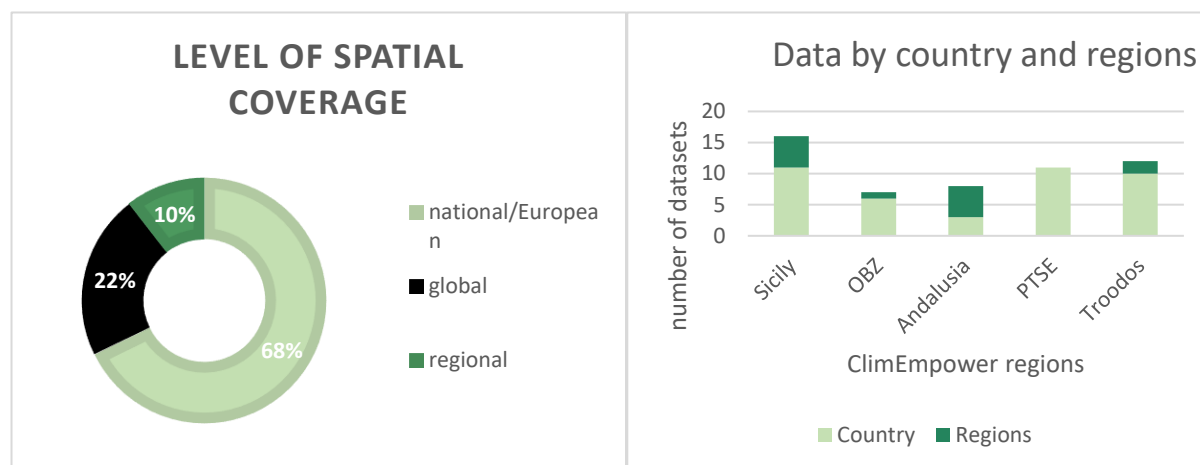


Figure 8: Spatial coverage of available data; own presentation based on the found datasets (full list in 2.4.2)

Those non-gridded datasets are available on regional, national, European or even global scale (Figure 9).

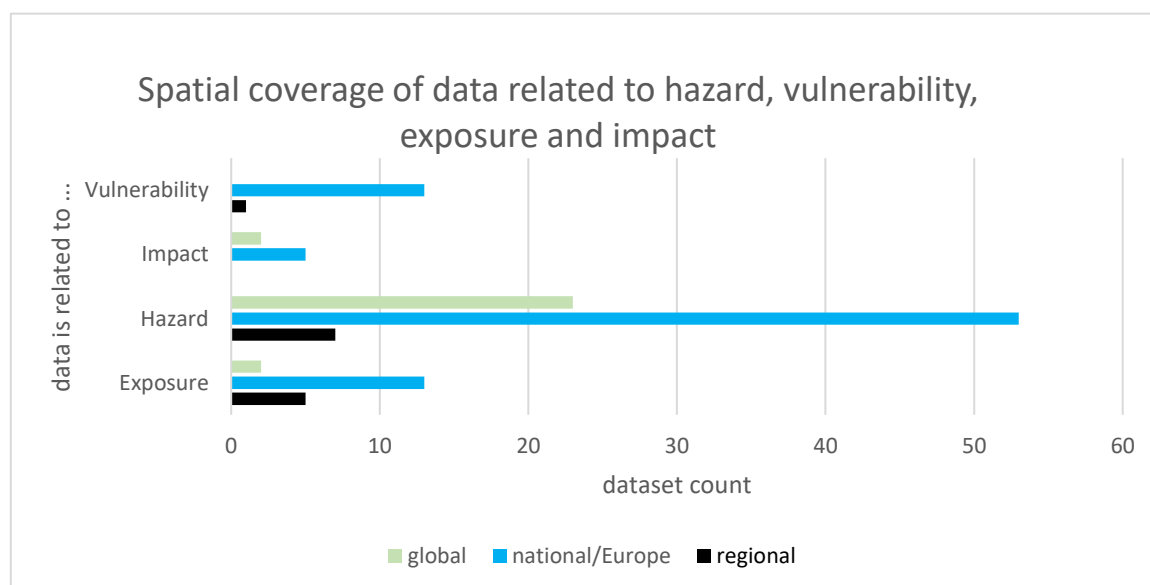


Figure 9: Spatial coverage of hazard, vulnerability, impact and exposure data; own presentation based on the found datasets (full list in 2.4.2)

Successful regional risk or impact assessment is dependent on the availability of data related to hazard, vulnerability, and exposure on a regional scale. Especially vulnerability related data can differ the most between regions. Figure 10 gives an overview on how the different data classifications are distributed. Hazard and exposure related data are more often provided on a regional level, vulnerability and especially impact related data is lacking on the regional scale,

also displaying the complexity to retrieve and compute these aspects. This applies to all ClimEmpower regions, as can be seen in Figure 10.

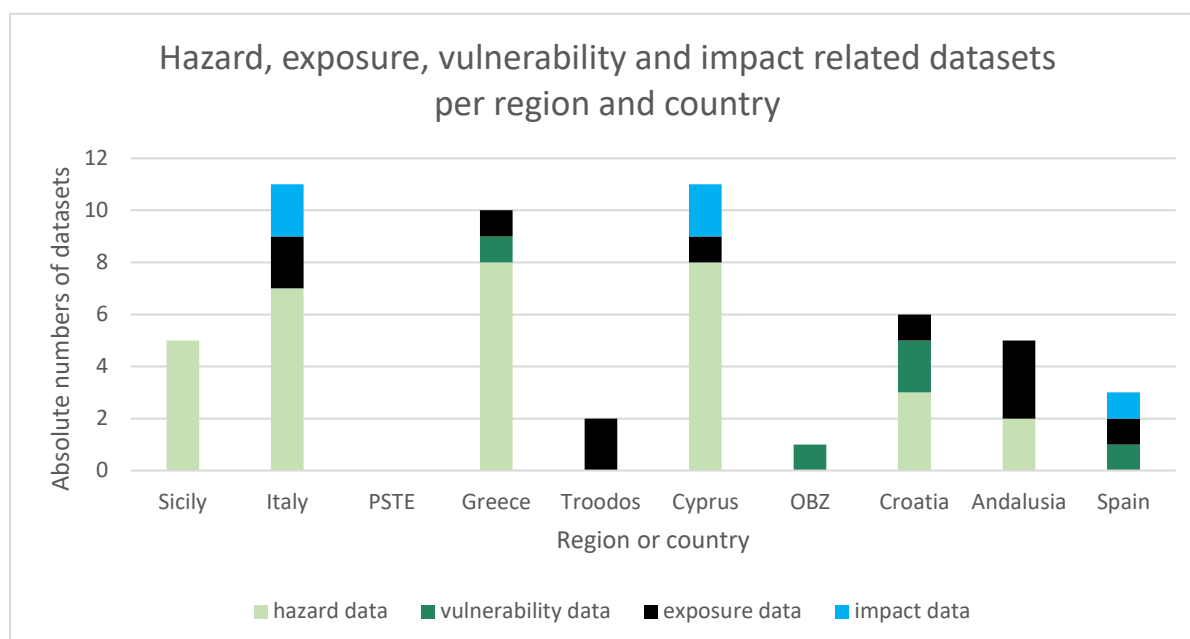


Figure 10: Hazard, exposure, vulnerability and impact related data per region and country; own presentation based on the found datasets (full list in 2.4.2)

4.2 Selected examples of available datasets

In this section, a few selected highlights of the analysed datasets are provided, while the full lists are available on Zenodo, the links are provided in Table 1.

4.2.1 Hazard data

Most available datasets, as seen in Figure 10, are mainly related to hazards and serve as hazard data themselves or as input for hazard models (e.g. using precipitation and river basin as input to compute the hazard flooding). A full and detailed description of all datasets is not feasible within this document thus an overview of a few highlighted datasets is given.

4.2.1.1 EURO-CORDEX

EURO-CORDEX is an initiative of the World Climate Research Programme and the European branch of the global CORDEX (Coordinated Regional Climate Downscaling Experiment) project, which aims to produce **regional climate change projections for Europe** using dynamical and empirical-statistical downscaling techniques. EURO-CORDEX provides a wide range of mean and extreme climate projections for various parameters such as temperature, precipitation, and wind, among others.

These projections are derived from multiple global climate models from the Coupled Model Intercomparison Project Phase 5 (CMIP5) and they extend to the year 2100, covering various emission scenarios. At date of this deliverable, the complete set of downscaled climate data from EURO-CORDEX based on CMIP6 (which corresponds to the IPCC 6th Assessment Report) has not been fully published.

EURO-CORDEX is available on 12 km (0.11 degrees) resolution for Europe, which allows for detailed analysis of regional climate patterns and their impacts across Europe.

4.2.1.2 CDS: Bioclimatic indicators from climate projections

The “Downscaled bioclimatic indicators for selected regions from 1950 to 2100 derived from climate projections” is one of many hazard-related climate datasets that are available from the **Copernicus Climate Data Store (CDS)**. It contains variables that can be used to assess how climate impacts on ecosystems. It has European wide coverage and a spatial resolution of 1 km². It contains monthly or annual data from 1950 up to 2100, derived from climate projections (CMIP5). It covers 76 indicators and bioclimatic variables for the land environment, characterising surface energy, drought, soil moisture and (near-) surface climate parameters including wind. This dataset contains variables of interest for risk assessment, including:

- Precipitation and temperature information (annual mean precipitation is shown in Figure 11),
- Dry days and frost days,
- Max. length and intensity of dry spells.

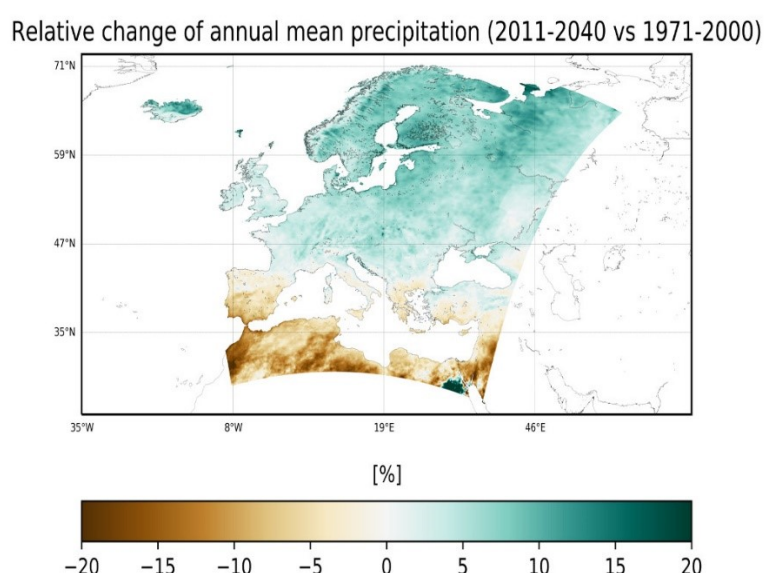


Figure 11: Copernicus dataset 'Downscaled bioclimatic indicators', depicted is the relative change of annual mean precipitation over Europe; Source: (CDS, 2021)

4.2.1.3 Agro-topoclimatic Atlas of Sicily

This atlas, viewable online and available as a GIS web service, allows for a highly **detailed climatic characterization of the entire Sicilian territory**. Created by the Regional Department of Agriculture, it focuses heavily on providing agricultural data but also offers valuable information for analysing hazards such as global solar radiation and precipitation. These data are divided by month and are based on historical series. In Figure 12 solar radiation (a parameter that can be used to assess heat stress) in June in Palermo, Sicily, is displayed.

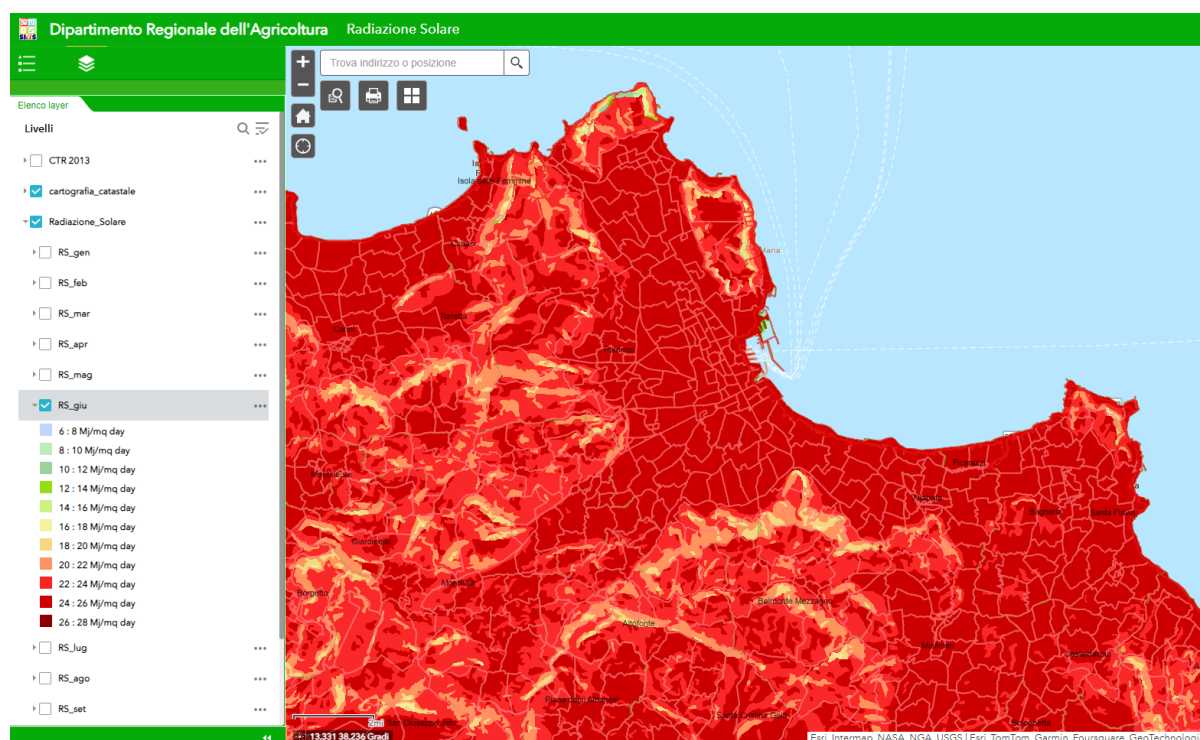


Figure 12: Average solar radiation in June over Palermo, based on historical climate data; Source: (Ambra, 2014)

4.2.1.4 HydroBASINS from HydroSHEDS

The HydroSHEDS database provides a comprehensive suite of global **digital data layers to support hydro-ecological research and applications**. Among its various products, the HydroBASINS dataset stands out as a series of vectorised polygon layers representing sub-basin boundaries at a global scale. HydroBASINS provides seamless global coverage of consistently sized and hierarchically nested sub-basins, which are essential for analysing catchment topology, including upstream and downstream connectivity.

