Deliverable Phase 2 – Climate risk assessment

Climate Risk Analysis and Adaptation strategy for the mediterranean county of La Foia de Castalla (CLIMAAX4CAST)

Spain, Excma. Diputacion Provincial de Alicante

HORIZON-MISS-2021-CLIMA-02-01 - Development of climate change risk assessments in European regions and communities based on a transparent and harmonised Climate Risk Assessment approach

Funded by the European Union

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101093864. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Document Information

Deliverable Title	Phase 2 – Climate risk assessment
Brief Description	This deliverable provides a comprehensive climate risk assessment for La Foia de Castalla, focusing on heatwaves and agricultural droughts. By integrating high-resolution local data with global climate projections (RCP 4.5 and 8.5), the study quantifies escalating hazards, socio-economic exposure, and systemic vulnerabilities. Key findings highlight a transition from episodic to structural water scarcity and a dramatic increase in extreme heat events, projecting annual agricultural losses of €4.1 million by mid-century. The report concludes with an adaptation framework based on circular water management and regional cooperation to enhance territorial resilience.
Project name	Climate Risk Analysis and Adaptation strategy for the mediterranean county of La Foia de Castalla
Country	Spain
Region/Municipality	Excma. Diputacion Provincial de Alicante (DPA)
Leading Institution	Excma. Diputacion Provincial de Alicante (DPA)
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Deliverable submission date	19/01/2026
Final version delivery date	19/01/2026
Nature of the Deliverable	R – Report
Dissemination Level	PU - Public

Version	Date	Change editors	Changes
1.0	...	AIJU	Deliverable submitted
2.0	...	CLIMAAX's FSTP team	Review completed
5.0	...		Final version to be submitted

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3. Abbreviations and acronyms

Abbreviation / acronym	Description
ADAPTECCA	Spanish Platform for Adaptation to Climate Change (Plataforma Española de Adaptación al Cambio Climático)
AEMET	Spanish State Meteorological Agency (Agencia Estatal de Meteorología)
AI	Aridity Index
AIJU	Technological Institute for Children's Products and Leisure (Instituto Tecnológico de Producto Infantil y Ocio) - Valencian research institute
AWC	Available Water Capacity
CAP	Common Agricultural Policy (Política Agrícola Común - PAC)
CLIMAAX	Climate Risk Assessment for Adaptation Planning
CMIP5	Coupled Model Intercomparison Project Phase 5
CMIP6	Coupled Model Intercomparison Project Phase 6
CORDEX	Coordinated Regional Climate Downscaling Experiment
CRA	Climate Risk Assessment
CSV	Comma-Separated Values
DEM	Digital Elevation Model
DOP	Protected Designation of Origin (Denominación de Origen Protegida) - Spanish certification
ERDF	European Regional Development Fund
ET0	Reference Evapotranspiration
ETCCDI	Expert Team on Climate Change Detection and Indices
ETP	Potential Evapotranspiration (Evapotranspiración Potencial) - Spanish term
EURO-CORDEX	European branch of CORDEX - Regional climate projections for Europe
FAO	Food and Agriculture Organization (United Nations)
FAO-56	FAO Irrigation and Drainage Paper 56 - Crop evapotranspiration methodology
GDP	Gross Domestic Product
GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change
Kc	Crop Coefficient - Factor relating crop evapotranspiration to reference evapotranspiration
Ky	Yield Response Factor - Crop-specific parameter relating water deficit to yield reduction
MCA	Multi-Criteria Analysis

MPI-ESM-LR	Max Planck Institute Earth System Model - Low Resolution
NC	NetCDF (Network Common Data Form) - Scientific data file format
NDVI	Normalized Difference Vegetation Index
OBS	Observations - Refers to E-OBS observational dataset
PAC	Common Agricultural Policy (Política Agrícola Común) - Spanish acronym for CAP
PDF	Portable Document Format
PDO	Protected Designation of Origin
RCP	Representative Concentration Pathway - Climate change scenario framework
RCP 4.5	Representative Concentration Pathway 4.5 - Intermediate emissions scenario (mitigation)
RCP 8.5	Representative Concentration Pathway 8.5 - High emissions scenario (business-as-usual)
REMO2009	Regional Model version 2009 - Regional climate model for EURO-CORDEX
SCADA	Supervisory Control and Data Acquisition
SPEI	Standardized Precipitation Evapotranspiration Index
SSP	Shared Socioeconomic Pathway - Climate change scenario framework
SSP2-4.5	Shared Socioeconomic Pathway 2-4.5 - Middle-of-the-road scenario with moderate mitigation
SSP5-8.5	Shared Socioeconomic Pathway 5-8.5 - High emissions with fossil fuel intensive development
TFM	Master's Thesis (Trabajo Fin de Máster) - Spanish academic term
WASP	Weighted Anomaly of Standardised Precipitation
WMO	World Meteorological Organization

4. Executive summary

This deliverable presents the Phase 2 climate risk assessment for the Foia de Castalla region (Valencia, Spain), addressing the escalating threats of heatwaves and agricultural drought under climate change. Building upon Phase 1 screening results, this phase provides quantitative risk analysis combining hazard projections, economic exposure, and vulnerability assessments to inform adaptation planning. The assessment evaluates impacts on two primary sectors: public health (heatwave exposure) and agriculture (drought-induced crop losses), which represent the most critical climate risks for the region's 45,000 inhabitants and agricultural economy.

Main Results and Findings

Hazard Assessment Refinements: Phase 2 integrates ADAPTECCA Climate Change Scenarios Viewer for high-resolution regional projections (5 km) based on EURO-CORDEX data. The analysis incorporates local evapotranspiration data, aquifer level monitoring, and sector-specific vulnerability indicators not available in Phase 1. Two emission scenarios are evaluated: RCP 4.5 (mitigation) and RCP 8.5 (business-as-usual) for mid-century (2046-2050), alongside SSP scenarios for long-term heatwave projections (2015-2100).

Agricultural Drought: The hazard assessment employs a dual methodology combining Aridity Index with FAO-56 simplified crop water balance models. Results indicate severe water deficits (869-985 mm/year) leading to critical yield losses: 72% for rainfed grape cultivation and 41% for olive. These losses translate to annual economic risks of €4.1 million, representing 37.8% of current agricultural production value. The convergence of impacts between RCP 4.5 and RCP 8.5 scenarios (difference <1%) at the 2046-2050 horizon indicates that significant agricultural impacts are unavoidable regardless of global mitigation efforts within this timeframe.

Heatwaves: Temporal trend analysis reveals dramatic increases in extreme heat indicators. Hot days (Tmax ≥35°C) are projected to increase from 7.8 days/year (historical baseline, 1950-2014) to 36.4 days/year under SSP2-4.5 and 46.9 days/year under SSP5-8.5 (+366% and +501%, respectively). Heatwave duration extends from 4.7 to 27.8 days per event under the high-emission scenario. Warm nights (Tmin ≥20°C) increase from 7.5 to 48.4 nights/year (+545%), indicating sustained thermal stress with compounded health impacts, particularly for vulnerable populations including elderly residents, outdoor agricultural workers, and urban dwellers.

Risk Assessment Integration: The CLIMAAX risk framework (Risk = Hazard × Exposure × Vulnerability) quantifies economic and health impacts. For agriculture, vulnerability is determined by irrigation infrastructure availability: 60% of grape cultivation and 75% of olive cultivation remain rainfed and therefore highly vulnerable. Cost-benefit analysis demonstrates that irrigation adaptation is economically justified for grape cultivation (benefit-cost ratio 5.2:1) but requires public subsidies for olive cultivation (ratio 0.7:1). Priority adaptation investments of €10-15 million could prevent €2 million in annual agricultural losses.

Data Integration: Phase 2 incorporates multiple data sources including ADAPTECCA regional climate projections, satellite-based evapotranspiration estimates (Hengl & Gupta 2019), local groundwater monitoring data from the Júcar River Basin Management Plan (2022-2027), and regional agricultural statistics from the Valencian Government. This multi-source integration addresses Phase 1 data gaps and enables sector-specific vulnerability quantification.

Conclusions

Three key findings emerge from this assessment. First, agricultural drought represents an immediate and critical economic threat, with projected losses equivalent to more than one-third of current agricultural value, necessitating urgent adaptation measures within the 20-year planning window to 2046. Second, the minimal difference between moderate and high emission scenarios at mid-century indicates that adaptation must be prioritized over mitigation at the regional scale for near-term planning. Third, the dramatic escalation in heatwave frequency and intensity poses severe public health risks that will require comprehensive heat action plans, urban cooling strategies, and vulnerable population protection systems.

The economic viability of irrigation-based adaptation for grape cultivation, combined with the severity of projected impacts, provides a clear pathway for immediate investment. However, the broader challenges of declining aquifer levels, increasing evapotranspiration rates, and limited water resources require integrated water management strategies extending beyond individual farm-level adaptations.

Plans for the Final Phase

Phase 3 will develop detailed adaptation pathways for priority sectors, evaluate the feasibility of specific interventions (drip irrigation systems, heat early warning systems, urban green infrastructure), and provide implementation roadmaps with timelines and resource requirements. Stakeholder engagement sessions will validate findings and prioritize adaptation measures based on economic, social, and environmental criteria. The final deliverable will include policy recommendations aligned with regional climate adaptation plans and EU funding mechanisms.

1 Introduction

1.1 Background

The Castalla basin, is a natural and historical subregion located in the interior of the province of Alicante, in the Valencian Community. It is formed by the municipalities of Ibi, Onil, Castalla, and Tibi, and has a total population of approximately 44,856 inhabitants. The region is characterized by its mountainous landscape, with sierras such as Maigmó, Castalla, Menejador (Ibi), Onil, and Peña Roja (Tibi). The valley is located at an altitude between 550 and 800 meters, while the surrounding mountains exceed 1000 meters. Historically, the economy of the Castalla basin was based on dryland agriculture, but since the 1950s and 1960s, the region experienced rapid industrialization, especially in the manufacturing of toys and dolls in Ibi and Onil. Currently, the industry has diversified towards sectors such as Furniture, Automotive and Food Packaging, with specialised companies in plastics, metal, and molds manufacturing.

1.2 Main objectives of the project

The primary objective of Phase 2 was to conduct a comprehensive Climate Risk Assessment (CRA) tailored to the specific geographical and socio-economic context of the Castalla Basin. By transitioning from generic regional data to localized indicators, this phase aimed to provide the municipalities of Ibi, Onil, Castalla, and Tibi with a scientifically validated evidence base to guide future policy. For the community, the significance of this phase lies in its ability to transform climate awareness into actionable intelligence by identifying specific vulnerability hotspots—such as urban heat islands and groundwater-dependent agricultural zones—and quantifying the potential financial impacts of drought to justify resilience investments. Furthermore, it has fostered unified governance by establishing a shared understanding of risk between municipal technicians, regional authorities, and the industrial sector.

The implementation of the CLIMAAX Handbook provided a standardized, rigorous framework that ensured methodological consistency across the hazard, exposure, and vulnerability workflows. This structured approach allowed for a transparent assessment comparable to other European regions while utilizing the CLIMAAX evaluation dashboard to move from subjective perceptions to a data-driven prioritization based on severity and urgency. However, the decisive factor in the success of Phase 2 was the integration of local data and contextual expertise. By incorporating high-resolution meteorological data and specific aquifer recharge models, the project bypassed the limitations of coarse regional projections to deliver a 1km-scale resolution essential for municipal planning. Additionally, the inclusion of local census data and qualitative insights from healthcare and agricultural experts allowed for a refined assessment of social resilience, ensuring the results reflect the specific needs of the region's elderly population and industrial water requirements that global models typically overlook

1.3 Project team

Débora Sorolla Rosario, PhD in Materials Science, specializes in gas chromatography-mass spectrometry and thermal techniques. She works at AIJU, focusing on environmental decontamination, polymer analysis, circular economy, and advanced energy technologies.

Joaquín Vilaplana Cerdá, PhD in Chemistry and Director of Innovation at AIJU, has over 30 years of experience in environmental solutions and R&D management.

Dionisio Cartagena González, Industrial Engineer, is completing a Master's in Automation and Robotics, with expertise in system modeling, SCADA programming, and robotics, working as a Project Technician in the Advanced Manufacturing Department at AIJU.

Miguel Fernandez Mejuto: Head of the Water Technologies Unit of the Water Cycle Department of the Alicante Provincial Council.Associate Professor in the Department of Earth and Environmental Sciences at the University of Alicante.

1.4 Outline of the document's structure

This document is organized to provide a comprehensive overview of the Phase 2 Climate Risk Assessment, beginning with an introduction to the project's main objectives, the significance of the assessment for the Castalla Basin, and the benefits of integrating the CLIMAAX Handbook with localized data. The report then transitions into a detailed summary of the technical findings, specifically focusing on the characterization of heatwave and drought hazards, their projected severity under different climate scenarios, and the resulting vulnerability of the region's social and economic sectors. Following the technical results, the document outlines the risk prioritization process, explaining the criteria used to determine the urgency and resilience capacity for each hazard. The final sections detail the stakeholder engagement and communication activities executed during this stage, the institutional governance structure, and the achievement of key performance indicators and milestones. The report concludes with a synthesis of the main findings and a description of how these outputs directly inform the strategic adaptation planning scheduled for the subsequent phases of the project.

