Integrated Methods for Regional Climate Risk and Resilience

Data integration, risk assessment, resilience indicators and decision support in ClimEmpower

Key contributions

5	4	531	36	90
pilot regions	major climate hazards	resilience indicators reviewed	indicators linked to recommendations	actionable recommendations

ClimEmpower develops and integrates methods for transforming heterogeneous climate and territorial information into regionally relevant evidence for resilience planning. The scientific work combines climate and Earth observation data, socio-economic and infrastructure information, hazard modelling, resilience indicators, social sensing and stakeholder knowledge. The result is a multi-layered approach that links diagnosis of climate risk and resilience with practical decision support.

1. Integrated climate-risk framework

The project treats climate risk as the interaction between hazard, exposure and vulnerability. This allows the same climatic event to be interpreted differently depending on the people, assets, systems and sectors that are exposed and on their capacity to cope or adapt.

Hazard × Exposure × Vulnerability → Climate Risk

Hazard	Exposure	Vulnerability	Risk
Heatwaves, droughts, floods and wildfires	Population, buildings, infrastructure, agriculture, ecosystems and other assets	Sensitivity, adaptive capacity and local territorial conditions	Asset- and context-specific consequences requiring targeted action

Risk mapping is therefore not treated as a purely climatological task. For floods and wildfires, for example, hazard information can be combined with population, land-use, infrastructure and socio-economic data to derive more decision-relevant risk information. The same logic supports asset-specific risk profiles across sectors.

2. Multi-source climate intelligence and spatial downscaling

A central methodological challenge addressed by ClimEmpower is the mismatch between the spatial scale of many climate datasets and the scale at which regional or local decisions are made. The project therefore investigated methods for integrating multiple data sources and increasing the spatial usefulness of available information.

- **Climate data:** Climate and meteorological data, including Copernicus Climate Data Store resources and regional information.
- **Earth observation:** Satellite-derived vegetation and moisture information, including NDVI, EVI, NDWI, NDDI and related indices.
- **Socio-economic data:** Population and socio-economic information, including standardised gridded data such as the EUROSTAT 1 km grid.
- **Exposure data:** Infrastructure, land-use and other territorial datasets needed to characterise exposure.

- **Historical hazards:** Historical event records and hazard-specific sources, including fire and flood event information.
- **Social sensing:** Locally relevant online information used as a complementary source for event detection and contextualisation.

For Sentinel-2 data, ClimEmpower tested spatial downscaling from 20 m to 10 m using Brovey, IHS, Wavelet and PNN methods. Brovey, IHS and PNN produced the strongest visual results in the project tests, while the Wavelet approach showed weaker performance and more visible artefacts. The work demonstrates the potential value of enhanced spatial resolution for applications such as agriculture, urban planning and local climate-risk analysis.

3. Multi-indicator drought monitoring

Drought monitoring illustrates the value of combining complementary indicators rather than relying on a single signal. ClimEmpower considered information from vegetation condition, atmospheric demand and soil moisture to capture different dimensions of drought.

Vegetation response	Meteorological stress	Soil conditions
NDVI, EVI, NDWI, NDDI and related satellite indicators	SPEI, vapour pressure deficit (VPD), KBDI and related indices	Soil-moisture information supporting interpretation of agricultural and ecosystem stress

4. Resilience assessment: from indicator review to actionable evidence

ClimEmpower reviewed 531 resilience indicators and used this evidence base to support a structured regional resilience framework. The work showed that resilience cannot be represented adequately through environmental indicators alone; social, economic, infrastructural and governance conditions are also essential.

The final framework covers six resilience dimensions:

- Health & Wellbeing
- Population & Education
- Economy & Labour Market
- Infrastructure
- Governance
- Environment, Nature & Settlement Areas

The methodological emphasis is on interpretable individual indicators rather than opaque composite indices. Useful indicators should be context-specific, measurable, comparable and actionable, while their practical value depends strongly on the availability of sufficiently local data.

5. Linking resilience indicators to recommendations

A key integration step in the final ClimEmpower framework is the direct link between resilience indicators and resilience recommendations. The project developed 90 concrete recommendations mapped to 36 resilience indicators, across seven fields of application and six resilience dimensions.

Indicator condition → Relevant hazard → Local context → Targeted recommendation

This tiered decision-support logic allows the system to move from a broad diagnosis of low resilience to increasingly context-specific recommendations. Recommendations are further characterised by governance level, implementation timeframe, policy roadmap, hazard relevance, environmental/social/economic co-benefits and best-practice evidence.

6. Social sensing and AI-assisted contextualisation

ClimEmpower explored social sensing as a complementary source of information for understanding climate-related events. The workflow includes monitoring and crawling online posts, extracting location information, estimating relevance, detecting events and analysing context.

Localized search terms were developed in English, Croatian, Italian, Spanish and Greek. A proof-of-concept used approximately 20,000 wildfire and fire-danger social posts in Greece together with large-language-model and retrieval-augmented-generation techniques. The approach is intended to complement, not replace, authoritative climate and hazard datasets.

7. Integration in the ClimEmpower Toolbox

The ClimEmpower Toolbox provides a common decision-support environment in which scientific outputs can be explored together. Its modular architecture connects climate data access, risk visualisation, resilience indicators, vegetation monitoring, historical hazard information, social sensing and resilience recommendations.

ACCESS DATA	EXPLORE & MONITOR	ASSESS RISK	MEASURE RESILIENCE	GET RECOMMENDATIONS	TAKE ACTION

Scientific relevance and reuse potential

The scientific contribution of ClimEmpower lies primarily in the integration of methods rather than in a single model or dataset. The project demonstrates how heterogeneous climate, Earth observation, socio-economic and stakeholder information can be combined within a transparent workflow that connects risk, resilience and action.

- **Methodological reuse:** Testing and comparison of spatial downscaling methods for local-scale Earth-observation use.
- **Indicator reuse:** A transparent resilience-indicator framework that can be adapted to different regional contexts.
- **Decision-support reuse:** A structured linkage between measurable resilience conditions and targeted recommendations.
- **Technical reuse:** Modular services and workflows that support integration into broader climate-service and decision-support environments.
- **Transferability:** A place-based approach that combines scientific evidence with regional validation and stakeholder knowledge.

Scientific value emerges from connecting data at the right spatial scale with interpretable indicators, context-specific risk assessment and decision-relevant recommendations.