It has to be stated, that the HydroBASINS dataset does not represent hazard data per se. However, this dataset is particularly useful for hydrological modelling and therefore, an important source for modelling hazard of flooding in combination with climate data.

Below is a sample image (Figure 13) of the HydroBASINS dataset showing Sicily divided into all its sub-basins, with the sub-basins of each main basin coloured in the same colour, and the HydroRIVERS layer on top showing rivers as lines.

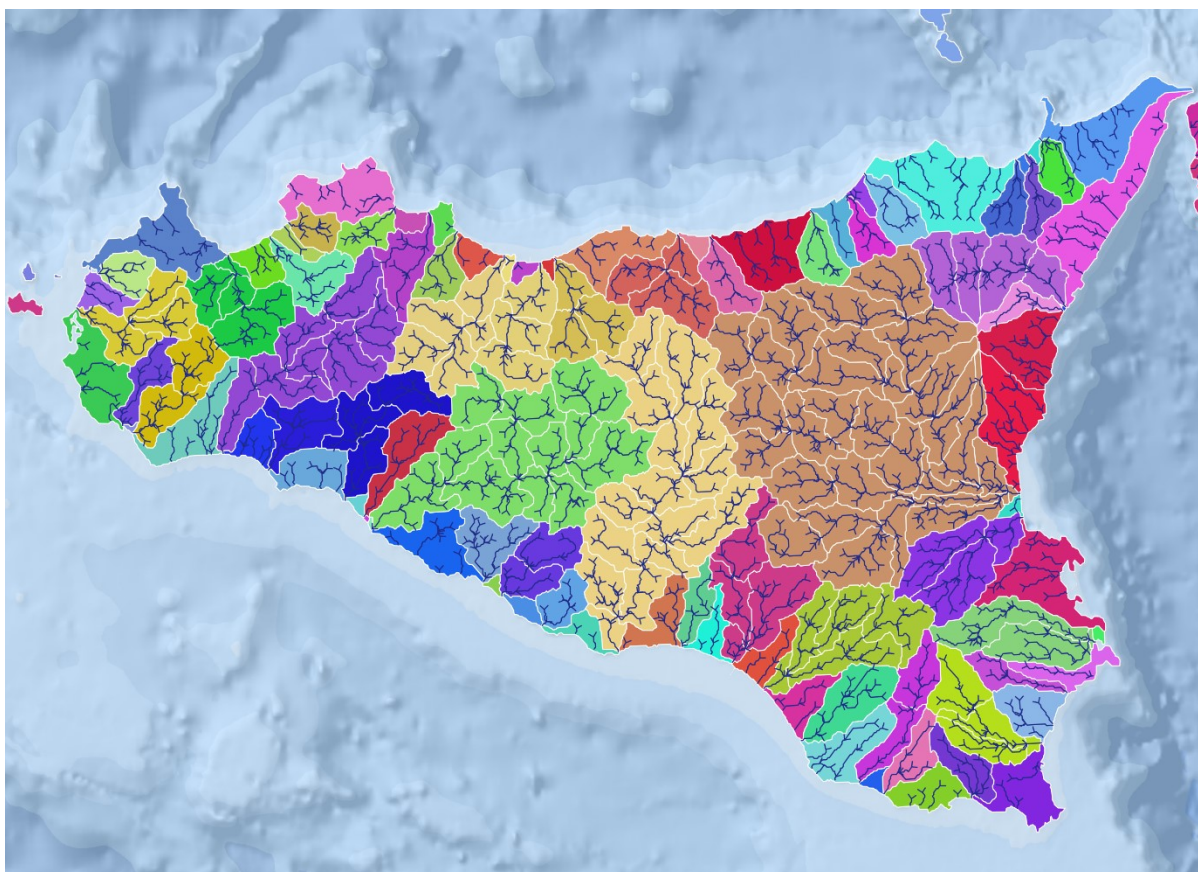


Figure 13: Hydrological basins; Source: (HydroSHEDS, 2014)

4.2.2 Exposure data

4.2.2.1 OSM critical infrastructure

OpenStreetMap is a **free, editable map of the whole world** made by volunteers. Within their framework, special datasets can be downloaded as shapefiles.

Note: *OSM data has to be used with caution, as it cannot be guaranteed to be correct or complete.*

The "[OSM open infrastructure map](#)" offers **geospatial information on critical infrastructure** such as power lines, power generators or switches, any other type of power plants, oil and gas infrastructure, pipelines and many more. Each element contains information additional to its exact location:

- Name of operator,
- energy source and output (if applicable),
- indicator if element is under construction,
- date of first operational service,
- a link to a related Wikipedia article, if available.

The downloadable data is identical with the displayed OpenStreetMap data in map format, shown in Figure 14. All available layers and information captured within OSM is displayed.

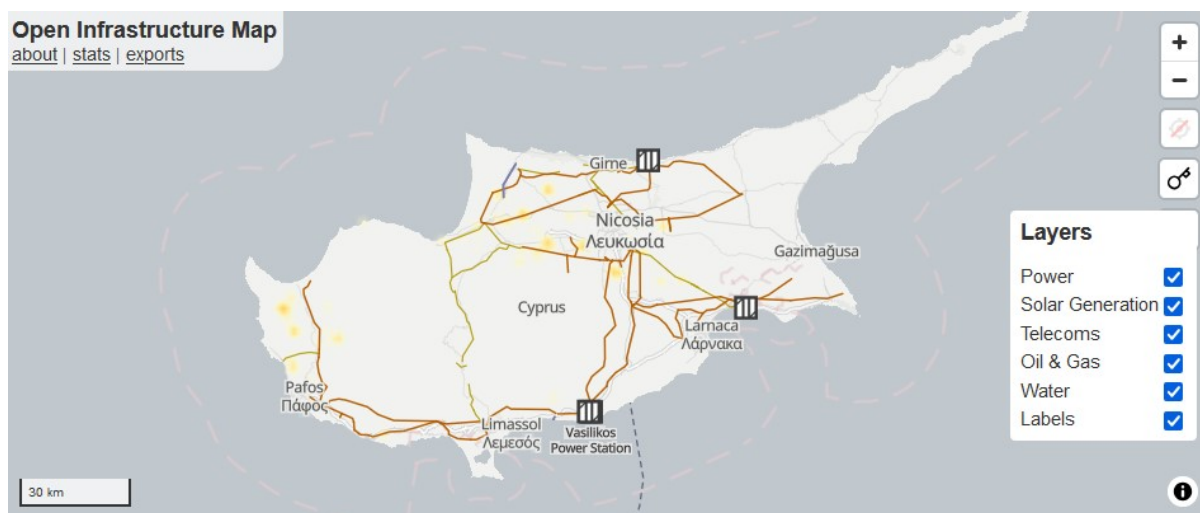


Figure 14: OSM critical infrastructure dataset, zoomed to Cyprus; Source: (OSM, n.d.)

4.2.2.2 REDIAM Golf course placement in Andalusia

This dataset is provided by REDIAM (Red de Información Ambiental de Andalucía) by the Andalusian region. It is an **example of a regional exposure related dataset, that is specific to the Andalusian region** and might not be applicable to any other ClimEmpower region.

It was created 2007 and offers **information about Golf courses**, consisting of their size and placement as well as general technical characteristics, climatic, and water data. The data is provided as an ESRI shapefile containing specific geospatial information and is only available at the respective exposed location of the asset, which are golf courses in this case. The shapes can be opened and displayed with GIS-software tools, as seen in Figure 15.



Figure 15: REDIAM Golf course placement in Andalusia, example of one golf course (green shape); Source: (Rediam, 2007)

4.2.2.3 SNCZI (Spanish National Cartography System of Flood-Prone Areas)

The SNCZI ("Sistema Nacional de Cartografía de Zonas Inundables" - National Cartography System of Flood-Prone Areas) is a web service that primarily identifies and maps **areas at risk of flooding across Spain**, creating flood extent and coastal and fluvial flood hazard maps for different return periods. It considers historical flood data, topography, and hydrology, and uses various models and studies depending on the area to calculate flood risks.

In addition, it also provides GIS layers that consider the **possible impact on different assets** (such as ports, railways, wastewater treatment plants, buildings, roadways, etc). that have historically been damaged due to coastal or fluvial inundations or have probability to be damaged in future events.

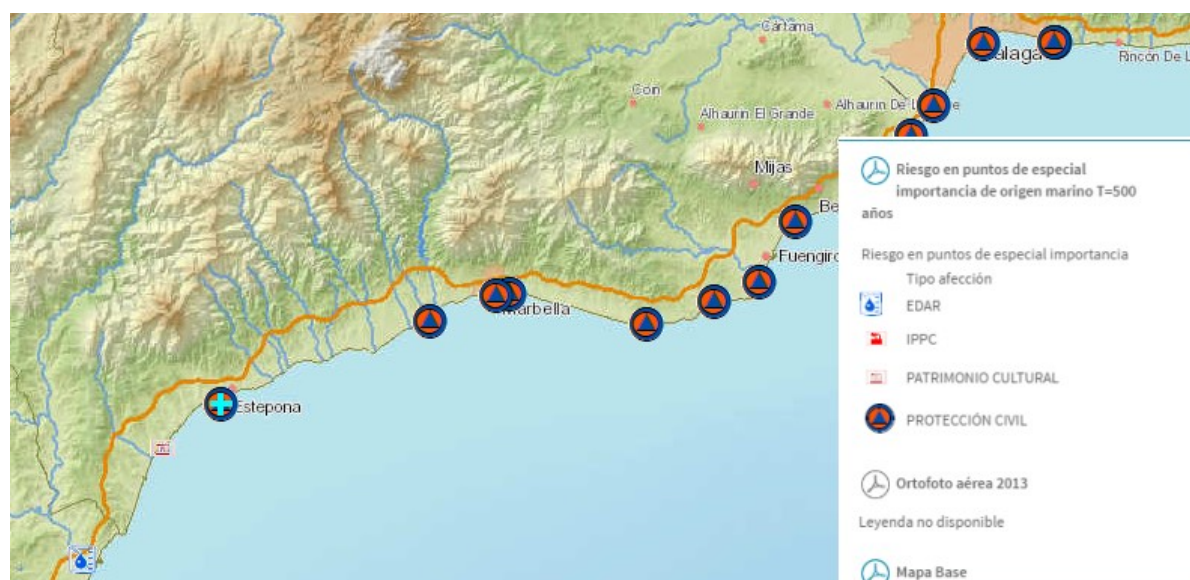


Figure 16: Marine flood risk maps for points of special importance. Scenario T=500. Each point represents cultural heritage, wastewater treatment plants and other assets. By clicking in each point, more information about the asset is displayed. Source: (SNCZI, n.d.)

4.2.2.4 Crowdsourced georeferenced social media data

Crowdsourced georeferenced social media data, such as X, former Twitter, posts, offers valuable location-specific insights. A key tool for collecting these data is the crawler module, which gathers relevant posts on hazards like heatwaves, floods, and fires via Twitter's API. Before development, it's crucial to define keywords, phrases, and Twitter accounts to filter the data in collaboration with pilot leaders whose local language expertise ensures accurate search criteria. The crawler monitors Twitter in near-real-time, filtering posts and querying recent tweet counts for event detection. Outlier detection identifies significant spikes in activity, prompting post retrieval every 30 minutes from the past seven days. As fewer than 1% of tweets include geotags, ClimEmpower employs a deep learning algorithm to geotag posts by detecting location-related words and querying the OpenStreetMap API for coordinates. Once geolocated, the system processes the data to extract meaningful insights tailored to user needs. Also, as crowdsourced data collected from diverse groups of people, captures the range of interactions and hazards that individuals are exposed to.

Additional details on the dataset and the methodology used to create it will be provided in D2.3.

4.2.3 Vulnerability data

4.2.3.1 EUROSTAT Population on 1st January by age, sex and type of projection

EUROSTAT is the statistical office of the European Union offering mainly Europe-wide, socio-economic datasets in various sectors and resolutions. From the numerous datasets offered on the website, 10 were listed as interesting for ClimEmpower and added to the ClimEmpower: Datasets and Services for Climate Resilience Assessment (see section 2.4.2).

The dataset 'Population on 1st January by age, sex and type of projection', as seen in Figure 17, offers **population statistics (age and sex) from 2022 up to 2100 in 5-year steps**, always counted on January 1. The spatial coverage level for EUROPOP2023 data set is **national** and not divided into further census regions, but EUROPOP2019 data set also provides projections at **NUTS3** (Nomenclature of territorial units for statistics) level, which translates to small regions.