2 Climate risk assessment – phase 2

2.1 Scoping

2.1.1 Objectives

The primary objective of Phase 2 of the climate risk assessment in the Castalla basin is to deepen the evaluation of specific climate risks, focusing on droughts and heatwaves, using the latest local climate data available. This phase aims to update the assessment carried out in Phase 1 and provide a more detailed analysis of how these risks impact public health, agriculture, and infrastructure in the region.

The application of results in policy and decision-making is a key aspect, as these results will inform the need for adaptive measures to reduce the vulnerability of local communities and strengthen resilience to climate change. Expectations for this phase include generating specific recommendations for improving water management, the efficient use of natural resources, and the enhancement of adaptation infrastructures.

It is acknowledged that the availability of specific local-level data remains a limitation. Although recent data has been obtained, some areas still present data gaps, particularly regarding the direct economic impacts of extreme weather events. The lack of deeper engagement with all vulnerable sectors during Phase 1 is also a barrier, which will be addressed in this phase.

2.1.2 Context

So far, climate risk management in the Castalla basin has been limited to general environmental diagnostics and some studies on the effects of droughts and heatwaves, but without an exhaustive analysis linking specific climate projections with regional planning. This project aims to fill that gap by providing a detailed evaluation of current risks and their future projections.

La Foia de Castalla is in the southeast of the Iberian Peninsula, an area where the advance of desertification processes is highly evident. Because it is a valley at a considerable altitude, its climate is somewhat more continental and colder, a microclimate that favis favorable for forests cover in the surrounding mountains, and Mediterranean dryland farming in the lower areas of the valley. Any increase in temperature and drought periods can seriously affect existing ecosystems balance, increasing the risk of desertification. Visualising these impacts and potential effects is necessary to promote the adoption of preventive measures to mitigate these effects.

The context for this analysis is framed within the national and regional legal frameworks for climate change adaptation, such as the Spanish Climate Change Law and the National Adaptation Plans. At the regional level, the Valencian Community has implemented certain adaptation strategies, but these need to be reinforced with more precise data to better adjust to the local climate realities. Key sectors such as agriculture, industry, and public health are particularly exposed to the identified risks, and their adaptation will be crucial for improving the region's resilience.

2.1.3 Participation and risk ownership

Since 2022, a series of workshops and meetings have been held to diagnose the environmental challenges facing the region, as part of an initiative called shared agendas for environmental innovation. This initiative involved a series of phases of debate, seeking to involve as many local social actors as possible, including the local council, businesses, trade unions, cooperatives, and associations. All this work has led to the establishment of a roadmap that aims to develop actions to promote the circular economy in the region and improve its sustainability and resilience.

The application of the CLIMAAX methodology has allowed for a more in-depth technical analysis of the risks arising from climate change and highlighted the need to define measures to mitigate and address them.

On October 24, 2024, the climaax project was presented at a round table discussion held at a circular economy event organized by AIJU.

In June 2025, a regional workshop was held in Valencia, bringing together key representatives from local city councils, the Júcar Hydrographic Confederation (CHJ), and the Public Wastewater Sanitation Entity of the Valencian Community (EPSAR). The event featured specialized working groups focused on the circular economy of water, providing a platform for participants to discuss the primary challenges and technical difficulties currently facing the sector.

Building on this momentum, a follow-up event was organized at AIJU in November 2025. This meeting gathered a wide range of stakeholders, including regional municipal representatives, universities, private companies, and various organizations, to review the progress of the CLIMAAX project. During the session, the results obtained to date were presented, showcasing the practical applications of the research. A central outcome of the event was the proposal of a collaborative agreement among regional city councils. This agreement aims to establish a unified framework for addressing climate change-related challenges and enhancing territorial resilience through shared strategies and collective action.

Risk ownership is organized across multiple levels: local governments are responsible for mitigation and public health, the Diputación de Alicante provides regional coordination and strategy alignment, and AIJU offers methodological and technical guidance. Specific priority groups—including the elderly, agricultural workers, and water-dependent households—were identified as essential for tailoring adaptation strategies due to their high exposure.

The region's acceptable risk level is determined through governance and stakeholder feedback; while moderate risks may be tolerated if adaptation is feasible, high risks associated with heatwaves and water scarcity are deemed unacceptable due to their threats to health and economic stability. To maintain this collaborative approach, an organizational chart defines the responsibilities among all actors, ensuring a coherent response to climate risks across all administrative levels.

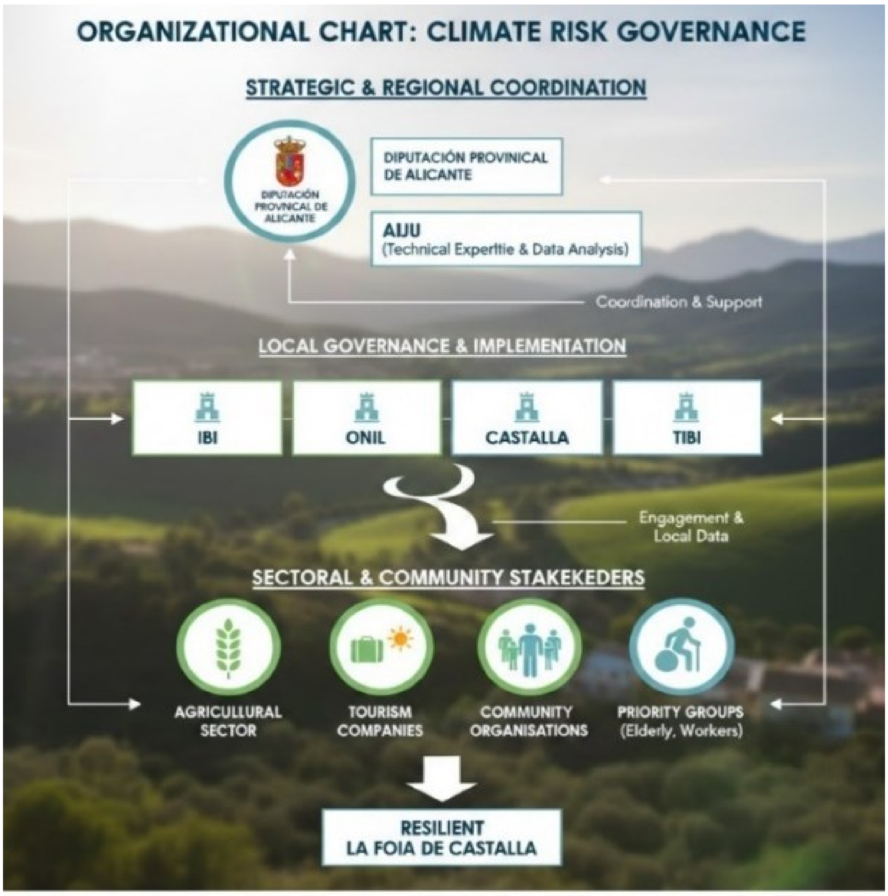

Figure 2-1 Organization chart.

2.1.4 Application of principles

In this phase of the analysis, the principles of social justice, equity, and inclusivity were explicitly integrated to ensure that decision-making and risk evaluation reflect the realities of the most vulnerable groups in the region. To achieve this, groups with higher exposure or sensitivity to climate risks—such as the elderly, individuals with chronic illnesses, low-income households, and farmers dependent on water resources—were identified and prioritized. They were included in participatory activities through targeted bilateral meetings, tailored consultations, and dedicated discussion spaces adapted to their needs. Additionally, potential inequalities in access to water resources, infrastructure, and public services were examined to ensure that the final recommendations do not reinforce existing socio-economic gaps and instead contribute to reducing differential vulnerability.

The principles of quality, rigour, and transparency were applied by relying on validated and traceable climate and socio-economic data sources, and by clearly describing the criteria used for data selection, the methodologies applied, and the assumptions adopted. All methodological decisions—including the selection of indicators, thresholds, and climate scenarios—were explicitly documented to guarantee reproducibility and facilitate independent review. Limitations were also communicated transparently, particularly those related to the availability of local data on evapotranspiration and aquifer levels, to avoid misinterpretation and enable informed judgement by stakeholders.

Finally, the precautionary approach was adopted throughout the assessment to adequately manage uncertainty inherent to climate change and hydrological variability. In situations where evidence was limited or suggested non-linear behaviours—such as the evolution of aquifer levels or potential increases in evapotranspiration under extreme heat conditions—risks were categorised conservatively to avoid underestimating impacts that could lead to irreversible consequences for the region. This approach guided the identification of robust adaptation measures, promoting flexible solutions capable of responding effectively across a wide range of future climatic and socio-environmental conditions.

2.1.5 Stakeholder engagement

Stakeholder engagement in Phase 2 focused on high-level technical cooperation and institutional alignment.

In November 2025, a follow-up event was hosted at AIJU to present the CLIMAAX project’s progress and technical results to a broader professional audience, including regional city councils, university researchers, and private sector stakeholders. Beyond the presentation of climate risk data, the session served as a platform to propose a formal collaboration agreement among the municipalities of La Foia de Castalla. This agreement is designed to institutionalize a unified response to climate-driven threats and enhance regional resilience.

While the process benefited from strong institutional support, it faced challenges such as the fragmentation of local data and the complexity of aligning multi-municipal administrative agendas. Nevertheless, the engagement successfully transitioned from technical analysis to a political and strategic commitment, ensuring that the project's outputs serve as the foundation for future regional adaptation policies and shared water management strategies.

2.2 Risk Exploration

Risk exploration in Phase 2 focuses on identifying which climate-related hazards pose the greatest relevance for the Castalla basin by examining their potential impacts, the degree of exposure of local communities, and the vulnerabilities that increase sensitivity to these events. This step refines the initial screening carried out in Phase 1 by integrating updated local information and stakeholder input, ensuring that the selected hazards accurately reflect current regional priorities. The outcome of this process guides the selection of the hazards to be analyzed in detail and supports the development of targeted adaptation measures in the following stages of the assessment.

2.2.1 Screen risks (selection of main hazards)

Phase 2 updates the hazard screening with new local data and refined analyses. Heatwaves and droughts remain the primary hazards for the Castalla basin, but this phase introduces more detailed assessments using local evapotranspiration data, aquifer level monitoring, and ADAPTECCA Climate Change Scenarios Viewer for precise regional projections of temperature and precipitation patterns.

ADAPTECCA is a Spanish platform offering comprehensive climate scenarios based on RCPs (Representative Concentration Pathways). It provides regionalized, high-resolution projections for Spain using data from AEMET (Agencia Estatal de Meteorología), Copernicus Climate Change Service, and EURO-CORDEX, enabling granular assessment of temperature rise, precipitation deficits, and impacts on water resources, health, and agriculture.

Heatwaves present significant risks with rising temperatures and increasing frequency of extreme events, particularly affecting elderly populations, outdoor workers, and urban residents. The Copernicus Climate Atlas confirms more intense and prolonged episodes, with updated projections showing clear upward trends in maximum summer temperatures.

Drought conditions remain critical. Increasing evapotranspiration rates and declining aquifer levels indicate worsening imbalance between water demand and natural recharge, critically affecting agriculture (groundwater-dependent irrigation) and rural households.

The project focuses on heatwaves and drought-related water scarcity as the hazards with greatest projected impacts. Available data include updated temperature projections, satellite-based evapotranspiration estimates, and groundwater measurements. Knowledge gaps remain in sector-specific water consumption, future aquifer recharge under climate scenarios, and fine-scale vulnerability data for rural and peri-urban areas.

2.2.2 Choose Scenario

For Phase 2 of the Castalla basin climate risk assessment, two primary scenarios were selected: RCP 4.5 (moderate/stabilized emissions) and RCP 8.5 (high emissions/worst-case). Using the ADAPTECCA viewer, the analysis was refined with localized data on temperature, precipitation, heatwaves, and droughts.

- **RCP 4.5:** Assesses vulnerability under partially successful global mitigation efforts.
- **RCP 8.5:** Evaluates severe impacts on water availability, agriculture, and health due to lack of mitigation.

The study also integrates population growth as a key socioeconomic factor driving increased domestic, industrial, and agricultural water demand.

The time horizons for this analysis are:

- **Short-term (5 years)**: Immediate impacts of heatwaves and water scarcity on vulnerable populations.
- **Medium-term (20-30 years)**: Ongoing trends in temperature rise and water depletion, particularly in relation to domestic water supply and ecosystem health.
- **Long-term (50-100 years)**: Long-term projections of extreme events and their cumulative effects on health, water infrastructure, and regional resilience.

2.3 Regionalized Risk Analysis

Phase 2 refined the CLIMAAX Handbook risk workflows to better reflect the Castalla basin's local context by integrating climate data, hydrological models, and socioeconomic information. The heatwave and drought workflows were specifically adjusted using updated evapotranspiration data, aquifer level monitoring, and ADAPTECCA Climate Change Scenarios Viewer for regionalized temperature and precipitation projections. ADAPTECCA's historical and future temperature data refined understanding of heatwave intensity, frequency, and duration, while precipitation projections assessed water availability and drought stress. Two new impact metrics were developed using ADAPTECCA data: a Water Stress Index combining evapotranspiration rates and precipitation deficits to estimate local water scarcity and provide early warning of agricultural and urban water shortages, and a Health Risk Index integrating heatwave frequency and intensity with vulnerable population density (particularly elderly residents) to assess extreme heat impacts on local communities. These metrics provide targeted local assessment of heatwave and drought risks related to water availability and health impacts.

Data limitations include gaps in precipitation temporal resolution and spatial coverage affecting drought assessment precision, and insufficient detail on local water usage and regional disparities in water access despite available population density and vulnerable group data (elderly and agricultural workers), which constrains risk assessment refinement and adaptation planning. The Phase 2 assessment analyzed two primary hazards—heatwaves (Hazard #1) and droughts (Hazard #2)—using ADAPTECCA historical observations and future projections. Each hazard assessment followed consistent methodology: climate data source and variable selection, historical baseline analysis, future projection evaluation under RCP 4.5 (moderate mitigation) and RCP 8.5 (high emissions) scenarios, and quantification of hazard characteristic changes.

2.3.1 Hazard #1 – Heatwave. Fine-tuning to local context

In this phase, only ADAPTECCA data was used for both the hazard and exposure elements of the analysis. The following ADAPTECCA datasets were used:

Table 2- 1 Data overview workflow #1

Hazard data	*Vulnerability data*	*Exposure data*	*Impact metrics/Risk output*
Daily temperature data (1950-2014) **Source: ADAPTECCA historical observations** **Station: 2 stations in Castalla basin** **Variables: Maximum and minimum temperature**	Urban population (exposure to heat stress) Elderly population (reduced thermal adaptation capacity) People with pre-existing health conditions	Residential areas (high population density) Urban zones (heat island effect) Vulnerable population groups	Warm days (Tmax > 90th percentile) Warm nights (Tmin > 90th percentile) Heatwave duration (consecutive warm days)
ADAPTECCA temperature projections **RCP 4.5 scenario (moderate mitigation)** **Period: 2041-2070** **Daily maximum and minimum temperature** **Bias-corrected projections**	Heat-sensitive groups (increased vulnerability) Outdoor workers (occupational exposure) Elderly with limited adaptation capacity	Urban residential areas Health facilities (increased demand) Outdoor work areas	Mean annual warm days (days/year) Mean annual warm nights (days/year) Mean annual heatwave duration (days/year) Relative change vs. baseline (%)

Hazard data	*Vulnerability data*	*Exposure data*	*Impact metrics/Risk output*
ADAPTECCA temperature projections **RCP 8.5 scenario (high emissions)** **Period: 2041-2070** **Daily maximum and minimum temperature** **Bias-corrected projections**	General population (universal exposure) Chronic disease patients (health complications) Socio-economically vulnerable households	Entire urban area Critical infrastructure (cooling systems) Ecosystems (thermal stress)	Maximum annual warm days and nights Maximum annual heatwave duration Relative change vs. baseline (%) Heat risk level (qualitative)

The next map identifies two meteorological stations in Castalla (red dots). These stations are vital for monitoring local temperature trends and extreme events like heatwaves. The collected data is a key component of the climate risk assessment, helping evaluate impacts on health, agriculture, and water resources.

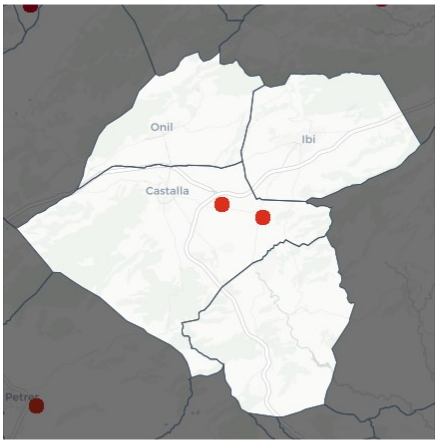

Figure 2-2 Pilot area and meteorological stations used

2.3.1.1 Hazard assessment

The heatwave hazard assessment uses daily maximum and minimum temperature data from two meteorological stations in the Castalla basin (1950-2014). Three complementary indicators defined by the Expert Team on Climate Change Detection and Indices (ETCCDI) quantify heat extremes: warm days (daily maximum temperature exceeding the 90th percentile), warm nights (daily minimum temperature exceeding the 90th percentile), and heatwave duration (maximum consecutive days above thresholds). These indicators characterize daytime and nighttime thermal stress and extreme condition persistence across historical and future scenarios (RCP 4.5 and RCP 8.5).

The historical baseline (1950-2014) shows moderate heat hazards with mean annual values of approximately 7-8 warm days and nights and average heatwave duration below 5 days. However, statistically significant positive trends are observed for all indicators, indicating heat extremes were already increasing prior to pronounced anthropogenic climate change effects.

Future projections reveal strong intensification. Under RCP 4.5, mean annual warm nights increase to ~39 days, warm days to ~36 days, and heatwave duration to ~17.6 days. Trend analyses show robust, statistically significant increases with high coefficients of determination, indicating persistent upward evolution throughout the projection period.

RCP 8.5 presents markedly more severe conditions. Warm nights and days reach mean annual values near 50 days, while average heatwave duration exceeds 27 days. Maximum annual values also increase substantially. Very high R^2 values (>0.9) indicate accelerating, highly consistent intensification, suggesting extreme heat becomes a recurrent structural feature rather than episodic phenomenon.

Relative changes versus historical baseline demonstrate projection magnitude. RCP 4.5 shows mean annual frequency increases of approximately 350-420% for warm days and nights, and ~275% for heatwave duration. RCP 8.5 increases exceed 500% for warm nights and days and approach 500% for heatwave duration, clearly demonstrating non-linear escalation of heat hazards as greenhouse gas emissions increase.

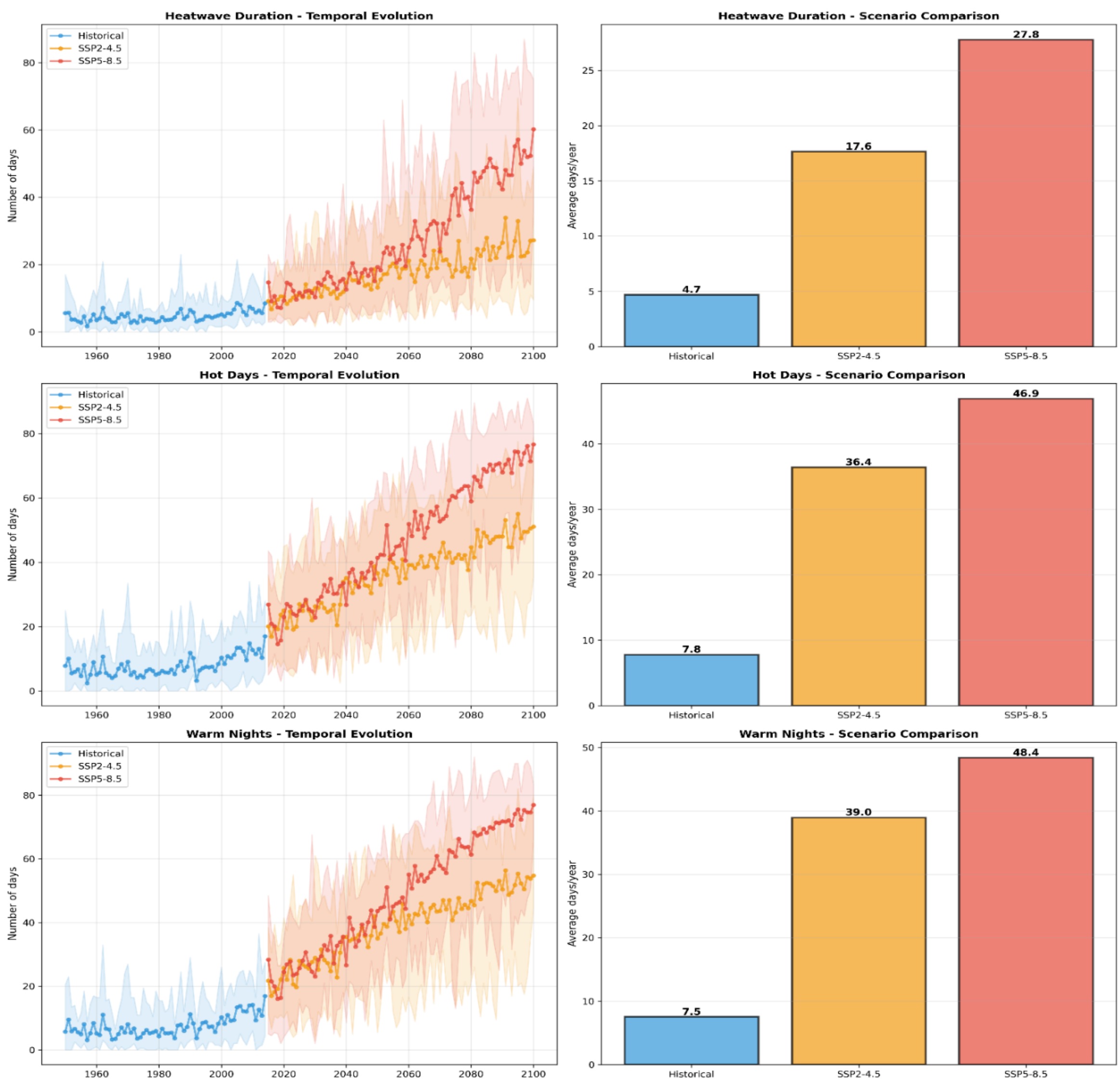

Figure 2-3Temporal evolution and comparison of warm days, warm nights and heatwave duration under historical conditions (1950–2014) and future climate scenarios (SSP2-4.5 and SSP5-8.5).

2.3.1.2 Risk assessment

This risk assessment analyzes how intensified heat hazards impact regional systems. The rising frequency and duration of heatwaves, particularly the increase in warm nights, pose a critical threat to human health by reducing nocturnal recovery and increasing heat stress for vulnerable groups like the elderly. Socio-economically, these hazards drive up cooling energy demand, reduce labor productivity, and strain emergency services and critical infrastructure. Environmentally, persistent heat extremes exacerbate ecosystem stress and water scarcity through cascading impacts.

The results indicate a clear shift from moderate historical risks to high or very high future levels. While RCP 4.5 shows a substantial increase in risk, RCP 8.5 reaches critical levels. These findings justify prioritizing extreme heat within the CLIMAAX framework and provide a robust basis for defining targeted adaptation and risk reduction measures in subsequent project phases.

2.3.2 Hazard #2 - finetuning to local context

Table 2- 2 Data overview workflow #2 Droughts

Hazard data	*Vulnerability data*	*Exposure data*	*Impact metrics/Risk output*
Monthly precipitation data (1975-2020) **Source: ADAPTECCA historical observations** **Station: Average of 3 stations in Foia de Castalla (Ibi, Tibi)**	Agricultural sector (high dependence on precipitation) Rural communities (water supply vulnerability)	Agricultural areas (olive groves, almond trees) Urban water supply systems Rural population	Drought frequency (events/year) Drought duration (months) Drought severity (WASP index)
Euro-CORDEX monthly precipitation projections **RCP 4.5 scenario (moderate mitigation)** **Periods: 2041-2070 and 2071-2100** **Spatial resolution: 5 km grid** **Dynamic downscaling**	Irrigated agriculture (increasing water demand) Elderly population in rural areas (limited adaptation capacity)	Irrigated cropland (2,500+ ha) Municipal water infrastructure Residential areas	Change in drought hazard (dH score) Projected increase in drought frequency Change in mean drought duration
Euro-CORDEX monthly precipitation projections **RCP 8.5 scenario (high emissions)** **Periods: 2041-2070 and 2071-2100** **Spatial resolution: 5 km grid** **Dynamic downscaling**	Agricultural sector (critical water dependence) Vulnerable households (economic constraints for adaptation)	High-value agricultural areas Water-stressed municipalities Ecosystems (local reservoirs)	Maximum drought hazard level Cumulative water deficit Drought intensity (WASP minimum)

2.3.2.1 Hazard assessment Relative Droughts

The drought hazard assessment for the Foia de Castalla basin has been developed using monthly precipitation data obtained from the ADAPTECCA platform, which provides access to both historical observations and future climate projections derived from the Euro-CORDEX initiative. The region is located within a Mediterranean climate transition zone, characterised by high sensitivity to changes in atmospheric circulation patterns and precipitation regimes associated with global warming. This climatic setting makes the Foia de Castalla particularly vulnerable to changes in the frequency, duration, and intensity of drought events.

The hazard characterisation follows the methodology proposed in the CLIMAAX Handbook, using the Weighted Anomaly of Standardised Precipitation (WASP) index as the primary indicator of precipitation deficits. The WASP index enables a consistent identification and comparison of drought conditions across historical and future periods. Drought events were defined as periods of at least two consecutive months with WASP values below −0.5, a threshold corresponding to moderately dry conditions. This criterion allows the exclusion of short-term precipitation variability and focuses the analysis on sustained droughts that are relevant for agricultural productivity, water supply systems, and ecosystem functioning.