If no national statistics agency (for example CYPSTAT, ISTAT, INE, ...) offers higher resolved data, EUROSTAT is a well-sorted, user-friendly data source that can help filling regional data gaps, especially regarding future projections.

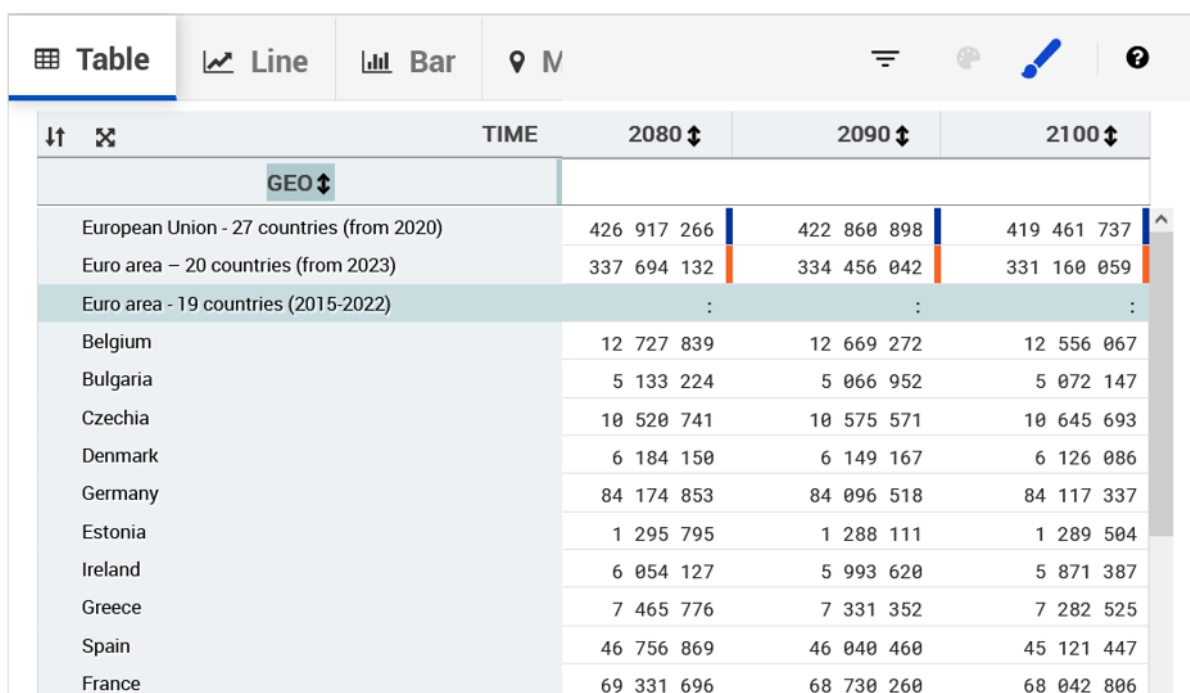


Table	Line	Bar	Map	TIME	2080	2090	2100
				↓	↓	↓	↓
GEO							
European Union - 27 countries (from 2020)				426 917 266	422 860 898	419 461 737	
Euro area – 20 countries (from 2023)				337 694 132	334 456 042	331 160 059	
Euro area - 19 countries (2015-2022)				:	:	:	
Belgium				12 727 839	12 669 272	12 556 067	
Bulgaria				5 133 224	5 066 952	5 072 147	
Czechia				10 520 741	10 575 571	10 645 693	
Denmark				6 184 150	6 149 167	6 126 086	
Germany				84 174 853	84 096 518	84 117 337	
Estonia				1 295 795	1 288 111	1 289 504	
Ireland				6 054 127	5 993 620	5 871 387	
Greece				7 465 776	7 331 352	7 282 525	
Spain				46 756 869	46 040 460	45 121 447	
France				69 331 696	68 730 260	68 042 806	

Figure 17: EUROSTAT Population on 1st January by age, sex, and type of projection; Source: (EUROSTAT, 2023)

4.2.3.2 ISTAT Socio economic indicators by census section

ISTAT census sections are the smallest territorial units used by the Italian National Statistics Institute (ISTAT) to conduct population and housing censuses. These sections provide a granular level of data that is crucial for **detailed demographic and socio-economic analysis**. Each census section typically covers a few city blocks or a small rural area, allowing precise data collection and analysis at a very localised level.

A wide range of socio-economic indicators can be derived or calculated from these census sections. These include **demographic indicators such as population density, age distribution and household composition**, important to assess the peoples' vulnerability for

instance towards heat. **Economic indicators such as employment rates, income levels and educational attainment** can also be extracted. In addition, **social indicators such as housing conditions, access to services and migration patterns** can be analysed. These indicators are particularly useful for urban planning, policymaking, and resource allocation, as they provide insight into the socio-economic conditions of specific areas, enabling targeted measures and informed decision-making.

In Figure 18, an example of a composite indicator of socio-economic vulnerability, elaborated by PLINIVS, applied to Sicily using ISTAT data for 2021 is provided.

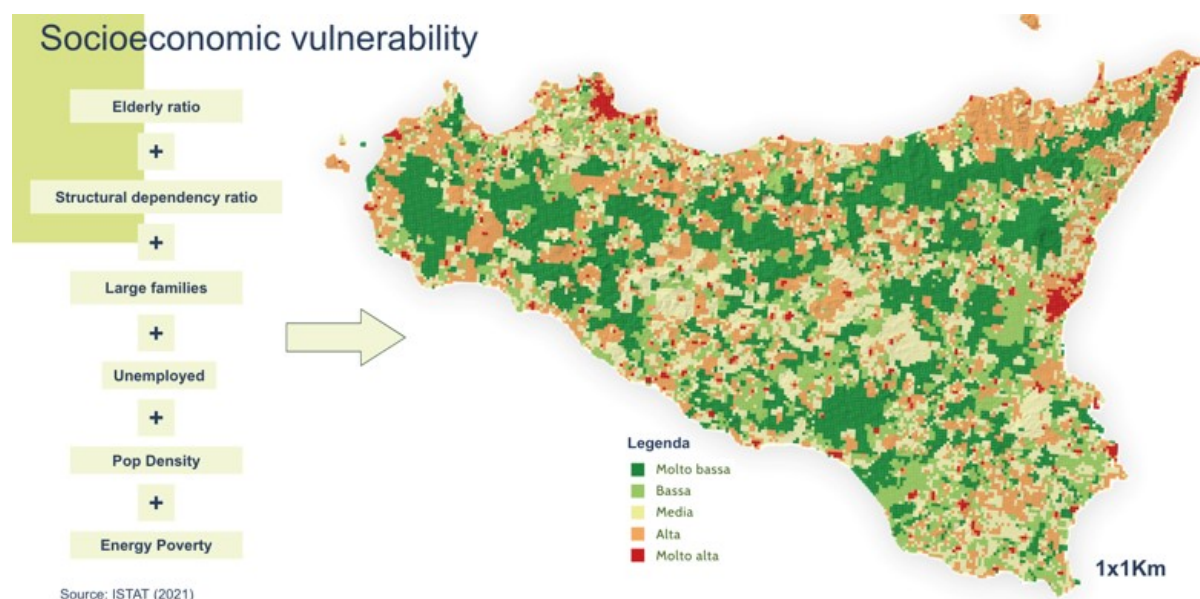


Figure 18: Socio-economic vulnerability map for Sicily, Source: PINIVS based on ISTAT 2021

4.2.4 Impact data

4.2.4.1 EM-DAT: Disaster Database

Hosted by The Centre for Research on the Epidemiology of Disasters (CRED), the International Disaster Database EM-DAT is an open access data portal. It contains data on the **occurrence and impacts of over 26,000 mass disasters worldwide from 1900 to the present day**. The database is compiled from various sources, including UN agencies, non-governmental organizations, reinsurance companies, research institutes, and press agencies.

The dataset related to **economic impact variables** of historic disasters, includes, among others:

- Reconstruction Costs,
- Insured Damage,
- Total Damage.

The data is provided as CSV files and contains a country code as well as some information (magnitude and type) of the disaster if applicable, as seen in Figure 19. In addition, the database also provides information on **human impacts** (deaths, injuries).

	Dis No	Year	Seq	Disaster Group	Disaster Subgroup	Disaster Type	Disaster Subtype	Disaster Subsubtype	Event Name	Entry Criteria	...	End Day	Total Deaths	No Injured
0	1900-9002-CPV	1900	9002	Natural	Climatological	Drought	Drought	NaN	NaN	NaN	...	NaN	11000.0	NaN
1	1900-9001-IND	1900	9001	Natural	Climatological	Drought	Drought	NaN	NaN	NaN	...	NaN	1250000.0	NaN
2	1902-0012-GTM	1902	12	Natural	Geophysical	Earthquake	Ground movement	NaN	NaN	Kill	...	18.0	2000.0	NaN
3	1902-0003-GTM	1902	3	Natural	Geophysical	Volcanic activity	Ash fall	NaN	Santa Maria	Kill	...	8.0	1000.0	NaN
4	1902-0010-GTM	1902	10	Natural	Geophysical	Volcanic activity	Ash fall	NaN	Santa Maria	Kill	...	24.0	6000.0	NaN

Figure 19: Overview of data contained in EM-DAT Source: (EM-DAT, n.d.)

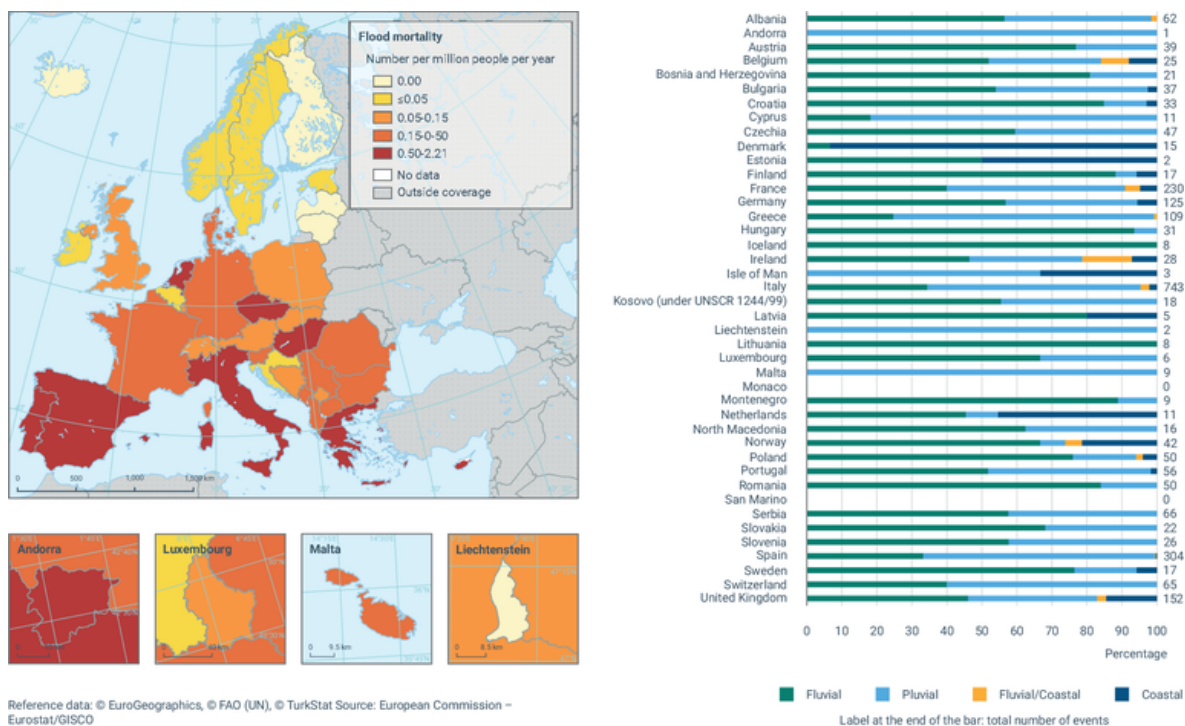
4.2.4.2 HANZE database of historical damaging floods in Europe

The HANZE (short for Historical Analysis of Natural Hazards in Europe 1870-2016) dataset was created by the [Faculty of Civil Engineering and Geosciences Department of Hydraulic Engineering TU Delft](#) and is openly available on their database platform.

Next to other relevant datasets, it provides a **compilation of past damaging floods in Europe**, which contains information on dates, locations, and losses for 1564 events (1870–2016) called „HANZE database of historical damaging floods in Europe, 1870-2016. “It includes, among others,

- Flood events (date, location, intensity, area flooded)
- Flood mortality by country (as seen in Figure 20)
- Economic losses due to flooding (if available)

Demographic and economic data encompassed in HANZE allow to ‘normalize’ information on losses for **price inflation as well as changes in population, production and wealth**.



4.3 Climate Services

4.3.1 Definition of Climate Services

Climate services provide climate information tailored to the needs of the user. They aim at enabling informed decision-making and increasing resilience and adaptation capacity. They address existing or emerging risks and provide climate relevant information to enhance the capabilities of a timely adaptation and of seizing the opportunities of the transition to a low-carbon economy (European Commission, 2015).

“Climate services cover the transformation of climate-related data — together with other relevant information — into customised products such as projections, forecasts, information, trends, economic analysis, assessments (including technology assessment), counselling on best practices, development and evaluation of solutions and any other service in relation to climate that may be of use for the society at large. As such, these services include data, information and knowledge that support adaptation, mitigation and disaster risk management (DRM)” (European Commission, 2015).