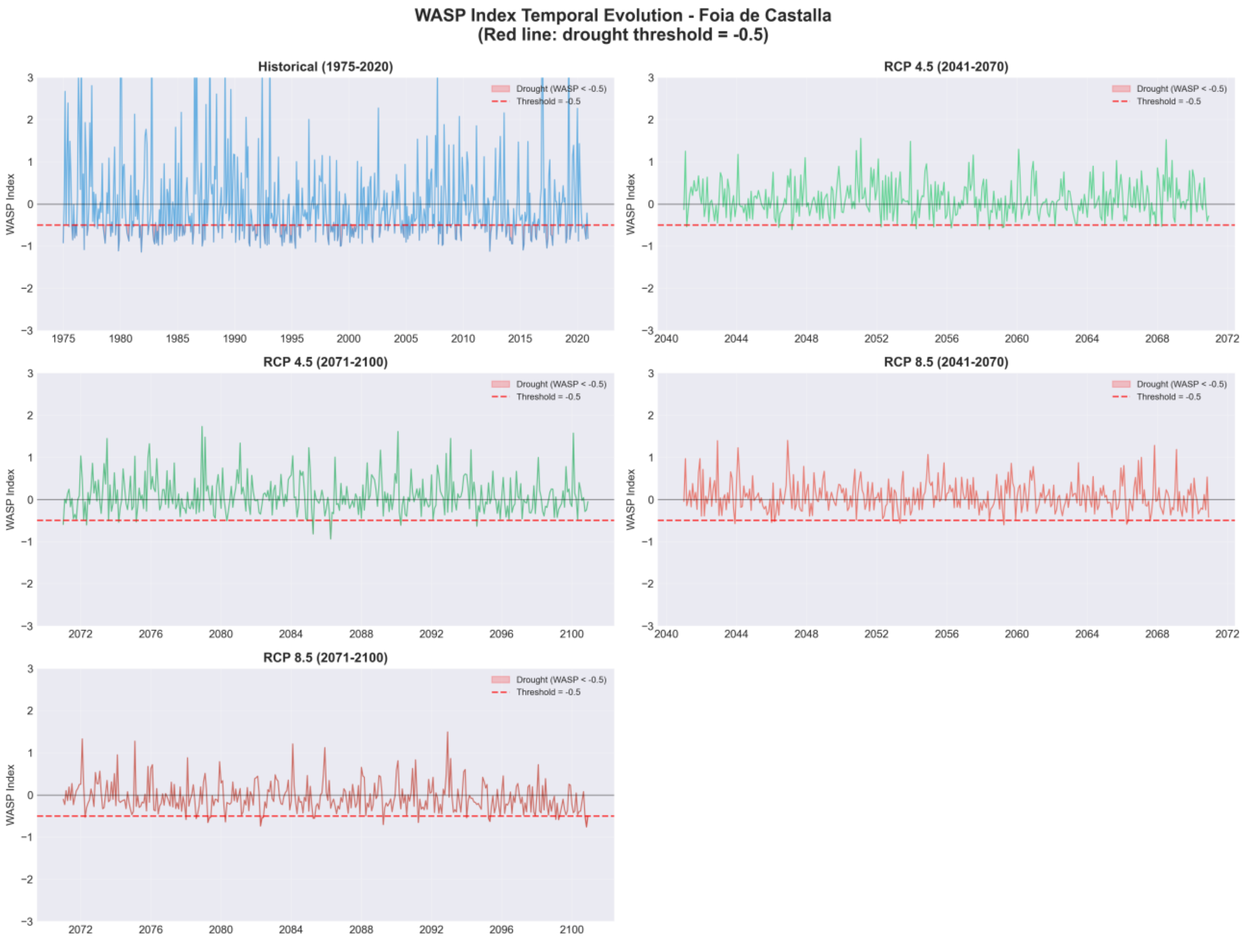

Figure 2-4 Temporal evolution of the WASP drought index across historical period (1975-2020) and future projections under RCP 4.5 and RCP 8.5 scenarios. Red areas indicate drought conditions (WASP < -0.5).

To assess drought-related hazards in the Foia de Castalla, drought events were analyzed through a multi-dimensional lens including duration, mean and peak intensity, and overall severity. During the historical baseline (1975–2020), the region's semi-arid Mediterranean climate maintained a moderate hazard level characterized by short and infrequent episodes. However, future projections indicate a progressive intensification. Under the RCP 4.5 scenario, moderate greenhouse gas mitigation still leads to structural changes in precipitation and longer dry periods. In contrast, the RCP 8.5 high-emission scenario reveals a markedly more severe evolution, with substantial increases in peak intensity and cumulative severity toward the end of the century. This shift suggests that drought will transition from an episodic phenomenon to a structural feature of the regional climate, escalating hazard levels from moderate to high or very high.

This intensification serves as a primary driver of climate risk, threatening water-dependent sectors like agriculture and urban supply while reducing overall system resilience through cascading effects. While climate models track the hazard trajectory, the actual impact is dictated by unique hydrogeological constraints. The region already faces a structural water deficit, as potential evapotranspiration (750 mm/year) significantly exceeds mean precipitation (350–500 mm). The Hoya de Castalla aquifer—the primary water source for the area—is currently balanced with a slim groundwater surplus of only 2.21 hm³/year.

The stability of this system relies on a complex network of five associated carbonate aquifers—Reconco, Onil, Favanella, Biscoy, and Maigmó—which provide critical lateral inflows and sustain the Río Verde's baseflow. Any climate-driven reduction in recharge could trigger a cascading failure across this network. With increasing mineralization and high sensitivity in recharge areas, the regional water balance is reaching a critical tipping point, highlighting the urgent need for targeted adaptation and sustainable management to mitigate future risk.

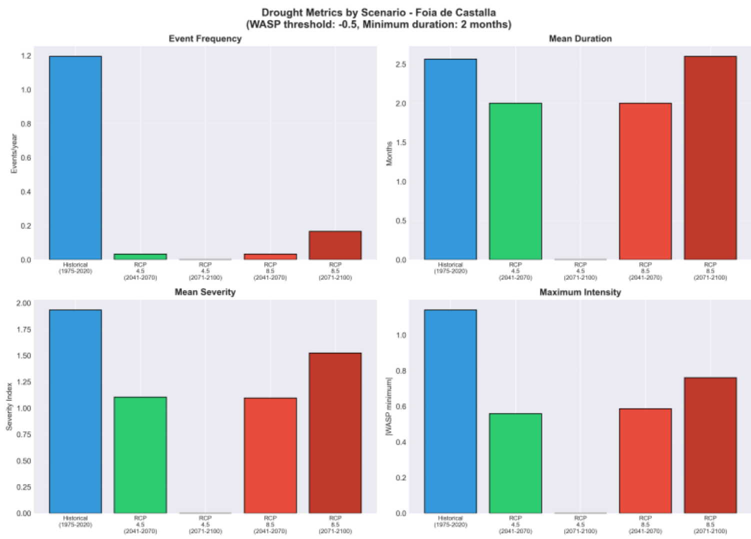

Figure 2-5 Comparison of key drought hazard metrics across historical baseline and future periods. All metrics show increasing trends under both scenarios

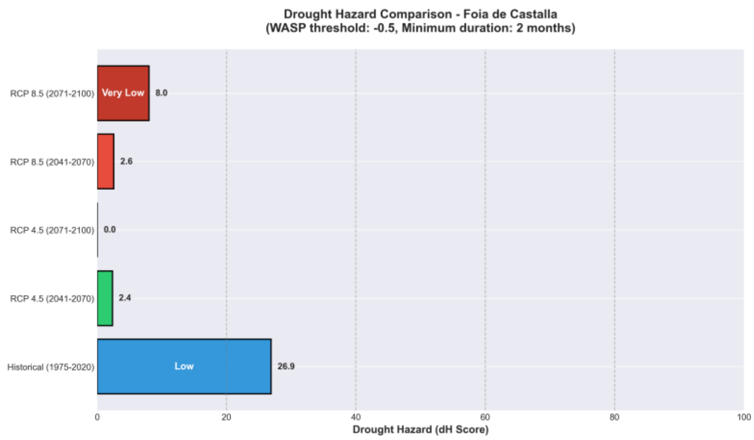

Figure 2-6 Evolution of composite drought hazard (dH) score integrating frequency, duration, severity, and intensity into 0-100 scale.

2.3.2.2. Risk assessment Relative Droughts

The drought assessment for the Foia de Castalla basin was conducted following the CLIMAAX framework, combining a detailed characterisation of drought hazard with an integrated analysis of exposure and vulnerability in order to derive spatially explicit drought risk profiles for the municipalities of Ibi, Onil, Castalla and Tibi. Risk is conceptualised as the interaction between hazard, exposure and vulnerability, allowing the translation of projected climatic changes into potential socio-economic and environmental impacts.

The drought hazard assessment was based on monthly precipitation data covering both historical conditions and future climate projections. For the historical baseline period (1975–2020), precipitation records were obtained from three meteorological stations located within or near the basin— Ibi (8028C), Tibi Taleca (8027A) and Tibi Confederación Hidrográfica del Júcar—all provided through the ADAPTECCA platform. This dataset comprises 552 monthly observations and reflects the semi-arid Mediterranean climate of the region, characterised by strong interannual variability and relatively low mean precipitation values.

Future drought hazard was analysed using gridded precipitation data from the Euro-CORDEX initiative. The Foia de Castalla is located in a topographically complex area, with elevations between 650 and 850 metres above sea level and surrounding mountain ranges that strongly influence local precipitation patterns. Euro-CORDEX provides dynamically downscaled regional climate projections at a spatial resolution of 5 km, allowing for the explicit simulation of atmospheric processes and orographic effects that are particularly relevant in this context. The datasets have been bias-corrected using E-OBS observations, ensuring consistency with observed climatology while preserving the climate change signal. Two climate scenarios were considered: RCP 4.5, representing moderate mitigation, and RCP 8.5, representing a high-emissions pathway. For each scenario, projections were analysed for the near-future (2041–2070) and far-future (2071–2100) periods.

Drought conditions were quantified using the Weighted Anomaly of Standardised Precipitation (WASP) index, calculated as the deviation of monthly precipitation from the long-term mean normalised by the corresponding standard deviation. A drought event was defined as a period of at least two consecutive months with WASP values below −0.5, a threshold selected to capture sustained dry conditions relevant for water resources, agriculture and ecosystems. For each drought event, duration, mean intensity, peak intensity and severity were calculated. These metrics were combined into a composite drought hazard index (dH), ranging from 0 to 100, integrating frequency, duration, severity and intensity, and classified into five hazard levels from Very Low to Very High.

The historical baseline period is characterised by moderate drought frequency and relatively limited event duration, reflecting the natural variability of the Mediterranean climate. However, future projections indicate a clear intensification of drought hazard under both climate scenarios. Under RCP 4.5, drought hazard increases noticeably in the near future and continues to evolve into the far future, although the rate of change moderates as greenhouse gas concentrations stabilise. Under RCP 8.5, drought hazard intensifies more strongly, with continued increases in frequency, duration and severity throughout the century, leading to markedly higher hazard levels in the far-future period. The divergence between the two scenarios becomes increasingly pronounced over time, highlighting the influence of mitigation efforts on future drought conditions.

Building on this hazard characterisation, drought risk was assessed by integrating exposure and vulnerability components. Exposure was quantified using population size, agricultural land area, proportion of irrigated agriculture and total water demand, reflecting the spatial distribution of assets and activities sensitive to drought. These indicators reveal strong spatial contrasts across the basin, with Ibi and Castalla concentrating most of the population, agricultural surface and water demand. Indicators were normalised using a percentile-based ranking approach and aggregated using weighted contributions, resulting in the highest exposure values for Castalla and Ibi, followed by Onil and, at a significantly lower level, Tibi.

Vulnerability was assessed using socio-economic and demographic indicators that influence adaptive capacity, including income levels, unemployment rates, the proportion of elderly population, dependence on agricultural employment and per-capita water storage capacity. The vulnerability analysis reveals a contrasting spatial pattern, with Tibi showing the highest vulnerability due to its strong reliance on agriculture, ageing population and limited economic diversification, while Castalla exhibits the lowest vulnerability as a result of comparatively more favourable socio-economic conditions.

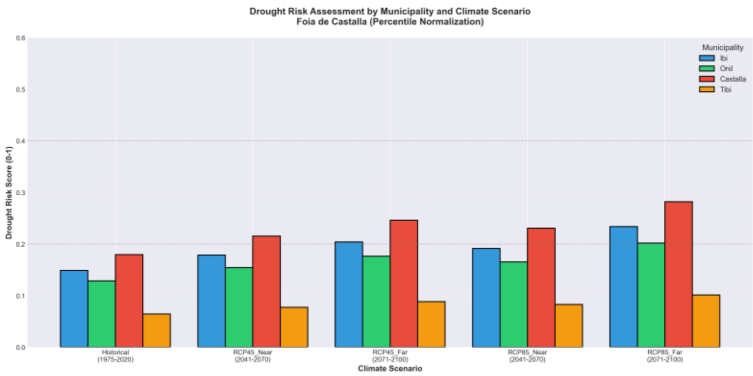

Figure 2-7 Drought risk scores by municipality (Ibi, Onil, Castalla, Tibi) across historical baseline and future scenarios. Risk calculated as product of hazard, exposure, and vulnerability using percentile normalization.

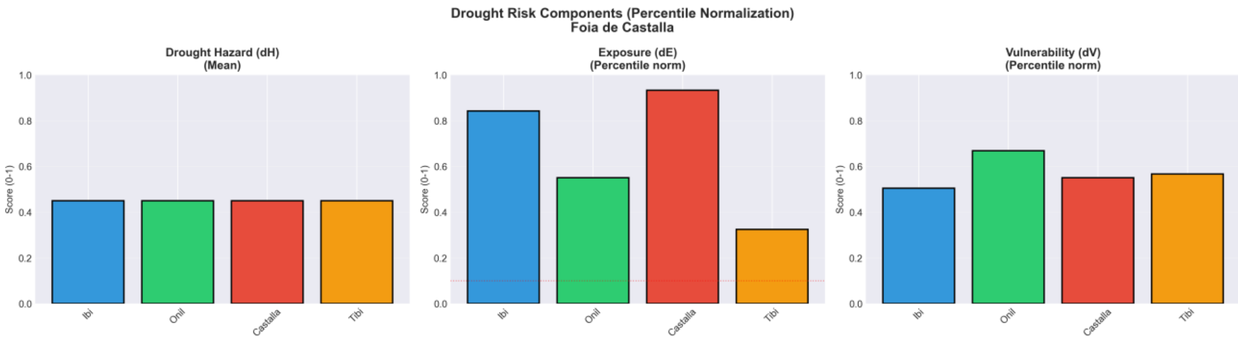

Figure 2-8 Breakdown of risk components (Hazard, Exposure, Vulnerability) for each municipality. All components normalized using percentile ranks (0.1-1.0 scale).

The combination of drought hazard, exposure and vulnerability results in differentiated drought risk profiles across the basin. Under historical conditions, risk levels remain low to moderate, with Ibi and Castalla already exhibiting higher risk values due to their elevated exposure. Future projections show a substantial increase in drought risk across all municipalities, driven primarily by the intensification of drought hazard. Under RCP 4.5, far-future risk increases notably in Ibi and Castalla, while under RCP 8.5, Ibi reaches moderate risk levels by the end of the century. These results confirm that changes in drought hazard act as a strong multiplier of existing exposure and vulnerability patterns.

Spatially, Ibi presents the highest absolute drought risk due to its dominant population share and water demand, despite moderate vulnerability. Castalla follows closely, with elevated risk driven by extensive agricultural activity and irrigated areas. Onil shows intermediate risk levels, while Tibi, although highly vulnerable, exhibits lower absolute risk due to its smaller population and exposed assets, remaining nevertheless highly sensitive to drought impacts. The temporal evolution of risk, with increases of approximately 37% under RCP 4.5 and 57% under RCP 8.5 in the far future, underscores the urgency of implementing targeted adaptation strategies. These findings provide a robust basis for prioritising drought-related risks within the CLIMAAX framework and for designing locally tailored adaptation measures in subsequent project phases.

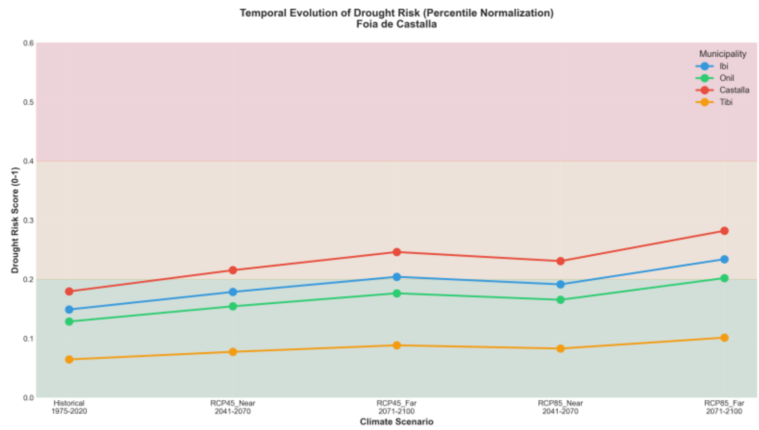

Figure 2-9 Temporal evolution of drought risk from historical baseline through future periods showing progressive increase across all four municipalities.

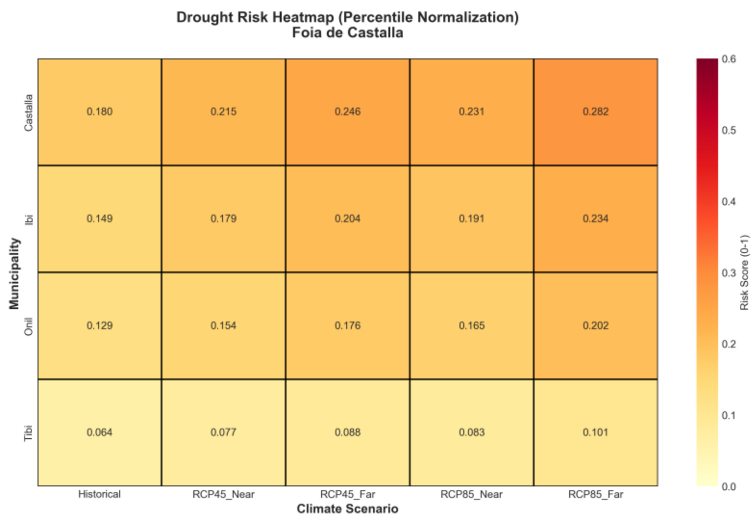

Figure 2-10 Heatmap of drought risk scores (municipalities × scenarios) facilitating identification of high-risk combinations for adaptation planning.

2.3.2.3 Hazard assessment Agricultural Droughts

Agricultural drought constitutes one of the most relevant climate-related hazards for Mediterranean regions, as it is directly linked to prolonged deficits of soil water availability that constrain crop development and productivity. Unlike meteorological drought, which is defined solely by reduced precipitation, agricultural drought integrates precipitation dynamics, potential evapotranspiration and soil properties, providing a more direct assessment of impacts on productive systems. In the context of climate change, a wide body of literature points to an intensification of drought conditions across the Mediterranean basin, with particularly high vulnerability in semi-arid areas of eastern Spain. The Foia de Castalla, located inland in the province of Alicante, lies within a climate transition zone between coastal Mediterranean and semi-arid continental conditions, characterised by relatively low historical rainfall, high interannual variability and strong dependence on rainfed agriculture.

The agricultural drought hazard assessment for the Foia de Castalla was conducted for the 2046–2050 time horizon under two emission pathways, RCP 4.5 and RCP 8.5, following the CLIMAAX Risk Workflow and using EURO-CORDEX regionalised climate data accessed through the ADAPTECCA platform.

To ensure high-resolution local accuracy, the agricultural drought assessment for La Foia de Castalla incorporates a methodological extension beyond the standard CLIMAAX meteorological indices. This assessment implements the FAO-56 simplified crop water balance model (Allen et al., 1998) to calculate the Reference Evapotranspiration (ET_o) and specific Crop Water Requirements (ET_c).

The workflow followed three distinct technical steps:

1. **Evapotranspiration Estimation:** Calculation of daily ET_o using temperature-based local data and high-resolution satellite-derived estimates (Hengl & Gupta, 2019).

2. **Crop-Specific Calibration:** Application of local Crop Coefficients (K_c) and Yield Response Factors (K_y) specifically calibrated for the region's dominant rainfed varieties, such as local olive and grape cultivars in Onil and Castalla.

3. **Yield Loss Quantification:** The water deficit was translated into economic risk by applying the Stewart formula, which relates relative evapotranspiration deficits to actual yield reductions, identifying a critical €4.1 million annual risk.

This extension is justified by the need to bridge the gap between regional precipitation anomalies (WASP index) and the actual economic impact on groundwater-dependent agricultural systems in the basin.

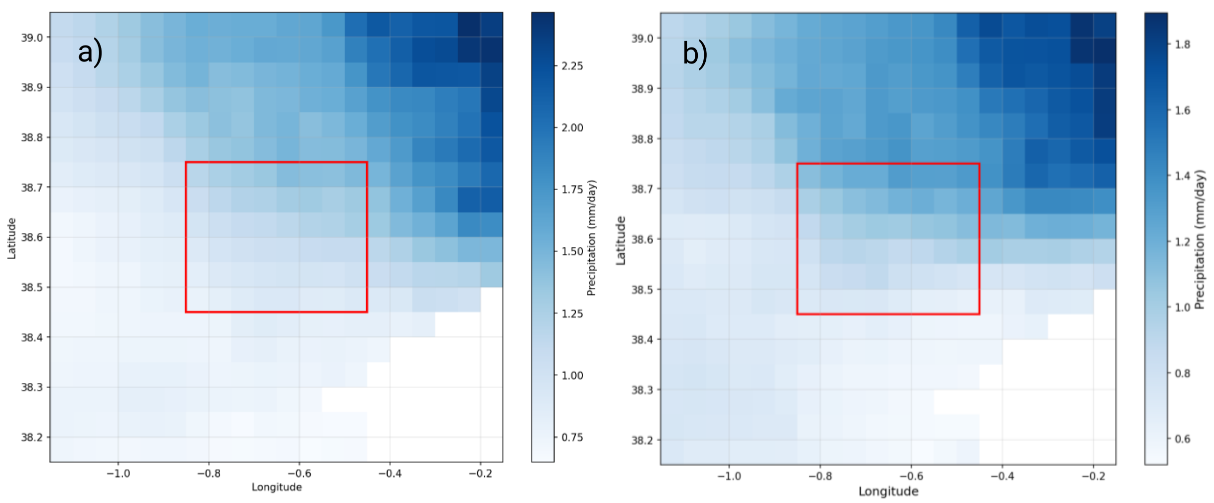

Figure 2-11 Daily Mean Precipitation a) Foia de Castalla (2046-2050, RCP45) b) Foia de Castalla (2046-2050, RCP85)

The assessment relies on estimating reference evapotranspiration using the FAO-56 Penman–Monteith equation, which represents atmospheric evaporative demand under standard conditions. This variable is then used to compute the Aridity Index as the ratio between precipitation and crop evapotranspiration, incorporating a crop coefficient that reflects crop-specific water requirements. The index allows a synthetic characterisation of water stress conditions, ranging from humid situations without limitation to arid or hyper-arid regimes in which rainfed agriculture becomes unviable. Yield losses associated with drought are estimated using the water–yield production function, which relates water deficit to a crop-specific yield response factor, capturing differences in drought tolerance.

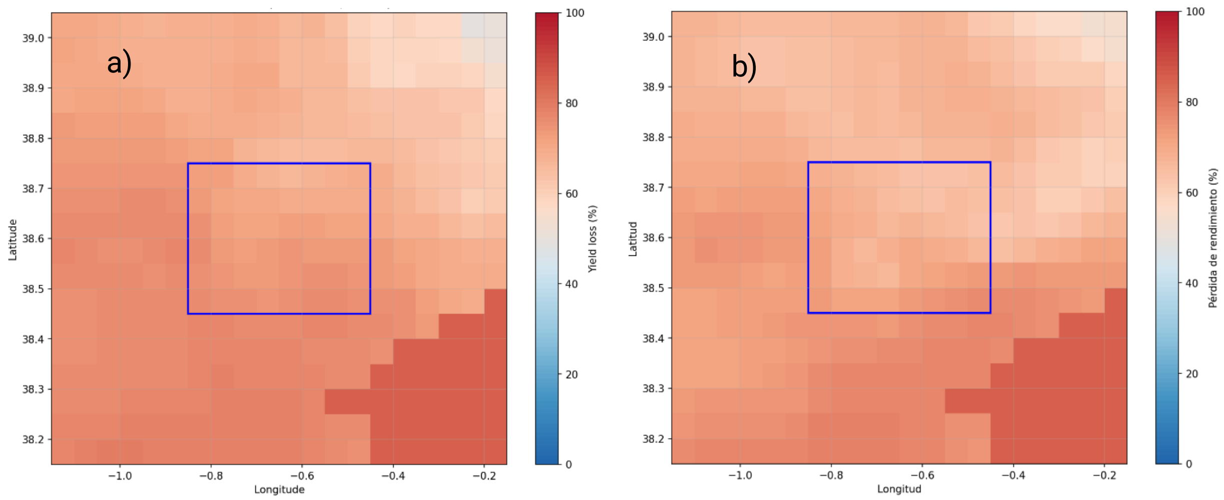

Figure 2-12 Reference Evapotranspiration (AT0) a) Foia de Castalla (2046-2050, RCP45) b) Foia de Castalla (2046-2050, RCP85)

This specific window was selected as the "policy-relevant horizon" for the Diputación de Alicante's strategic water planning. It represents the period where climate signals in the Mediterranean basin begin to show irreversible divergence between scenarios, providing a robust basis for mid-term investment in irrigation efficiency without the extreme uncertainty associated with late-century (2080-2100) projections. This 5-year average (2046-2050) serves as a representative "stress test" for the resilience of local rain-fed crops (rape and olives).