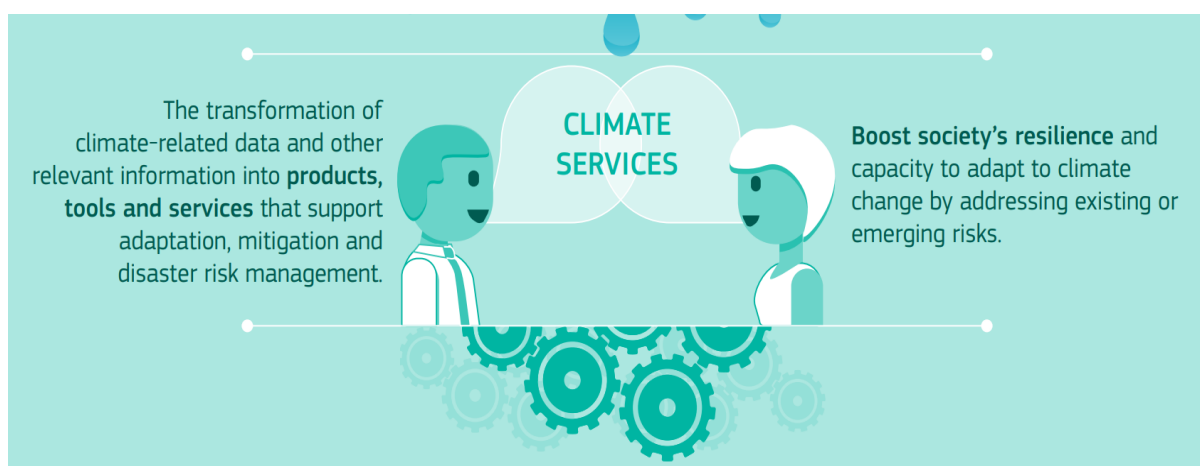


Figure 21: Climate Services translating climate data and information into successful adaptation and mitigation actions. Source: ClimateService-infographic-2May16-web (europa.eu)

The user plays a pivotal role in determining the success of a service. A climate service holds value and utility only when it is effectively applied by the user, provides them with tangible or added value, and ultimately leads to positive changes in their actions (Villwock, 2023). The objective of Task 2.1 was to compile a comprehensive overview of existing and useful European and region-specific datasets and services. To this end, the project team engaged regional stakeholders with the following inquiries:

- **What climate services are currently utilized in your region?**
- **What are the strengths and weaknesses of these services?**
- **How does your region benefit from these services?**
- **What gaps or needs remain?**

Given the broad scope of climate services, this approach with very generic questions did not yield the expected results. Thus, a more targeted approach with specific questions was necessary to obtain a thorough understanding of both the services already in use and the gaps

that remain. As a result, we conducted a literature review to identify the success factors of climate services, analyse existing typologies, and develop a structured framework for a survey and bilateral meetings with regional stakeholders.

4.3.2 Climate services – what makes them successful?

Climate services can be a combination of tools, data, consulting services, and products designed to provide climate-related information that supports decision-making and planning, especially in the context of adapting to climate change. These services aim to improve understanding of climate impacts, enhance capacity to respond and support better decision-making for adaptation to long-term climate challenges. They are developed through a collaborative process between users and producers. The success of a climate service can be measured by its ability to deliver timely, relevant, and credible information (Boon E. J., 2024). A complete definition of a successful climate service by (Boon E. J., 2024) is given as follows:

“A successful climate service for adaptation is relevant, credible, and accessible to users, acknowledges uncertainty, is communicated through a user-specific format, and is timely for user needs. It is developed by users and producers through tailored interaction, while building trust, and increasing users’ capacity for using the service and understanding the issue at hand. The service delivers benefits to the user and supports better decision-making for adaptation.”

For a climate service to be successful, its production needs to be efficient and well-designed. The socio-political context and availability of resources also play a crucial role, as tailored approaches may be required depending on the specific circumstances. Based on two studies by (Boon E. J., 2024), (Boon E. W., 2022), we identified the factors that are especially relevant for defining successful climate services. Climate services must provide information that is directly applicable to users' needs, ensuring that the data is relevant for decision-making, and addressing specific challenges. The information provided must be scientifically sound and trusted. This includes delivering high-quality data that users perceive as reliable, accurate, trustworthy. Successful climate services ensure that it's easy to access, interpret, and use given information. This includes delivering data in a user-friendly format and in a timely manner, making it actionable for planning and adaptation. The information should be delivered in a format that suits the specific context. Whether tangible or intangible, successful climate services must provide clear benefits to users, such as improved safety, better preparedness, or increased understanding of climate-related issues. Also, building a strong relationship of trust between users and producers of climate services is essential. This often involves co-production processes where both parties collaborate closely to ensure that the service is tailored to the specific context. The climate services should also help not only access the information but also develop the capacity to understand and apply gathered information. Next to improving users' knowledge it is also important to communicate well the inherent uncertainties in climate data and the limitations of the predictions, so the user can make informed decisions. Moreover, it is good practice if climate service presents complex information in a simplified manner, using stakeholders' language, with high level of interactivity and visualisations which attract attention to impacts. Finally, the successful climate service may deliver a diverse perspective which includes non-scientific local knowledge.

The above elements justify a complexity of the nature of climate services and how they can be used. Next to these factors, it is important that the needs of the targeted user are identified and addressed before developing a climate service, making the service more contextualised

where appropriate. The climate services shouldn't be a black box, where misunderstandings and misuse occur. Instead, they should lead to actual action and change, to be able to support better decisions and to sustain investments in climate services.

4.3.3 Services typologies

A typology of climate services is proposed to align supply with demand, helping providers, users, and policymakers better understand and articulate the types of services needed. It helps categorise climate services based on how tailored they are to individual users and how they are combined with other non-climate services. As proposed by (Visscher, 2020), based on how climate services are offered to the market, they can be **organized along two dimensions: customization and integration**.

First differentiates is between **services that are tailored to the specific needs of individual customers versus those that are designed as general offerings for a broad audience**. The generic services are standardised offerings designed for a broad audience. They are not tailored to individual needs but are widely applicable, aiming to meet common requirements across many users. On the other side there are customised services which are tailored to the specific needs and preferences of individual users or specific groups. These services are designed to address particular challenges or demands.

Second dimension differentiates between **services offered as distinct “climate services” versus those integrated into broader packages**. Former concentrate solely on climate-related information and they provide specific data or insights without combining them with other types of services. Later combine climate data with other relevant information, creating comprehensive packages that address a broader set of needs, such as policymaking, management, or strategic decision-making.

These dimensions help define different service types in the market, from publicly available tools for general use to complex, customized services integrated into broader decision-making processes. Additionally, (Visscher, 2020) categorised climate services into different types, each offering unique approaches and benefits. These are: Maps & Apps, Expert Analysis, Climate-inclusive Consulting, and Sharing Practices. This categorisation is also presented on the Figure 22.

4.3.3.1 Maps & Apps

These are user-friendly tools that provide general, easily accessible climate data and projections, often presented in familiar formats like maps or applications. They provide broad, accessible information to a wide audience and are usually free or low-cost.

Conditions for Implementation:

- Users must be knowledgeable about interpreting the data.
- There must be a unified data infrastructure to ensure consistent information access.

4.3.3.2 Expert Analysis

These services offer in-depth, tailored insights. They are provided by commercial climate experts who customize their advice based on specific user needs. This type of service can better address complex climatological and geographical conditions, but at a higher cost.

Conditions for Implementation:

- Users must recognize the relevance of climate issues to their decision-making.
- Professionalization of climate experts is essential.

4.3.3.3 Climate-inclusive Consulting

These services integrate climate data into a broader package of consulting services that may include management, engineering, or policy advice. The focus is on helping decision-makers consider climate impacts as part of a larger, more complex decision-making process, where climate issues are intertwined with other risks and opportunities.

Conditions for Implementation:

- Successful integration of climate and non-climate services.
- Consulting firms must develop sufficient climate expertise.

4.3.3.4 Sharing Practices

These services are focused on collaboration and sharing of climate-related knowledge and best practices among groups, such as scientific communities or industry networks. They encourage collective learning and shared solutions.

Conditions for Implementation:

- Requires knowledgeable "prosumers" (users who also provide services).
- The creation of platforms for effective knowledge exchange and collaboration.

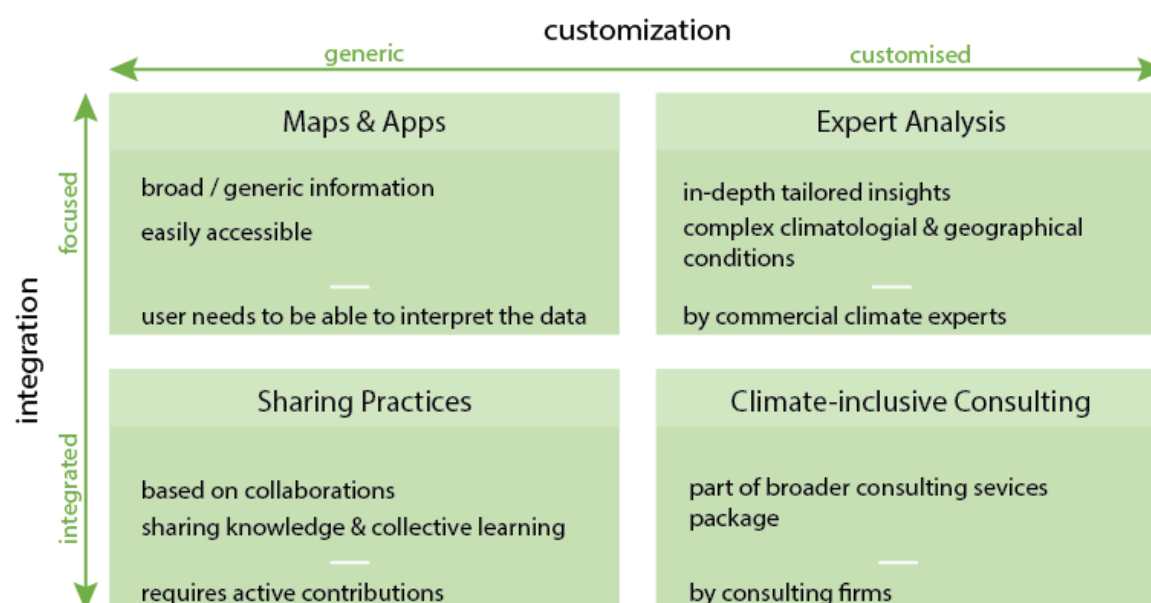


Figure 22: A typology framework of Climate Services, with specifications.

Different types of climate services come with distinct user preferences and challenges. The significant advantage of Maps and Apps is that they are inexpensive or even free, with simple, easy to access, intuitive interface. However, users working with complex scenarios may find these services lacking in specificity or geographical detail. Also, those unfamiliar with climate data may struggle to interpret and apply the information correctly. Small service providers may find it hard to maintain these platforms without consistent public funding or some form of revenue generation.

Expert Analysis are meant for users needing tailored, in-depth advice on specific, complex climatological conditions, where ability to provide precise, localized projections and advice is needed. However, they tend to be expensive, making them less accessible to smaller business and municipalities.

Climate-inclusive Consulting is beneficial for those users who have limited or no prior expertise in climate science, looking for climate advice within broader decision-making and strategic planning processes. Integrating climate services into broader consulting packages may result in high costs, with risk that the provider may struggle to provide sufficient climate knowledge along with other expertise.

Sharing Practices are well-known in scientific communities, supporting collaborations and knowledge exchange. However, the competitive dynamics could limit the exchange, and it requires active participation and engagement from different contributors.

In summary, user preferences lean towards more tailored and integrated services in complex decision-making situations, but costs, the need for expertise, and competitive factors often pose significant challenges. Depending on the needs, users may choose different types of the service. Also, based on our analysis of available climate services (4.3.4), some climate services may be classified by more than one type.

4.3.4 Available and highlighted services

Based on the approach described above, 55 climate services in total have been found that cover at least one of ClimEmpower's regions. Most of them, as shown in **Fehler! Verweisquelle konnte nicht gefunden werden.**, are globally available and not specific to a certain region. 22 % of the procured services are continent-specific and cover whole or most of Europe and 18 % are tailored to a country or, in a few cases, to a region. The difference between the ClimEmpower regions is vast: while regional services for Andalusia and Sicily exist, PSTE is only covered by two national services and for OBZ (Croatia) and Troodos Mountain Range (Cyprus) only European or global services are available.

The available collected services have been classified according to the typology introduced in 4.3.3. As services can combine several aspects of different typologies, some services were attributed to more than one type. The results of this mapping are shown in Figure 24.

Most services fall into the category "Maps & Apps", as they mainly aim to visualize or provide already existing, general data and information. Sometimes they occur in combination with the type "Sharing Practices" – which offers case studies, adaptation examples, learning material or exchange in some way. All region or country specific services were classified as "Maps & Apps". No "Sharing Practices" tailored to a ClimEmpower region have been found.

"Expert Analysis" and "Climate Inclusive Consulting" are usually paid services, and the results are therefore not freely available, which is the case for the 10 services listed as "Climate Inclusive Consultation". The paywall does not allow for a thorough examination of their services, and the classification has only been based on the descriptions of the respective website. One service has been identified to contain historical risk maps with extensive regional detail, created by experts. Despite being freely accessible, it was classified as an Expert Analysis due to the high level of expertise involved.

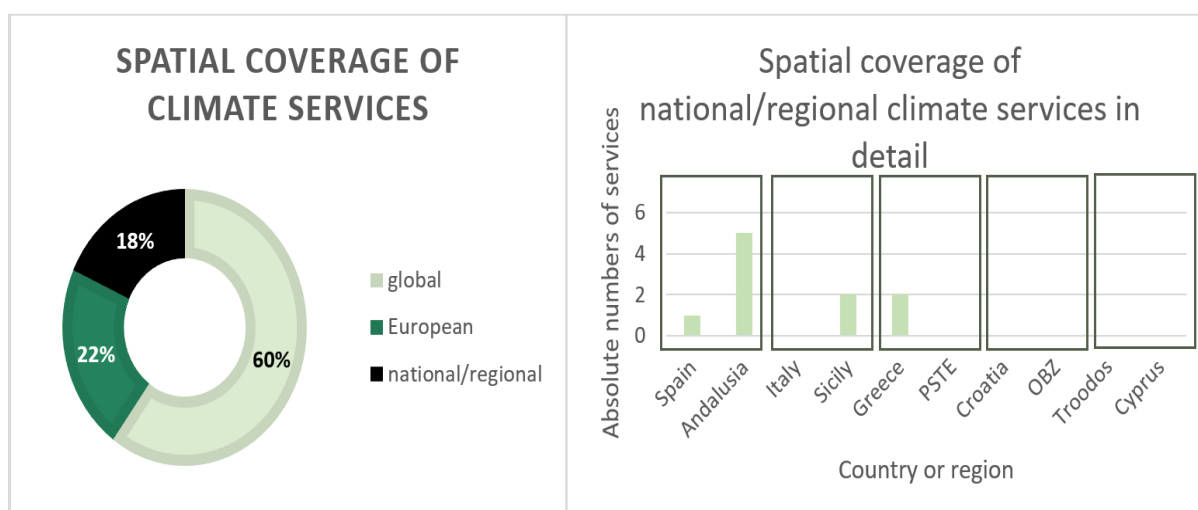


Figure 23: Spatial Coverage of Climate Services; own presentation based on the found climate services (in 2.4.2)

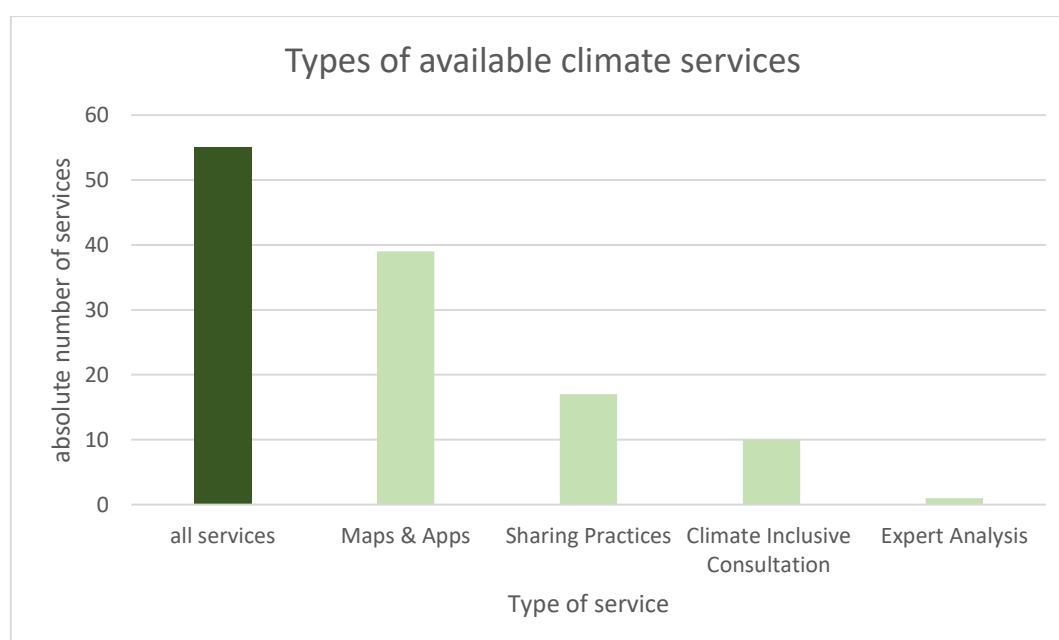


Figure 24: Types of available climate services; own presentation based on the found climate services (full list in 2.4.2)

Figure 25 depicts the identified target sectors and target groups of the various services. The attribution of a service to a certain target group has been decided based on the offered data granularity, the data format and the visualization and content of the service. A service can also address more than one target group, especially if it comprises various sub services.

Scientific datasets or composed indices were assumed to be too complicated for end users without prior knowledge and left to the target group of researchers and experts. Playful and eye-catching presentations, often based on qualitative data, were assumed to be created for the public or media and in certain cases also for policy makers and authorities. The target group “private businesses” was only attributed to services explicitly referring to it, as many climate services also state their intended target group on the landing page of their website or in the ‘about’-section.

To classify the target sectors, frequently mentioned sectors – often specified by the services themselves – were grouped into 8 main categories to provide an overview of the covered topics. Some services were not assigned to a specific target sector, while others were attributed to multiple fields based on the content available on their website.

Although “Tourism & Leisure” as well as “Infrastructure”, “Construction & Spatial Planning” are less comprehensively covered, they are just as relevant for ClimEmpower as the more extensively covered agricultural sector.



Figure 25: Target sectors and target groups of the available climate services; own presentation based on the found climate services (link to full list in 2.4.2)

4.3.4.1 Copernicus Climate Data Store (CDS)

One example of a maps and apps service is the Climate Data Store (CDS) from the Copernicus Climate Change climate service, which is targeted at researchers and experts.

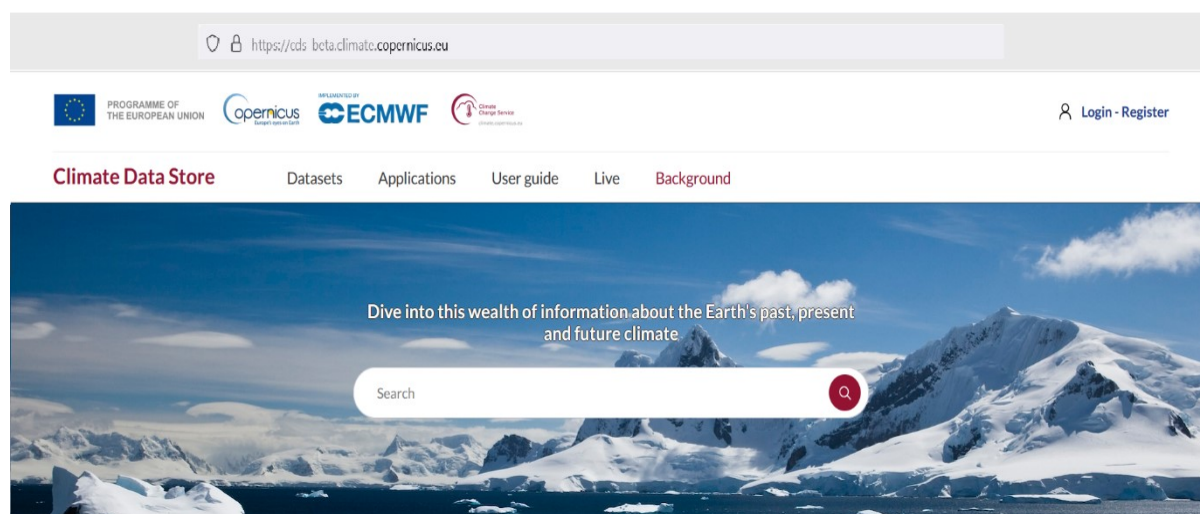


Figure 26: Screenshot from Copernicus Climate Data Store; Source: (Copernicus, 2024)

Hosted by **Copernicus**, the Earth observation component of the European Union's Space programme, the [Climate Data Store \(CDS\)](#) is an open source of climate information: past, present and future. It provides access to a wide range of climate datasets via a searchable catalogue, as is shown in Figure 26. It includes, among others:

- seasonal forecasts,
- climate projections,
- global and regional reanalysis data,
- in situ observations.

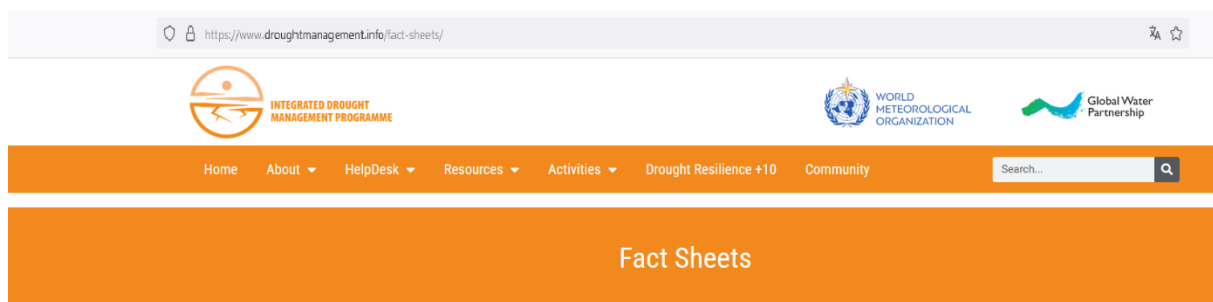
Most provided datasets are covering the Globe or Europe and can be downloaded in a gridded format (NETCDF, GRIB), however, there are also regional datasets for various purposes available. The spatial resolution ranges from around 1 m up to 55 km, depending on the dataset, and is usually higher for historical or reanalysis data.

Of the 128 available datasets containing various variables, 22 were handpicked to be relevant for ClimEmpower. The criteria were based on the spatial coverage of the ClimEmpower regions and the contained variables. Especially relevant are European-wide datasets covering future projections, as this information is scarcely available regionally and an example dataset is described at 4.2.1.2.

The C3S provides a great example for a Maps & Apps service, that is well structured and an extremely valuable source of datasets on all types and scales.

4.3.4.2 The Integrated Drought Management Programme by WMO

Hosted by The World Meteorological Organization (WMO), The Integrated Drought Management Programme offers a wide variability of services. However, its main focus is on the "Sharing Practices" type of service, offering various exchange platforms, training materials and fact sheets, as shown in Figure 27. The main target group of this service are policy and public decision makers.



Three pillars of Integrated Drought Management



Figure 27: The Integrated Drought Management Programme by WMO - Fact sheet screenshot; Source: (IDMP, n.d.)

The Integrated Drought Management Programme aims to bring together experts, countries, and practitioners to enhance drought resilience. Virtual or regional exchanges as well as a yearly conference to enhance drought resilience is hosted by the service.

A 'drought glossary' is also included to create a common understanding between scientific wording and practitioner's needs as well as a short description of the most important drought indices.

The Integrated Drought Management Programme is also focusing on support for policy makers and national drought management and offers guidelines as well as a handbook for end users, as seen in Figure 28.



Figure 28: The Integrated Drought Management Programme guideline for policy makers; (IDMP, n.d.)

4.3.4.3 EUROSTAT

EUROSTAT is the statistical office of the European Union offering mainly Europe-wide, socio-economic datasets in various sectors and resolutions.

From the numerous datasets offered on the website, 10 were listed as interesting for ClimEmpower and added to the lists in 2.4.2. and one dataset is further highlighted in section 4.2.3.1 (population projections). EUROSTAT therefore offers national and regional data that might be of use. Among others, the available datasets include:

- NUTS3 regions areas,
- various agricultural statistics at NUTS2 and NUTS3 level, such as “key farm variables”, “farmland use”, “farm livestock”, “farm labour force and management” – each with 4-5 sub-indices,
- regional demographic statistics (past data – but projections are also available – see below), and
- other, such as business, health, transport, water, energy, and poverty.

Data can be downloaded via the website itself and is also available on the JRC risk data hub: [DRMKC Risk Data Hub \(europe.eu\)](https://europe.eu/DRMKC-Risk-Data-Hub).

Figure 29 shows an example of NUTS 3 level “environmental dimension” indicators for Osijek-Baranja County.

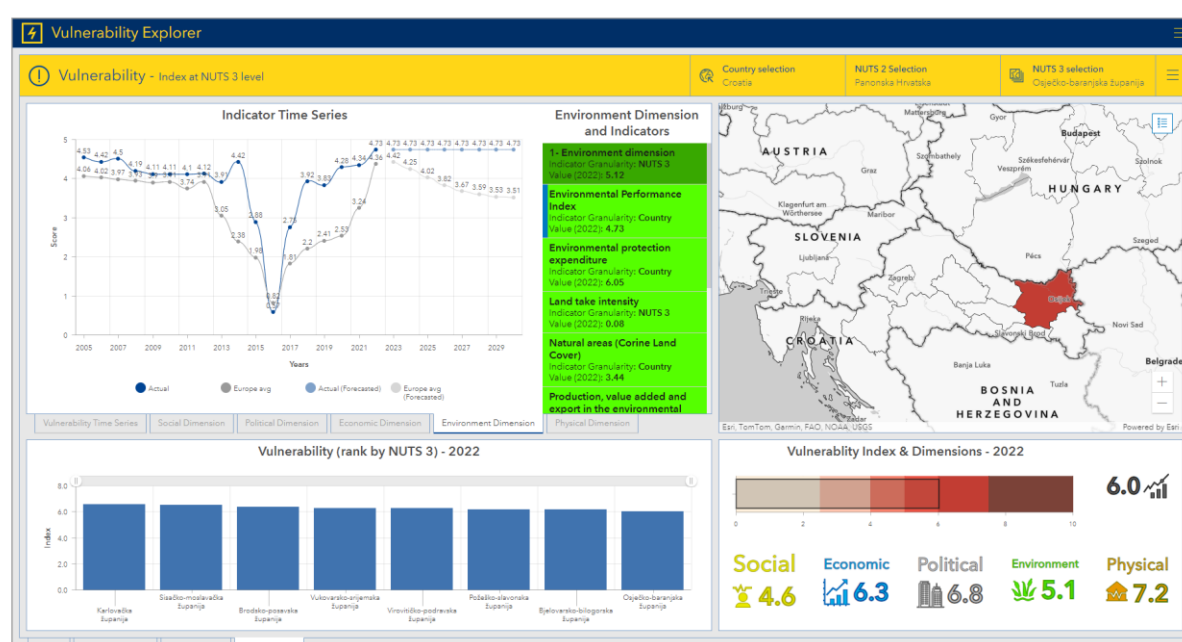


Figure 29: EUROSTAT’s ‘environmental dimension’ indicators provided via on the JRC risk data hub (Joint Research Center, 2024)

4.4 Gap analysis

To gain deeper insights into the climate data and services needed by the regions, including their intended purposes and applicable scales, bilateral online meetings were conducted with each region. These discussions helped clarify the regions' key concerns regarding climate change, whether they already have strategies, plans, data, and models in place, or if they are just beginning their transformation process. The meetings provided valuable input for the gap analysis but served only as a starting point for further discussions during upcoming COPs.