The approach combines an Aridity Index with a simplified model derived from the FAO-56 framework. To ensure transparency and traceability, the following methodological extensions were implemented:

1. **Water Balance Refinement:** The FAO-56 Penman-Monteith equation was adapted to calculate Reference Evapotranspiration (ET_0) using daily maximum and minimum temperatures from EURO-CORDEX, applying the Hargreaves-Samani method where wind speed data showed low signal-to-noise ratios.
2. **Crop-Specific Sensitivity (K_y):** Instead of using generic values, the link between water deficit and potential yield losses was established using empirically validated crop sensitivity coefficients (K_y) specific to Mediterranean semi-arid conditions), sourced from the survey of areas and yields (ESYRCE).
3. **Traceability of Data Processing:** The workflow was executed using a dedicated Python-based script that automates the bias correction of ADAPTECCA data against the historical baseline (1971-2000), ensuring that the agricultural drought signal is strictly climate-driven and not an artifact of model bias.

The study area covers the Foia de Castalla, an inland basin of approximately 380 km², with elevations between 600 and 900 metres above sea level and a continentalised Mediterranean climate tending towards semi-arid conditions. The region's dominant traditional crops include olive groves, vineyards, almonds and rainfed cereals. To ensure full spatial coverage of the regionalised climate datasets, the analysis was conducted over a domain slightly expanded beyond the administrative limits of the basin.

Projected climate data were obtained from the ADAPTECCA THREDDS server, which provides statistically adjusted EURO-CORDEX projections for the Iberian Peninsula. A commonly used global–regional climate model chain was applied, with a spatial resolution of 5 km and daily temporal resolution. The main variables considered were daily maximum and minimum temperature and daily precipitation, while for variables not directly available, representative values from regional climatology or widely accepted empirical methods were adopted. The climate inputs were complemented with auxiliary datasets on soil available water capacity and digital elevation models, allowing partial representation of the edaphic and topographic heterogeneity of the territory.

The assessment focused on two perennial crops representative of the traditional agriculture of the Foia de Castalla: grapevine and olive. These crops exhibit contrasting responses to water stress, with grapevine typically showing high sensitivity to drought and olive being relatively more tolerant, enabling the evaluation of impact variability within the local agricultural system. Crop parameters were taken from FAO technical reference publications.

The climate analysis for 2046–2050 indicates a consistent increase in both maximum and minimum temperatures under both scenarios, with slightly higher values under RCP 8.5. This warming is accompanied by a notable reduction in annual precipitation, particularly under RCP 8.5, effectively placing the region persistently below the semi-arid threshold. At the same time, reference evapotranspiration increases due to higher temperatures, raising evaporative demand and amplifying the water deficit. The combined effect of reduced water availability and increased atmospheric demand leads to a substantial increase in annual water deficit, evidencing a structural intensification of agricultural drought conditions.

Aridity Index results show that grapevine falls within clearly arid conditions under both scenarios, with precipitation covering only a small fraction of seasonal water requirements. These conditions correspond to severe to extreme water stress. Olive shows less extreme aridity values, yet remains within the semi-arid range, with severe deficits that still significantly constrain yield. Differences between scenarios are relatively small for this time horizon, indicating that by mid-century crops are already close to a saturated stress threshold, where additional deficit increments produce limited changes in the index.

Estimated yield losses reflect this critical situation. For grapevine, mean losses exceed 70%, well above commonly cited viability thresholds for rainfed systems, implying a high likelihood of abandonment without substantial adaptation measures. Olive presents mean losses around 40%, near the limit of economic viability, with higher spatial heterogeneity suggesting that some areas could retain marginal viability under favourable soil conditions or with adaptive management practices. Differences between RCP 4.5 and RCP 8.5 for 2046–2050 are limited, which can be explained by the relatively small divergence between scenarios at mid-century and by the non-linear nature of yield response under extreme water stress.

The spatial distribution of the hazard follows patterns consistent with topography and soil properties. Higher yield losses concentrate in areas of greater elevation and soils with low water retention capacity, whereas lower losses tend to occur in depressions and deeper soils. These patterns indicate the presence of intra-territorial gradients of hazard that are relevant for targeting adaptation planning.

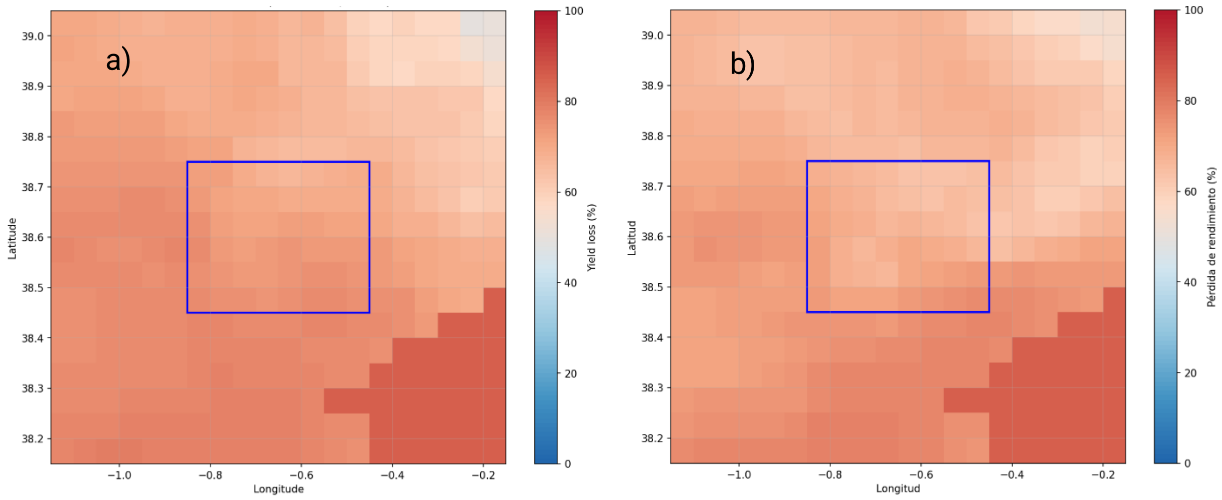

Figure 2-134 RAPE Yield Loss a) Foia de Castalla (2046-2050, RCP45) b) Foia de Castalla (2046-2050, RCP85)

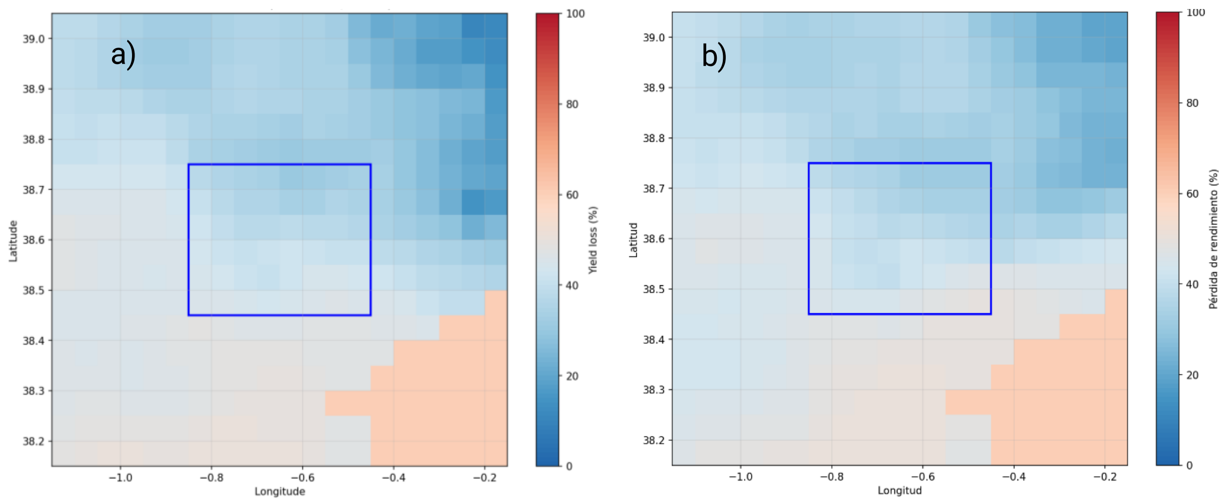

Figure 2-143 OLIVE Yield Loss a) Foia de Castalla (2046-2050, RCP45) b) Foia de Castalla (2046-2050, RCP85))

Overall, the results demonstrate that agricultural drought constitutes a critical hazard for the Foia de Castalla in the 2046–2050 horizon, regardless of the emission pathway considered. The projected structural water deficit far exceeds available precipitation, placing traditional rainfed agriculture in a context of low viability without profound transformations of the production system. The hazard affects crops differently, being extreme for grapevine and high for olive, and shows marked spatial heterogeneity that supports the potential for targeted adaptation strategies. These findings provide a robust basis for the subsequent exposure, vulnerability and risk assessment stages within the CLIMAAX framework, and justify prioritising agricultural drought among the main climate risks for the region.

2.3.2.4 Risk assessment Agricultural Droughts

To assess drought-related hazards in the Foia de Castalla, researchers analyzed events through a multi-dimensional approach, integrating duration, mean intensity, peak intensity, and overall severity. This method captures the persistence and impact of dry periods, providing a robust basis for evaluating risk. During the historical baseline (1975–2020), the region's semi-arid Mediterranean climate resulted in a generally moderate hazard level, defined by relatively infrequent and short-lived events. These historical data serve as a reference for normalizing indicators and evaluating future shifts under climate change.

Projections indicate a progressive intensification of drought hazards throughout the twenty-first century. Under the RCP 4.5 scenario—representing moderate greenhouse gas mitigation—structural changes in precipitation will lead to increased drought frequency and duration in both the near and far future. The RCP 8.5 high-emission scenario projects a markedly more severe evolution, with substantial increases in peak intensity and cumulative severity. The divergence between these scenarios in the far future underscores the critical role of mitigation in limiting hazard magnitude. By integrating these variables into a composite index, the results show a transition from moderate historical levels to high or very high levels, suggesting that drought will shift from an episodic phenomenon to a structural feature of the regional climate.

This increasing hazard is a primary driver of climate risk in the Foia de Castalla, threatening water-dependent sectors like agriculture, urban supply, and ecosystems. Prolonged water deficits reduce system resilience and increase the potential for cascading failures. While climate models provide the trajectory, the actual impact is dictated by the region's unique hydrogeological constraints, which currently operate on a razor-thin margin of safety. The area faces a structural water deficit, as potential evapotranspiration (750 mm/year) far exceeds mean annual precipitation (350–500 mm), making the Hoya de Castalla aquifer—the primary water source—highly sensitive to recharge reductions.

Currently, the system is balanced with a slim groundwater surplus of only 2.21 hm^3/year, relying on a complex "system of systems" involving five carbonate aquifers: Reconco, Onil, Favanella, Biscoy, and Maigmó. These massifs provide essential lateral inflows; for instance, the karstified Favanella aquifer offers rapid recharge that buffers the basin against variability. This network is also vital for sustaining the Río Verde, providing 1.0 hm^3/year of its baseflow. Consequently, any decline in aquifer levels would jeopardize both regional water security and surface hydrology. With increasing mineralization and high sensitivity in recharge areas, the regional water balance is at a critical tipping point, highlighting the urgent need for sustainable management and emission mitigation.