4.4.1 Croatia

The Croatian region involved in the project is a county situated in northeastern Slavonia and Baranja, within the Pannonian Plain. Its central city is Osijek, located in Baranja County. The region is predominantly characterized by agriculture and tourism, with key climate-related concerns including droughts, heatwaves, and floods. To address these challenges, the region requires support in multiple fields, especially for strategic planning in natural and agricultural areas:

- Model-based, generic maps focusing on droughts, heatwaves, and floods.
- Trainings and education material for end user sharing practices and providing a basic knowledge transfer regarding climate change risks, adaptation options and strategies.
- Customized services tailored to the regional needs:
 - expert analysis focused on historic climate data and impact analysis for agricultural and protected areas,
 - climate-inclusive consulting for supporting decision making and planning for a timely transition to a climate-resilient future.

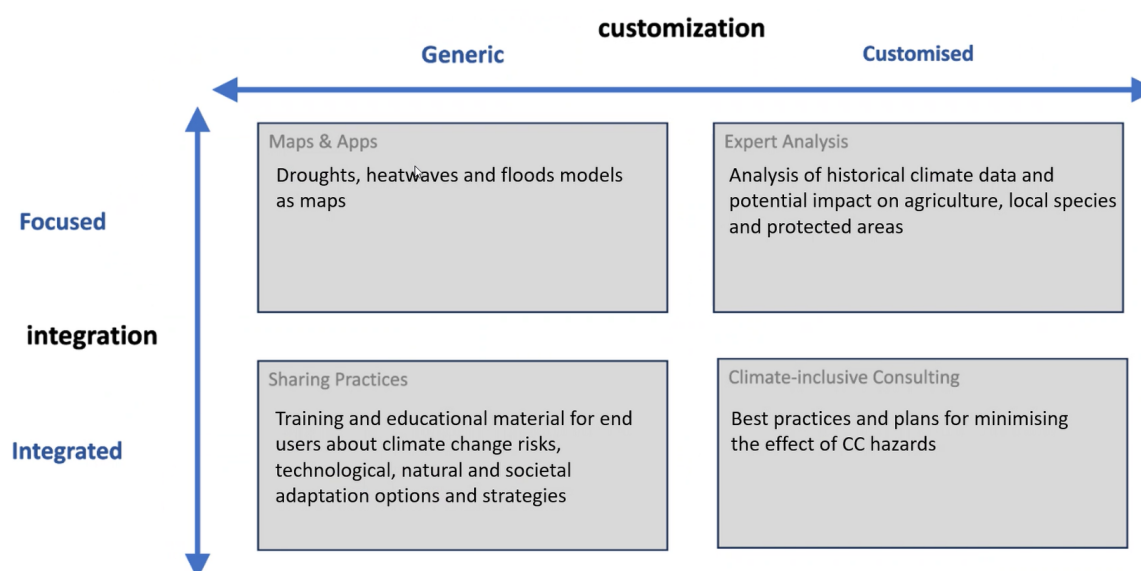


Figure 30: Services needed by the Croatian region; own presentation. Source: Survey

Available datasets/services and their limitations:

- CEMS offers a multi-hazard web app for droughts, floods and wildfires on European level, while DMCSEE provides maps and prevention measures more focused on

Southeastern Europe - including Croatia. WMO's Integrated Drought Management Programme as well as MeteoAlarm also offer hazard monitoring, however there is no service tailored to the specific needs of Osijek, Baranja County, such as a monitoring service specifically designed for farmers. A tool like AgriAdapt (<https://awa.agriadapt.eu/>) is very helpful as it addresses the specific adaptation needs of farmers. However, currently it does not include the area of Croatia.

- The Croatian government provides a flood risk assessment of the Danube and Drava, but assessments for other risks are missing. There are global/Europe-focused climate services such as The Climate Risk Dashboard to help assess risks in general, but the regional focus on Osijek is missing, e.g. it does not address key questions such as: How will drought and temperature evolve in the future? How will these changes impact my crops? And what crops will be viable in the future? Such services are mostly provided by consultants and paid services like e.g. Stantec's Climate Change Risk Assessment.
- EUROSTAT offers a dataset of economic losses due to climate change. EM-DAT provides data on human and economic losses for a large number of natural catastrophes, and HANZE offer some flood damage assessments that have already been normalised for inflation and change in population density and economic development. Services such as ClimINVEST or AgriADAPT offer some estimates of potential future losses. This is also offered by paid services around the world.
- Drought predictions are mainly included in multi-hazards and not provided as single hazard indicator.
- Technical solutions to protect the County's agriculture are often paid services and the open source AgriADAPT does not cover Croatia.

Based on the information collected from the Croatian region through CoPs, surveys, and bilateral meetings, the following **gaps** have been identified:

- There is no tool or model specifically tailored to the region's needs. The primary requirements are for drought prediction and heatwave forecasting.
- Information must be presented in a way that is both understandable and practical for end-users, including local administrations and farmers.
- Data on hazards are not sufficient; there is a need for data that reflects vulnerability and impacts. Key questions to be addressed include: How much damage will climate change cause? How many hectares will be affected? Which crops will be impacted?
- There is no model that assesses the relative importance of various risks for the region and prioritises preventive measures based on their impacts, especially on economic sectors.
- Paid services are costly and there is no guarantee for the maintenance and updates of developed models. However, the region needs an independent, cost-effective tool that can be utilized throughout the entire transition process.

TYPE	DATA GAP	OBJECTIVE
CROWDSOURCING NEEDS	Local climate observations (air and water quality, heat, soil humidity...)	Calibrate models for local climate observations
OTHER DATA GAPS	Exposure or vulnerability indicators and standardized methodology at European level	Assist authorities and all the actors involved in the decision process
	Data open to citizens, accessible and serving as educational support	Develop a reference database for further strategic planning of the development and renewal agriculture production
	Physical data that we cannot collect (under license, authorization, etc.)	

Figure 31: Data Gaps for the Osijek-Baranja County; Source: Presentation at Consortium Meeting in Thessaloniki September 2024

4.4.2 Central Greece

The Central Greece region is a traditional area of Greece, predominantly characterized by agriculture, forestry, and tourism. The region has several key needs, including access to climate and hazard related data, comprehensive training programs to enhance resilience building, and capacity-building for local agencies. There is also a demand for preparedness measures and integrated approaches, such as combining hydrological and socio-economic datasets. Based on these data, a comprehensive understanding can be gained for creating a resilience strategy. Additionally, tools for forecasting extreme weather events are needed to protect agriculture and raise social awareness. The region seeks technological solutions with a dual purpose both for mitigation and for education and training.

Following the scheme of the service typology, the region requires support in multiple fields:

- Maps and apps for general forecasts focusing on temperature and heatwaves.
- As a generic, but integrated framework a water conservation guideline applicable during droughts and across regions.
- Customized services tailored to the regional needs:
 - expert analysis focused on agriculture and food risk management,
 - climate-inclusive consulting for integrated environmental management e.g. in cities and sustainability assessment.

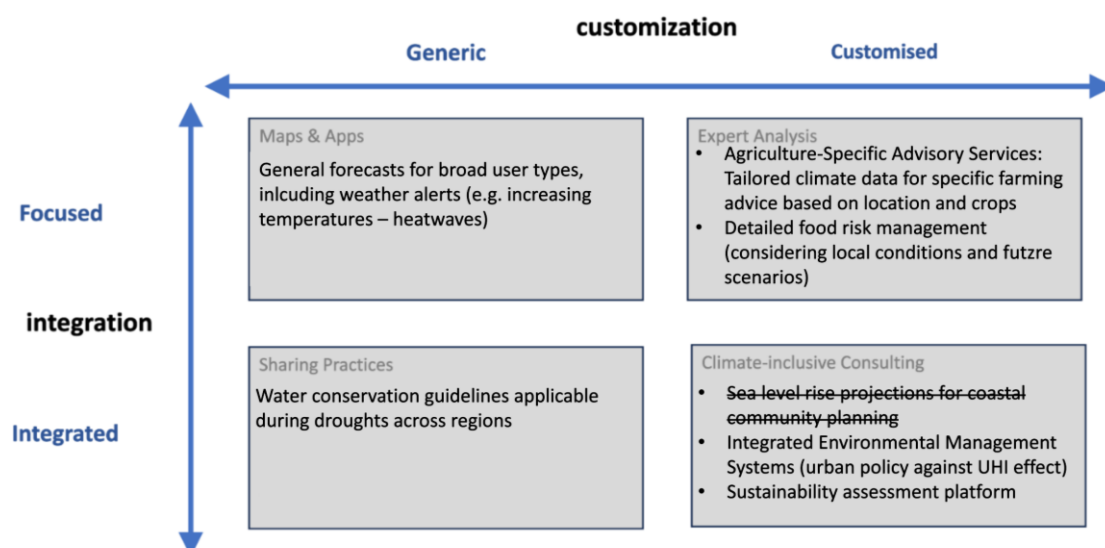


Figure 32: Services needed by Central Greece region; own representation; Source: Survey

Available datasets/services and their limitations:

- Resolution of most existing hazard maps and models on European level (around 11 km) provides a very good base but might be too coarse for local and tailored predictions regarding precipitation and drought pattern. Sea level rise projections as well as climate projections are also only available with 11 km resolution.
- There are many services providing general training on climate adaptation for agriculture, like ClimateADAPT or AgriADAPT. Tailored solutions to specific problems as well as technical solutions are however mostly provided by paid services such as Agrivi or Agxeed.
- Especially AgriADAPT provides an overview over easily implementable changes in agriculture to enhance climate resilience. However, technical solutions are highly dependent on the local situation; Various case studies are highlighted within ClimateADAPT.
- Flood risk assessment is historically available on European level but not for future climate scenarios.

Based on the information collected from the Centra Greece region through CoPs, surveys, and bilateral meetings, the following **gaps** have been identified:

- Lack of knowledge regarding technological solutions, indicators (particularly for exposure and vulnerability), and standardization methods.
- Significant gaps in knowledge and cooperation exist, highlighting the need for comprehensive resilience-building training programs and improved cooperation between public agencies.
- Lack of clear, reliable information to raise public awareness; diverse stakeholders require a wide range of information, with a particular need for tangible data such as showing the impacts on population and agriculture.
- Limited accessibility and usability of data; better data quality and open data is required. Crowdsourcing could be utilized to collect data on vulnerability and drought.

TYPE	DATA GAP	OBJECTIVE
CROWDSOURCING NEEDS	Drought, Vulnerable areas	Water management
OTHER DATA GAPS	Exposure or vulnerability indicators and standiration methodology at European level	Assist authorities and all the actors involved in the decision process
	Data open to citizens, accesible and serving as educational support	
	Physical data that we cannot collect (under license, authorization, etc.)	

Figure 33: Data Gaps for the Central Greece region; Source: Presentation at Consortium Meeting in Thessaloniki September 2024

4.4.3 Troodos Mountains/Cyprus

Troodos, the largest mountain range in Cyprus, is centrally located and extends across much of the western side of Cyprus. The region is home to numerous villages, churches, monasteries, as well as mine (e.g. copper) and forests. As a result, the main areas of concern regarding climate change are tourism, agriculture, and biodiversity.

Following the scheme of the service typology, the region requires support in multiple fields:

- Maps and apps providing generic fact sheets and impacts on agriculture, tourism, and biodiversity from hazards such as fires and droughts.
- Practices should be shared in trainings regarding risks of fires and increasing temperatures.
- Customized services tailored to the regional needs:
 - expert analysis providing information on impacts of climate change for communities, tourism, agriculture, and biodiversity,
 - climate-inclusive consulting for assessing the effects of climate change on the regional economy and facilitating the development of action plans.

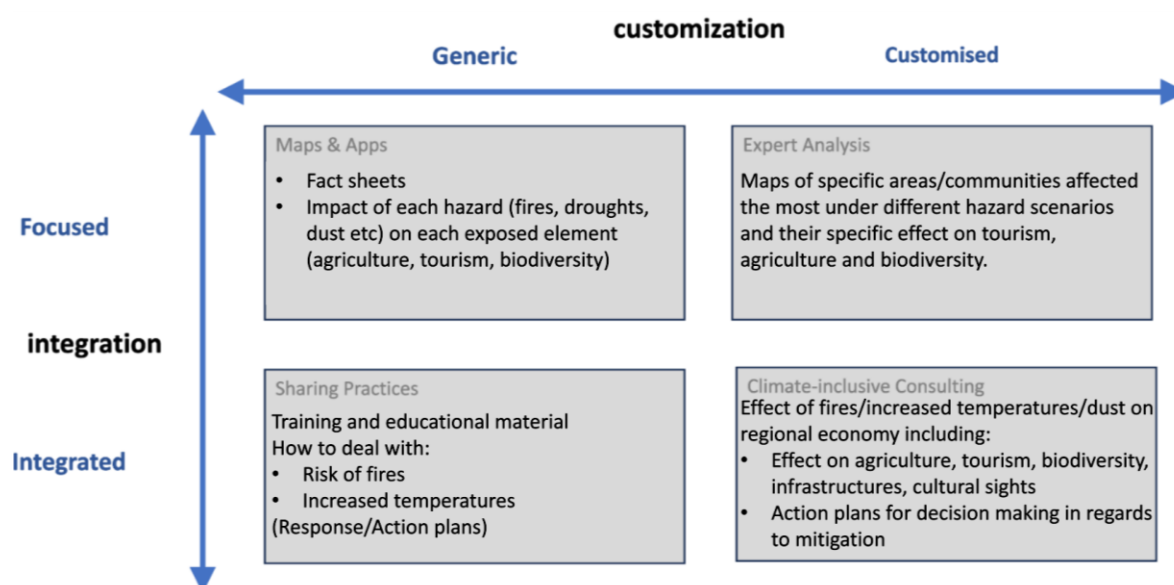


Figure 34: Services needed by the Troodos region; own presentation. Source: Survey

Available datasets/services and their limitations:

- Multi-hazard datasets can be found on European level in the Climate Data Store and regional data is provided by the Cypriot government - especially for wildfires, a lot of data is available. There is currently no data on saharan dust. In order to derive action plans and hazard management, CEMS might provide first ideas and policies, especially for wildfires. DMCSEE is currently not covering Cyprus, but does offer input for neighbouring countries with similar conditions.
- A focus on Cyprus and the Troodos Mountain Range is missing from most global services as they are often focusing on bigger countries. Impacts of hazards are mostly missing, however there are European datasets like EUROSTAT's climate impacts. Services that also raise awareness and are suitable for the public and media, include MyClimate Future and the Clima Health Portal. Again, many European projects excluded Cyprus like the IMPACT2WEB-Atlas.
- Especially for regional economy, no datasets are currently available. ClimINVEST and WRI or paid services such as Ortec Finance's ClimateMAPS might provide useful information on a more general level.
- The Cypriot government provides flood risk maps based on historical events; however, drought or wildfire risk maps are currently only available on European level which is too coarse for the needs of Cyprus. As the region provides many datasets related to exposure and vulnerability, computation of regional risks might be feasible.

Based on the information collected from the Troodos region through CoPs, surveys, and bilateral meetings, the following **gaps** have been identified:

- Cyprus is often excluded from European datasets and analyses, creating a need for data and maps on forest fires, heat waves and droughts. While national data are available at a sufficient resolution, the region requires tailored data and indices with clear visualizations.
- Most datasets do not require downscaling, as national-level data typically provide adequate resolution. However, the data is currently not easy to find neither provided on an adequate and easy to use format.

- There is a data gap concerning economic data and the integration of hazard information with exposure data.
- Available datasets (e.g. population, weather data, land use, cultural heritage sites and fires) need to be analyzed and combined to produce any meaningful data. A unified approach or platform to integrate various data sources is essential.
- The region requires practical, tangible solutions to minimize hazard impacts, aligned with local realities, including its economy and mentality. Solutions should visualize economic damages and enable filtering of information by district, prioritizing measures accordingly.
- There is a need for training materials in order to raise public awareness of climate-related hazards and support the implementation of strategies and plans, with a specific focus on wildfires prevention measures and action plans.

4.4.4 Sicily

Sicily is one of the five Italian autonomous regions and the one that suffers most from severe and prolonged drought events and high temperatures (Joint Research Center 2024). Thus, desertification is a main hazard in this region.

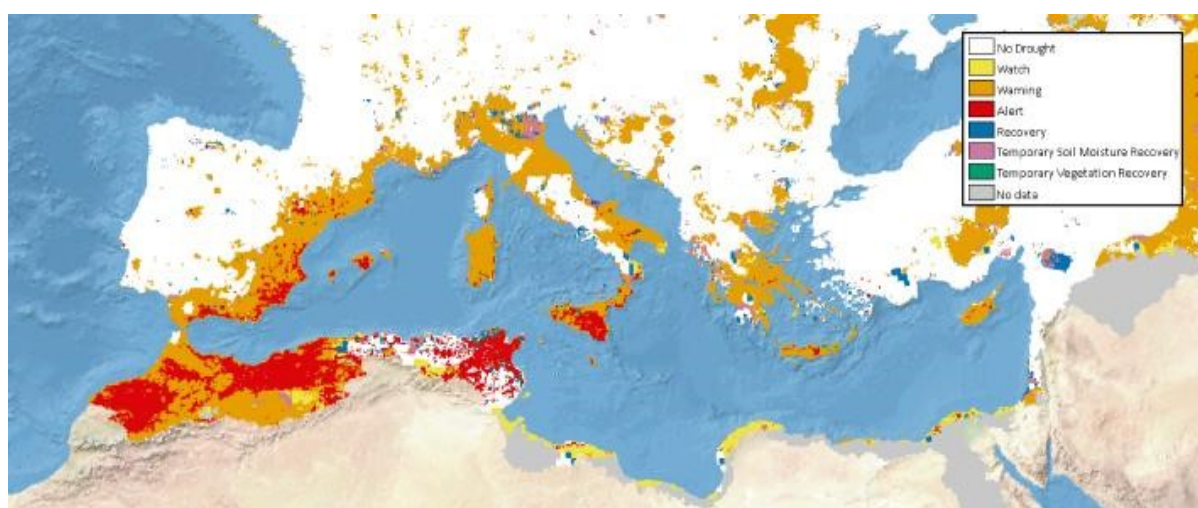


Figure 35: Combined Drought Indicator for the second 10-day period of January 2024; Source: (Joint Research Center, 2024)

Following the scheme of the service typology (Figure 36), the region requires support in multiple fields, especially for climate proofing of infrastructure projects:

- Maps and apps offering a range of climate indicators for monitoring, which can be used to assess infrastructure projects.
- From a broader perspective, Sicily requires integrated datasets that combine socio-economic, land use and climate data to develop a roadmap for improving infrastructure projects.
- Customized services tailored to regional needs, including:
 - expert analysis that provides information on historic climate parameters and assess ongoing changes,

- climate-inclusive consulting on “Climate Proofing” of infrastructure projects.

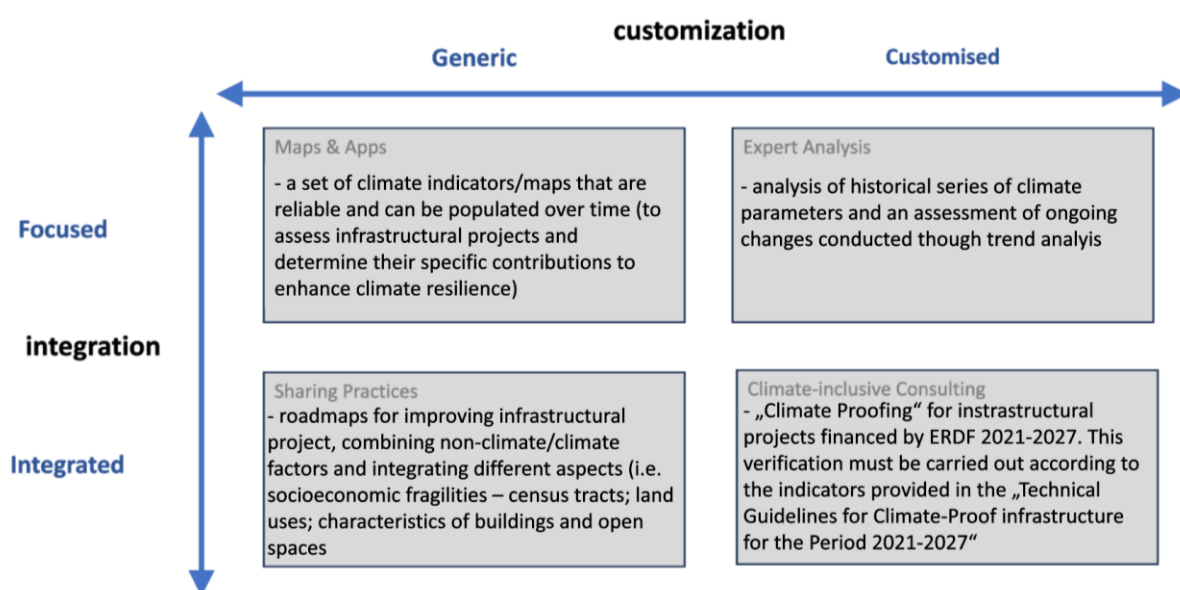


Figure 36: Services needed by Sicily; own presentation. Source: Survey

Available datasets/services and their limitations:

- Detailed factsheets on adaptation needs for the buildings and energy sector in Italy can be found in the 1.5°C national pathway explorer. ClimINVEST might provide insight into future investment developments related to climate change. However, there are no existing tools to support 'climate proofing' of infrastructure.
- Lower resolved data (11 km) is available European wide, however highly resolved data for Sicily is missing.
- Existing services such as Climate Solution Explorer, ClimateADAPT or Climate Risk Dashboard provide policies and strategies for decision makers, but they are too generic and coarse as they are not tailored specifically to Sicily. Although, the COPERNICUS climate data store offers various climate indicator datasets with a resolution of 11 km that are tailored to agriculture, tourism or water/sea level projections, higher resolved indices for Sicily are currently missing.
- The same applies to further European datasets: CEMS from the European Union as well as the Integrated Drought Management Programme by WMO offer hazard forecasts and maps for droughts and a corresponding European dataset is provided by EFFIS. Besides, MeteoAlarm provides general weather alerts. Hazard maps and hazard indicators are widely available on European level.
- Impact models are currently not available, but there are datasets providing information on historical flood damage and climate related economic losses.

Based on the information collected from Sicily through CoPs, surveys, and bilateral meetings, the following **gaps** have been identified:

- Regional partners in Sicily are required to ensure climate-proofing for all infrastructure projects, but they lack operational tools for this purpose. There is a need for services that provide climate hazard maps, impact, and risk models at various scales.

Additionally, tools and services tailored to rural areas are needed, however still insufficient.

- Climate hazard maps, including climate change scenarios, and risk/impact scenario analysis for infrastructure projects are needed.
- High resolution data is required, as the current national plan is too coarse for effective regional application.
- Comprehensive reports on flood and drought scenarios are necessary, ideally, a “report generator” could streamline climate proofing of infrastructure projects. Tools that help integrate climate change mitigation strategies into planning are also in demand.
- Information to support policy decision-making and drought planning is crucial and needed.
- The region requires models, training, and outreach tools, and platforms open to the public that provide climate data in a comprehensive way.

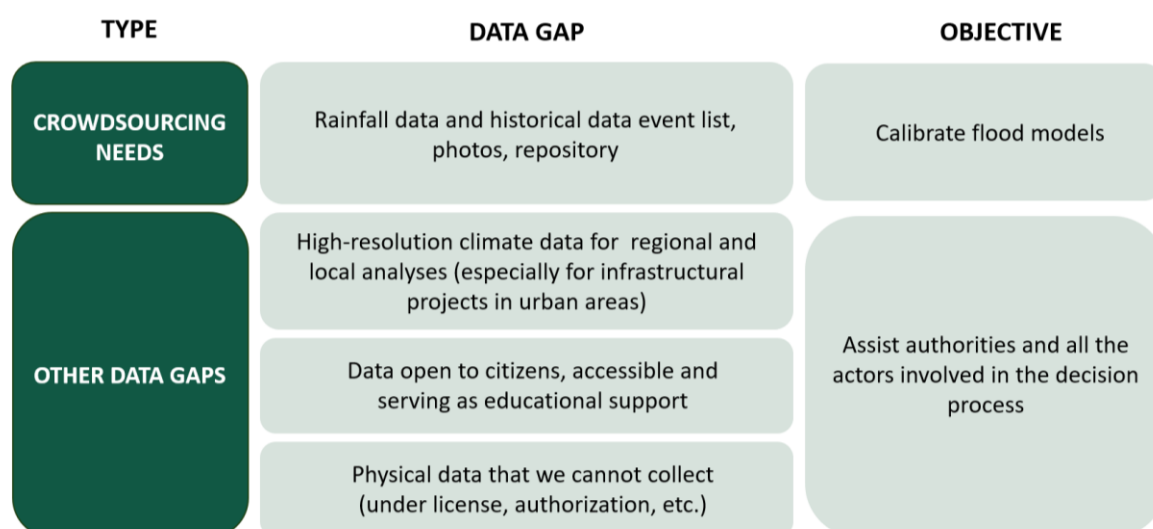


Figure 37: Data Gaps for Sicily; Source: Presentation at Consortium Meeting in Thessaloniki September 2024

4.4.5 Costa del Sol (Andalusia)

Costa del Sol, located in southern Spain, is the most populous area in Andalusia and has historically been centered around agriculture. With its rich history and culture, it is also a popular tourist destination, offering exclusive golf courses and accommodations. However, like Sicily, Andalusia is increasingly impacted by drought, which affect its agricultural sector and tourism. Additionally, Andalusia is prone to be affected by forest fires during hot and dry summer. Finally, due to its large coastline and the proximity of the urban areas to the sea, the region faces the effects of compound coastal and pluvial flooding. As a result, the region's primary focus is on water-related hazards, and discussions within the CoPs are largely centred on water management and related issues.

Following the scheme of the service typology, the region requires support in multiple fields, with the focus on drought and flooding models:

- Andalusia requires user-friendly models and maps that present clear, actionable information on wildfires, heatwaves, and droughts.
- While Andalusia can share best practices in climate risk assessment with other regions, it also needs education and training programs to empower local authorities and users.
- The region needs customized services tailored to its specific challenges, including:
 - Expert analysis on flood models, offering detailed assessments and flood risk evaluations,
 - climate-inclusive consulting services that provide best practices for integrating climate resilience into regional planning.