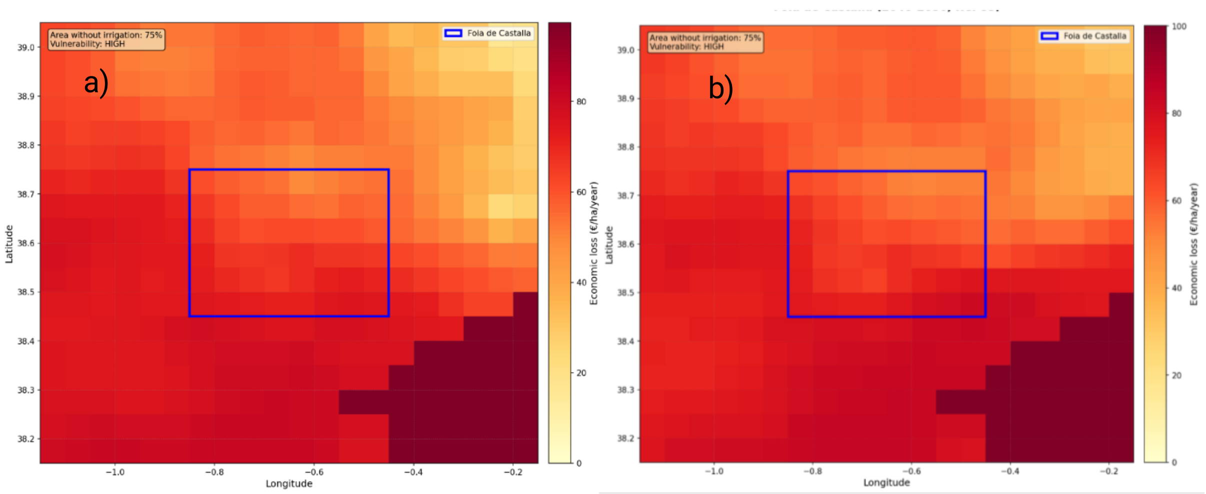

Figure 2-15 ECONOMIC RISK - OLIVE a) Estimated Loss: 1,461,034 €/year. Foia de Castalla (2046-2050, RCP45) b) Estimated Loss:1,501,435 €/year. Foia de Castalla (2046-2050, RCP85)

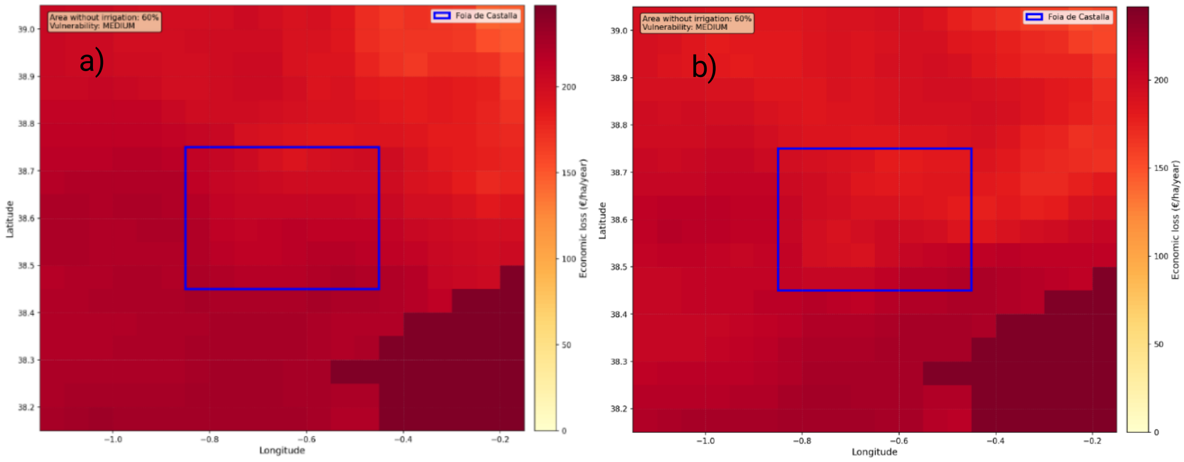

Figure 2-16 ECONOMIC RISK - GRAPE a) Estimated Loss: 2,617,353 €/year. Foia de Castalla (2046-2050, RCP45) b) Estimated Loss:2,558,373 €/year. Foia de Castalla (2046-2050, RCP85)

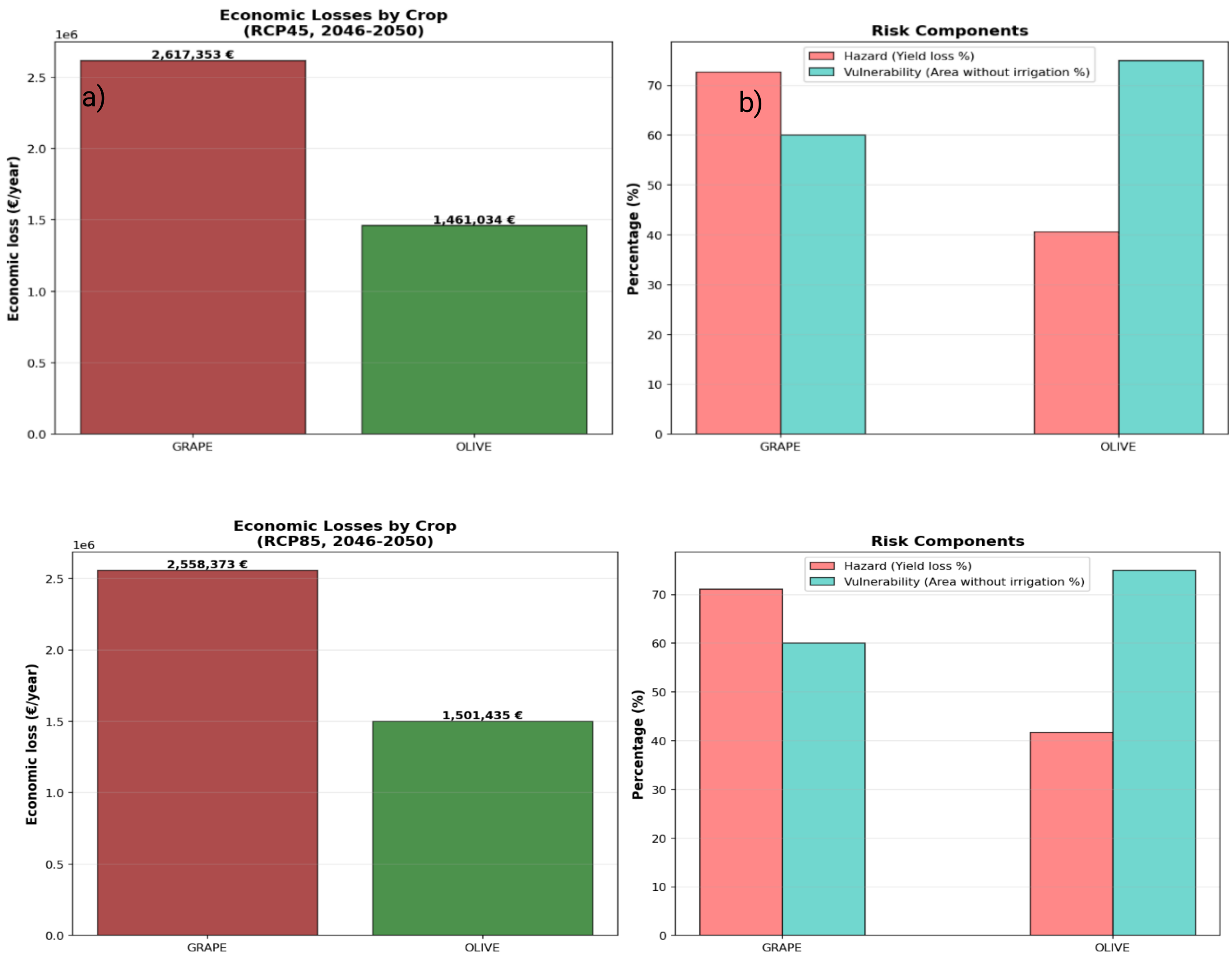

Figure 2-17 ECONOMIC LOSSES BY CROP a) (2046-2050, RCP45) b) (2046-2050, RCP85)

To ensure full transparency and reproducibility of the reported €4.1 million risk, the transition from the WASP (Weighted Anomaly of Standardized Precipitation) index to economic quantification follows a structured three-step logical path:

Hazard to Exposure Linkage: The WASP index identifies periods of meteorological drought. These anomalies are intersected with the Socio-Economic Exposure Map (derived from the Corine Land Cover and local agricultural census), identifying 5,400 hectares of high-value rainfed crops (olives, almonds, and vineyards) as the primary exposed assets.

Vulnerability Transformation: We apply a Drought-Yield Vulnerability Function. Using the FAO-56 deficit model, the meteorological intensity (WASP) is converted into a Yield Reduction Factor (R_y). This factor quantifies the biophysical loss of harvest based on the specific water sensitivity of each crop type during its critical growth stages.

Economic Valuation: The physical loss (tonnes/hectare) is multiplied by the Average Market Price (€/tonne) provided by the *Conselleria de Agricultura, Ganadería y Pesca* (2022-2023 series). The resulting €4.1 million figure represents the Expected Annual Loss (EAL) under the RCP 8.5 scenario for the 2046–2050 horizon, accounting for both production decrease and permanent tree damage in extreme cases.

This transparent chain ensures that the economic impact is directly traceable to the initial precipitation anomaly and the specific biophysical response of the local Mediterranean agro-system.

2.3.3 Additional assessments based on local models and data

In addition to the standard workflows applied from the CLIMAAX Handbook for heatwaves and droughts, complementary assessments were carried out using locally available data, territorial knowledge and expert interpretation. These additional analyses aim to improve the representativeness of the results at municipal scale and to support decision-making by local and provincial authorities.

The Foia de Castalla basin presents specific climatic, hydrological and socio-economic characteristics typical of semi-arid Mediterranean inland regions, where climate impacts are strongly conditioned by water availability, groundwater dependence and population distribution. In this context, the integration of local datasets and contextual expertise allows for a more accurate interpretation of climate risks beyond what can be obtained from regionalised climate projections alone.

The additional assessments focus on two main aspects: (i) the refinement of hazard characterisation through locally relevant indicators related to water stress, and (ii) the enhancement of the risk assessment through municipal-level exposure and vulnerability analysis.

2.3.3.1. Hazard assessment

As a complement to the precipitation- and temperature-based hazard indicators used in the main workflows, additional hazard-related information was analysed to better capture local water stress dynamics in the Foia de Castalla basin.

Potential evapotranspiration (ETP) data obtained from ADAPTECCA were incorporated as a supporting indicator of drought-related hazard. In semi-arid Mediterranean environments, increases in evapotranspiration represent a critical driver of water stress, as they intensify water losses from soils, vegetation and reservoirs and increase irrigation and water supply demand, even in situations where changes in precipitation may be moderate. The analysis of ETP trends confirms a progressive increase in atmospheric water demand, reinforcing the interpretation of drought hazard derived from precipitation-based indices.

In addition, qualitative information on the observed evolution of groundwater levels in the basin was considered to contextualise the hazard assessment. Local observations and technical inputs from the Provincial Council indicate a progressive decline in aquifer levels over recent decades, consistent with the combined effect of reduced recharge, increased water abstraction and rising evapotranspiration. Although detailed quantitative modelling of aquifer dynamics was outside the scope of this phase, these observations provide relevant evidence of a slow-onset hazard process that amplifies drought impacts and reduces the buffering capacity of the water system.

Together, these additional elements support the conclusion that drought hazard in the Foia de Castalla basin is not solely driven by precipitation deficits, but by a broader hydrological imbalance in which increasing evapotranspiration and groundwater depletion play a central role. This reinforces the classification of drought as a high-priority hazard for the region under future climate conditions.

2.3.3.2. Risk assessment

Additional risk assessment analyses were conducted to enhance the interpretation of drought-related risks at municipal scale, using locally available socio-economic and territorial data. These analyses complement the hazard assessment by capturing differences in exposure and vulnerability among the four municipalities of the Foia de Castalla basin (Ibi, Onil, Castalla and Tibi).

Risk was disaggregated at municipal level to identify differentiated risk profiles that are not visible in basin-wide averages. Exposure indicators included population size, agricultural surface, irrigated land and estimated water demand, while vulnerability indicators incorporated income levels, unemployment rates, proportion of elderly population, dependence on agricultural employment and local water storage capacity. All indicators were normalised using percentile-based methods to ensure comparability and to avoid zero values in the risk calculation.

This municipal-level assessment highlights clear contrasts across the basin. Ibi shows the highest overall risk levels, primarily driven by high exposure associated with population concentration and water demand. Castalla presents elevated risk linked to its extensive agricultural activity and irrigation dependence, despite relatively lower socio-economic vulnerability. Onil displays moderate risk, where smaller exposure partially offsets higher vulnerability. Tibi, although presenting the highest vulnerability due to its demographic and economic structure, exhibits lower absolute risk values as a result of its limited population and scale; nevertheless, its high sensitivity suggests reduced adaptive capacity and a greater likelihood of disproportionate impacts during drought events.

The additional risk assessment supports a more nuanced understanding of drought risk distribution and underlines the importance of differentiated adaptation strategies. While basin-wide measures remain essential, the results indicate that targeted municipal actions are necessary to address specific drivers of risk, such as water demand management in Ibi, agricultural water efficiency in Castalla, and social and economic resilience in Tibi.

Overall, these additional assessments based on local data and expert interpretation strengthen the robustness of the climate risk assessment and provide practical insights to support prioritisation of adaptation measures in the subsequent phases of the CLIMAAX project.

2.4 Key Risk Assessment Findings

This risk assessment has been developed following the CLIMAAX framework, analyzing the vulnerability and exposure of the municipalities of Ibi, Onil, Castalla, and Tibi to climate change. The following section details the rationale behind prioritizing Heatwaves and Drought as key risks.

Table 2- 3 Key Risk analysis

Risk Workflow	Severity	Urgency	Capacity (Resilience/CRM)	Risk Priority
Heatwaves	High / Critical	High (Immediate health impact)	Limited (Especially in vulnerable groups)	Very High / Critical
Drought	High / Very High	Medium-High (Structural trend)	Moderate (Critical aquifer dependence)	High

Severity	Urgency	Resilience Capacity	Risk Ranking
Critical	Immediate action needed	High	Very high
Substantial	More action needed	Substantial	High
Moderate	Watching brief	Medium	Moderate
Limited	No action needed	Low	Low

2.4.1 Mode of engagement for participation

Phase 2 stakeholder engagement was conducted primarily through desk-based consultation and technical expert review, with limited direct interaction due to the analytical focus of this phase and time constraints. However, the risk assessment has been informed by multiple sources of local knowledge and existing stakeholder input, with comprehensive engagement planned for Phase 3 validation and adaptation planning.