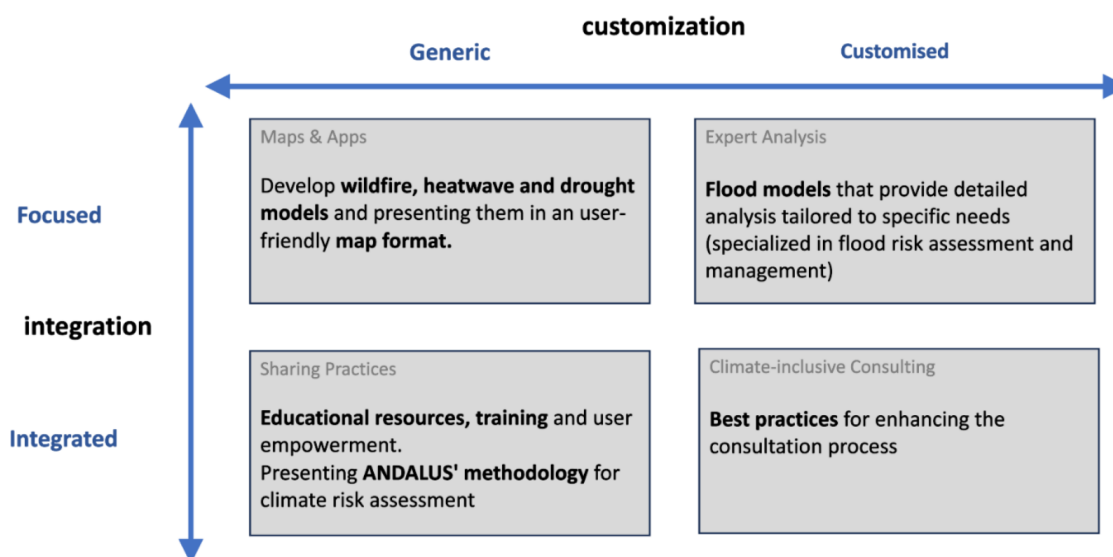


Figure 38: Services needed by Andalusia; own presentation. Source: Survey

Available datasets/services and their limitations:

- Resolution of existing hazard maps and models on European level (around 11 km) is potentially too coarse for local and tailored predictions. Sea level rise projections also exist only with 11 km resolution.

- Hazard management plans (and prioritization of measures) for droughts, wildfires and floods are available, especially on European level – however, not tailored to Andalusia.
- While hazards like fluvial floods and coastal floods are already covered with existing national tools, the region lacks models for pluvial floods (incl. urban flooding) and compound coastal and pluvial floods. In addition, the current tools and models do not account for future climate change scenarios, leaving a gap in long-term risk assessment and adaptation planning. National flood legislation requires the consideration of future scenarios.
- There are no tools for risk assessment available for the region. However, datasets exist on European level such as the COPENICUS extreme precipitation risk indicators for Europe and European cities from 1950 to 2019 dataset, even though they are mostly based on historic data (except for wildfire projections).
- There are many services providing training material on climate impacts, however less on socio-economic impacts - partly because they are highly linked to the local situation. The ClimaHealth portal can provide material related to impacts on health and health care.

Based on the information collected from Andalusia through CoPs, surveys, and bilateral meetings, the following **gaps** have been identified:

- There is a need for tools that build on existing datasets and models while avoiding overlap with current tools. In this sense, for example, a map considering compound flooding (coastal, pluvial) would be beneficial.
- Open platforms are essential to ensure the transferability of results, and costly licensed software should be avoided.
- A gap still remains in accessible, user-friendly tools that enhance coordination between entities and assist authorities and all stakeholders in the decision-making process.
- The impact of large seasonal population variation has not yet been adequately considered.
- The region requires the development of coupled coastal and pluvial flood models, as well as spatial distribution maps for heatwaves.
- Risk mapping is needed for droughts, heatwaves, and forest fires, along with geospatial assessments of forest fire risks.
- There is still a lack of integrated tools that combine water scarcity and drought data.
- Regarding precipitation, EURO-CORDEX primarily provides daily resolutions. However, for flood modeling, sub-daily temporal resolutions are recommended. In this context, generating finer temporal resolutions through downscaling techniques (Monjo, 2023), (Rodríguez, 2013) would be valuable for the Spanish Case Study.

TYPE	DATA GAP	OBJECTIVE
CROWDSOURCING NEEDS	Rainfall data and historical data event list, photos, repository	Calibrate flood models
OTHER DATA GAPS	Exposure or vulnerability indicators and standardized methodology at European level	Assist authorities and all the actors involved in the decision process
	Data open to citizens, accesible and serving as educational support	
	Physical data that we cannot collect (under license, authorization, etc.)	

Figure 39: Data Gaps for Andalusia; Source: Presentation at Consortium Meeting in Thessaloniki

Being aware of the data gaps and the needs of the CoPs, which are aligned with national strategies and directives requirements, some model solutions were discussed with stakeholders. In this discussion, it was highlighted that many service gaps had already been addressed in the region, allowing stakeholders to have clearer expectations of the types of solutions they needed and that could be provided.

The main data-collection challenge was addressing urban floods with the aforementioned innovative approach, as it had not been previously developed in the region. To achieve this, parallel work was carried out to bridge the gaps needed to set up these models.

In this regard, the previous work of the CoPs was leveraged, and necessary data not available in local, national, or European datasets was requested.

Some of the **data gaps that were already bridged** by the Andalusian Case Study included:

- Fine-resolution historical precipitation data: Hourly resolution data is available at the national level from different sources, including the national meteorological agency (AEMET), the river basin authority, and other water and agricultural entities at the regional level. However, finer resolution (10-minute intervals) was optimal for model calibration, and it was obtained by requesting it from these entities through the Region.
- Buoy data (including wave, wind, and currents data): This is available through the national port authority entity ("Puertos del Estado") upon request. Either individuals or the Region can make the petition. Historical datasets at an hourly resolution were provided.

Still existing gaps:

- Physical data of the sewage networks of the municipalities: To deliver a model that addresses urban floods without overlapping with existing tools, this data was needed. It includes pipes, manholes, and historic sensor data for calibration. This information was requested from municipalities that participated in the CoP, either through the Case Study Facilitator or the Region. As this data is difficult to collect, an algorithm developed within the "ICARIA project" or other strategies will be used to fill in missing parts of the

sewage network. Comparisons and indicators may be provided in the future to assess the accuracy of European flood maps with these calibrated models.

In Figure 40, some of the collected local information is shown. The map illustrates various data collection points and municipal participation. It includes buoys and rain gauges (green points indicate the available rain and buoy data, while a yellow point represents requested but not yet available pluviometers). Municipalities in green indicate those that have provided sewage data, while red are those which have not yet shared the sewage data.

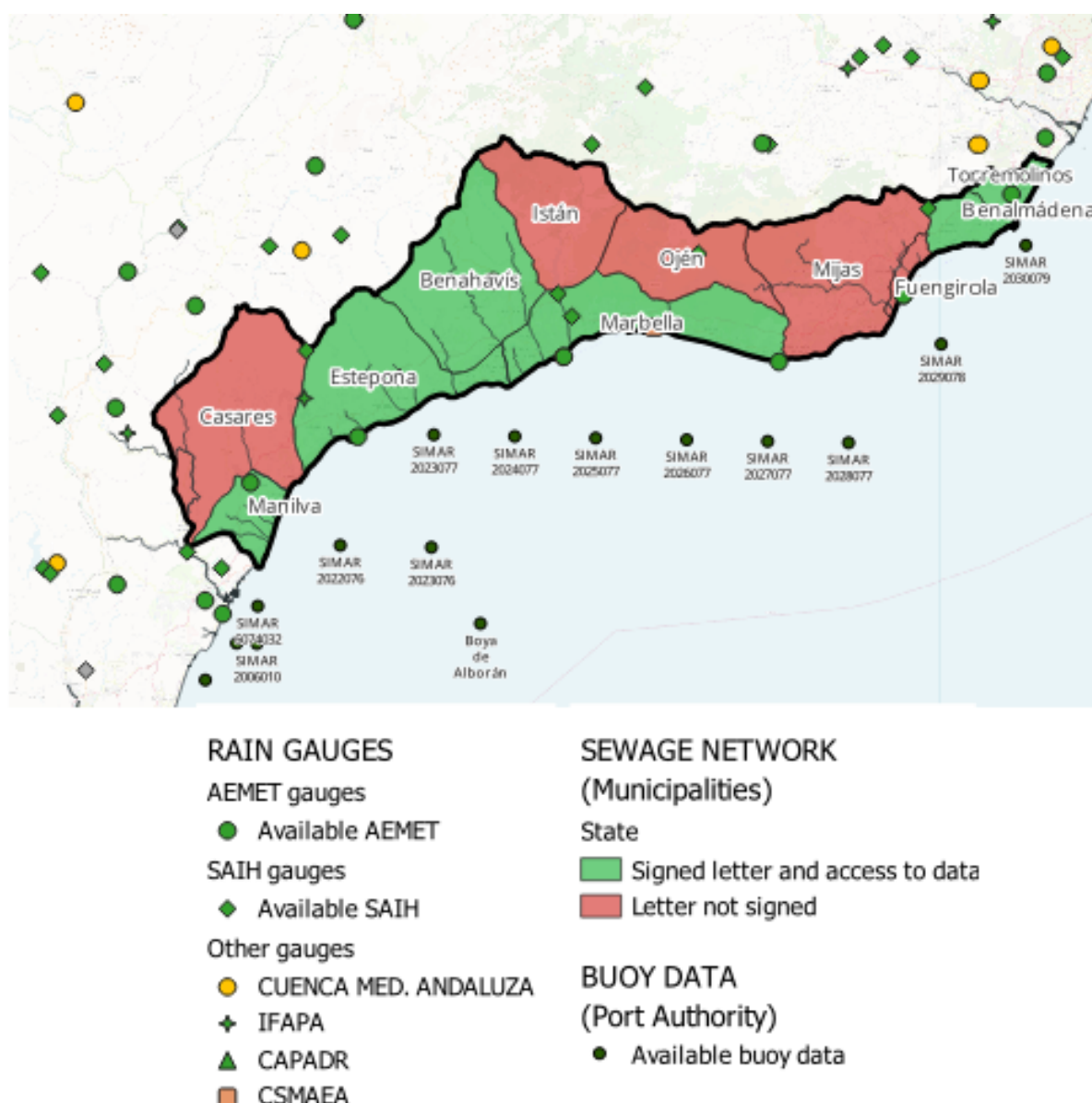


Figure 40: Distribution of local data sources in the Andalusian Case Study. Source: GIS elaboration.

5 Conclusions

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

Regarding **hazard** related data:

- Over the past years extensive datasets to simulate hazards (e.g. heat days, precipitation rates) have been set up and made available for Europe. This data provides great potential for a first understanding and assessment of future climate states. Higher resolution data may be necessary for some specific needs of the regions (e.g. heat load in urban areas, projected rainfall intensities).
- Regional datasets are available for the 5 regions considered, with most data identified for Sicily and least for Andalusia. The regional datasets provide important insights into local characteristics relevant for localized hazard computation.
- Hazard data is mainly available as gridded datasets, allowing the identification of different structures within one region.

Investigating **exposure** data the following conclusions can be drawn:

- European wide, OSM and land use data display important datasets for localizing critical infrastructure and agricultural areas.
- regional exposure data is well gathered by Andalusia, whereas Osijek County has only limited data available.
- Exposure data is often provided as point data (e.g. location of infrastructure) or mean over a specific area (e.g. number of people within 1 grid cell)

With respect to **vulnerability** data:

- The availability of vulnerability data is in general lower than e.g. hazard data. Most prevalent datasets focus on population characteristics and are available on various scales. Some historical EUROSTAT datasets, such as ‘Population structure indicators’ or ‘Population broad age group and sex’ are available on NUTS 3 level, whereas the majority of EUROSTAT’s vulnerability related data, is only available on country level. Future projections of population characteristics are not available yet for the newest EUROSTAT dataset from 2023, however data from 2019 could be used.
- EUROSTAT datasets can also be found with respect to agriculture.
- For the Sicily and Troodos regions there isn’t any vulnerability data available.

Overall, there is a **gap with respect to localized future hazard data and especially vulnerability data**, which needs to be tackled within T2.2, depending on the specific needs of the regions.

For the climate services, in total 55 services were investigated and classified according to the typology stated. Overall, most fall within the type of Maps & Apps.

A **Maps & Apps type of service** is generic and cannot provide a tailored expert view on a region’s specific needs and challenges, however it might provide datasets relevant for regions in an easy and user-friendly manner. Most **ClimEmpower regions lack a specific service**

combining all available and relevant data in one place and would profit from establishing one. Already available regional data portals, such as REDIAM for Andalusia, need to be considered and if necessary and possible, updated. A good Maps & Apps service can provide the foundation of a region-specific risk analysis and therefore address one of the biggest gaps for all regions.

Many of the current operational Maps & Apps services are also classified as **Sharing Practices** as they are also offering advice for decisions makers, learning material or factsheets. This is also highly relevant for the ClimEmpower regions, as they requested educational material in various forms. Sharing Practices also means exchange between countries, regions or municipalities facing similar challenges and hazards, which could also be of great benefit for the individual regions and providing examples of best practices in dealing with climate change impacts. While there are already some Shared Practice services in the sector of agriculture, none for tourism has been found, exposing a current gap.

Sharing Practices and Maps & Apps are open services and freely available, as any service or solution offered by ClimEmpower should be.

Expert Analysis and Climate Inclusive Consulting, which are tailored to a specific region and problem, will not be the main focus of ClimEmpower development. However, the need for **evaluation of specific infrastructure projects or agricultural questions** are of great importance to the regions, going beyond Maps&Apps and more towards customized expert analysis. Thus, within ClimEmpower a first climate service approach will be setup on providing this type of information for further use by experts.

For the regions, weather alerts and real-time warnings would also be highly relevant, however ClimEmpower focuses on climate related data and services and weather forecasts and tools are outside the scope of this project.

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