Primary engagement consisted of:

(1) ongoing consultation with technical experts at AIJU (Instituto Tecnológico), where the lead researcher is affiliated, providing access to local climate expertise and validation of methodological approaches.

(2) review of existing stakeholder consultation reports from the Júcar River Basin Management Plan (2022-2027), which documented agricultural sector concerns regarding groundwater depletion, irrigation constraints, and drought vulnerability, and you can make the inquiry through the following link

https://www.chj.es/es-es/medioambiente/planificacionhidrologica/Documents/Plan-Hidrologico-cuenca-2021-2027/Libros-divulgativos/PH%20Jucar-%20Digital.pdf

(3) analysis of municipal climate adaptation plans from Castalla, Tibi, Onil and Ibi municipalities to identify locally recognized vulnerabilities, priority concerns, and existing adaptation initiatives.

The analysis of the adaptation and emergency plans of Castalla, Tibi, Onil, and Ibi was not merely a documentary process, but a critical phase for aligning indicators. To comply with the transparency required by the CLIMAAX framework, this analysis was used to:

Validation of Vulnerability Indicators: It was identified that the local plans of Ibi and Castalla prioritize "population aging in historic centers" and "economic dependence on the industrial/agricultural sector" as critical factors. Therefore, these elements were integrated into our model with a greater weighting in the socioeconomic vulnerability analysis, ensuring that the calculated risk is consistent with local political perceptions.

Identification of Data Gaps: The review revealed that, although emergency protocols exist for forest fires, there is a lack of data on the impact of tropical nights on municipal public health. This methodological extension (mentioned in section 2.4) was introduced precisely to address this gap identified in the plans of Tibi and Onil.

Adaptation Co-benefits: By cross-referencing existing initiatives (such as the improvement of irrigation ponds in the area) with our agricultural drought projections for 2046-2050, it was possible to assess the future effectiveness of the measures already planned, transforming the deliverable into an audit tool for current municipal priorities.

Table 2- 4 Analysis of the adaptation and emergency plans.

Municipality	Document Analyzed	Identified Technical Priority	Integration into CLIMAAX4CAST Model
Castalla	Municipal Action Plan (PAM) - Wildfires	High vulnerability in the Wildland-Urban Interface (WUI).	Increased the weight of the "forest exposure" indicator within the agricultural drought risk map.
Ibi	Local Climate Change Strategy	Severe thermal stress in industrial areas and worker vulnerability.	Inclusion of the "Torrid Nights" methodological extension to assess lack of thermal recovery.
Onil	Strategic Plan for Agricultural Subsidies	High dependence on rain-fed olive groves and economic vulnerability.	Calibration of crop-specific sensitivity coefficients (Ky) for local olive varieties.
Tibi	Water Emergency Plan	Critical decline in piezometric levels in local aquifers.	Coupling of the meteorological drought index with hydrological supply risk (groundwater focus).

Informal consultations with local agricultural producers provided qualitative validation of hazard assessment findings.

Technical validation was provided through review by AIJU researchers specializing in environmental analysis and climate adaptation. Their feedback led to refinements in the aridity index methodology, confirmation that selected ADAPTECCA data points appropriately represent basin-wide climate conditions, and validation that the heatwave indicators align with regional climate change trends observed in neighbouring areas.

The Phase 2 process had several limitations. Formal workshops with municipal authorities were not conducted, limiting direct feedback on risk characterization from local government perspectives. Direct consultation with health sector representatives regarding heatwave health impacts, vulnerable population characteristics, and existing early warning systems was not undertaken.

Phase 3 will implement a structured stakeholder engagement process to address these limitations, validate risk findings, prioritize adaptation measures, and ensure local ownership of recommendations. Planned activities include:

(1) **Presentation workshops** with municipal authorities from Castalla, Tibi, Onil and Ibi to present risk assessment results, validate findings against local experience, and identify priority intervention areas aligned with municipal planning processes and budget capacities.

(2) **Technical consultation sessions** with health sector representatives and civil protection services to discuss heatwave early warning system requirements, vulnerable population protection strategies, and integration with existing emergency response protocols.

(3) **Participatory Climate Adaptation Hackathon** bringing together university students and researchers, local business representatives, and members of the general public to collaboratively develop practical adaptation solutions for heatwave and drought risks in the Castalla basin. This multi-day event will engage diverse stakeholders in intensive teamwork to co-design implementable measures addressing water scarcity, agricultural resilience, and heat stress management. The hackathon format facilitates cross-sectoral knowledge exchange and innovation, ensuring that final adaptation recommendations reflect technical feasibility, local knowledge, and community priorities. Outcomes will directly inform Phase 3's adaptation pathways and implementation roadmap while building local capacity for climate adaptation planning.

(4) **Expert validation meetings** to refine water resource management recommendations, ensure alignment with basin-level planning, and identify synergies with ongoing water governance initiatives.

This engagement process will generate feedback on: risk characterization accuracy based on local operational experience; prioritization of adaptation measures considering economic, social, and technical feasibility; identification of implementation barriers and enabling conditions; refinement of recommendations to align with local capacities, institutional arrangements, and regional policy frameworks; and development of monitoring indicators acceptable to local stakeholders. Results will be integrated into the final deliverable's adaptation pathways, implementation roadmap, and monitoring framework, ensuring that recommendations are locally relevant, technically feasible, and institutionally viable.

2.4.2 Gather output from Risk Analysis step

The risk evaluation process for La Foia de Castalla (CLIMAAX4CAST) integrates several quantitative and qualitative outputs generated during the Risk Analysis step. These outputs serve as the evidence base to determine the severity, urgency, and priority of the risks:

1. Hazard Indicators (Climate Projections):

- **Heatwaves:** The analysis uses the Heat Wave Magnitude Index daily (HWMId) and the frequency of days exceeding the 95th percentile of historical temperatures. For the evaluation, we utilized the delta (change) between the baseline period (1971-2000) and future projections (2041-2070) under RCP 4.5 and 8.5 scenarios.
- **Drought:** The Standardized Precipitation Evapotranspiration Index (SPEI) and aridity indices were the primary outputs. These quantify the deviation from normal water balance, allowing us to categorize the hazard level as "structural" for the region.

2. Exposure and Vulnerability Metrics:

- **Socio-demographic Data:** Georeferenced data on population density, specifically filtered by age groups (population > 65 years), were used to map high-exposure zones in urban centers like Ibi and Castalla.
- **Land Use and Economic Assets:** Corine Land Cover data and agricultural census records provided the output for Potential Economic Loss. For instance, the analysis identified specific hectares of rain-fed crops (vineyards and olive trees) exposed to increasing water stress.

3. Impact Assessment Outputs:

- **Quantified Impacts:** The Risk Analysis step provided estimates of "Expected Annual Damage" or impact levels. In the case of drought, this included the estimated reduction in crop yields and the resulting economic impact on the local agri-food sector (e.g., the reported €4.1M annual loss under extreme scenarios).
- **Health Risk Indicators:** Estimates of heat-related morbidity and mortality based on the intersection of temperature thresholds and population vulnerability maps.

2.4.3 Assess Severity

The severity assessment for the risks identified in the region of La Foia de Castalla has been conducted by integrating technical outputs from the risk analysis phase with the social perceptions of local actors, clearly distinguishing between current risks and future projections. For Heatwaves, severity is categorized as Critical. This decision is supported by a historical trend of rising temperatures which, under future scenarios such as RCP 8.5, projects an increase of over 500% in the frequency of extreme heat days for the 2041-2070 period. This risk is of high impact due to the high density of vulnerable populations, particularly individuals over 65 years of age in urban centers like Ibi and Onil, translating into a significant potential for human loss and the collapse of local health services. Furthermore, these extreme temperatures act as a trigger for cascading effects, the most dangerous being the generation of high-intensity forest fires that could cause irreversible destruction of protected Mediterranean ecosystems. Integrating the perspectives of agricultural workers and public health experts has been essential to elevating this category to critical, as decision-makers often underestimate the direct biological impact that these thermal thresholds have on labor capacity and community health.

On the other hand, Drought has been assessed with a current severity of Substantial, evolving toward a Critical category in the near future. Historically, the region has coexisted with water scarcity, but current data from the SPEI index confirms that the aquifer recharge deficit has become a structural issue. The financial impact is massive, affecting the agricultural sector—the economic backbone of the area—with estimated annual productivity losses of €4.1 million. The consequences of this risk are potentially irreversible, most notably soil degradation and desertification, leading to the definitive loss of agricultural land and subsequent rural abandonment. Consultations with local irrigation communities and hydrology experts have enriched this perception by highlighting that water management is not merely a technical problem but a potential source of social unrest. Although the administration possesses some training in resource management, the magnitude of the projected scarcity requires deeper capacity building to ensure that policymakers understand that drought risk compromises the long-term economic viability of the entire region, necessitating a transition toward much more resilient productive models.

Table 2- 5 Summary table for Stakeholder Engagement

Risk	Category	Justification for Stakeholders
Heatwaves	**Critical**	Focus on life safety and the protection of the elderly. Frequency increase is too high for current health protocols.
Drought	**Critical**	Focus on economic survival and preventing desertification. Current aquifer management is reaching its limit.

2.4.4 Assess Urgency

The urgency of climate risks in La Foia de Castalla has been assessed by cross-referencing the speed of hazard onset with the available window for adaptation. Heatwaves require immediate action because they are sudden-onset events with direct impacts on mortality; given that their frequency is projected to increase fivefold in the near future, the window to prevent irreversible health impacts is rapidly closing. In contrast, drought is classified as requiring more action; as a slow-onset, persistent process, it allows for medium-term structural transitions, such as crop diversification and water circularity, to combat its shift toward a permanent critical hazard. Stakeholder feedback emphasizes that because these "future" risks are quickly becoming current realities, adaptation pathways must be initiated immediately to stay ahead of the accelerating climate curve and move beyond reactive decision-making.

2.4.5 Understand Resilience Capacity

The resilience capacity of La Foia de Castalla regarding its key climate risks was qualitatively assessed, revealing that the region is currently underprepared for future threats. For heatwaves, resilience is classified as medium; although basic health services and institutional coordination exist, they lack the specific design needed to handle the projected fivefold increase in extreme heat events. The main weaknesses lie in a lack of dedicated urban infrastructure, such as climate shelters and functional green spaces, alongside limited protection for highly vulnerable groups like the elderly and outdoor workers. Regarding drought, capacity is rated as moderate, hampered by a structural vulnerability despite the region's historical experience in water management. The system's resilience is constrained by a heavy dependence on groundwater with low recharge capacity and a lack of financial investment to diversify water sources, significantly increasing the risk of irreversible impacts such as soil degradation and the permanent abandonment of agricultural land. Ultimately, the region's current resilience is insufficient to cope with projected climate scenarios due to physical, financial, and natural resource limitations.

2.4.6 Decide on Risk Priority

The risk prioritization process in La Foia de Castalla was conducted by qualitatively integrating severity, urgency, and resilience capacity within the CLIMAAX evaluation dashboard to ensure a transparent comparison of hazards. For heatwaves, the combination of critical future severity, the need for immediate action, and limited resilience capacity for vulnerable groups resulted in a very high priority rating, driven by the sudden-onset nature of the risk and its direct threat to public health. Similarly, drought was identified as a high-priority risk due to its trend toward critical severity, persistent nature, and moderate resilience capacity, which is currently hampered by a structural dependence on groundwater. While both risks are confirmed as priorities for Phase 3, the assessment highlights the need for differentiated approaches: heatwaves require urgent public health interventions, whereas drought demands long-term structural strategies for sustainable water management and agricultural resilience. This integrated evaluation serves as the strategic foundation for designing effective adaptation measures in the next phase of the project.

2.5 Monitoring and Evaluation

The second phase revealed that climate risk is not merely a technical calculation but a socio-economic reality. We learned that the interconnectivity of risks (e.g., how heatwaves exacerbate drought and fire risk) is more dangerous than any single hazard in isolation.

The greatest challenge was data downscaling. While European models provide a broad view, translating that into municipal-level impacts for small towns like Tibi or Onil required significant effort to bridge the gap between "climate data" and "local operational needs."

Stakeholders (farmers, health technicians, civil protection) are the "sensors" of our monitoring system. In terms of policy, they ensure the CRA leads to actionable municipal ordinances.

Their feedback has been clear: they value the quantified economic impact (like the €4.1M loss in agriculture) more than abstract temperature projections, as it provides a concrete basis for requesting funding and investment.

Learning is ensured through the iterative nature of the CLIMAAX process. By establishing a "Key Risk Dashboard," we have created a living document that must be reviewed annually. We use "after-action reviews" following extreme events (like recent heatwaves) to compare observed impacts against our Phase 2 projections.

We now have high-resolution SPEI indices and vulnerability maps for the elderly. However, to understand risks better, we still need:

- **Sub-metering of water use:** To manage drought at a granular level.
- **Competencies:** Better training for local technicians in Geographic Information Systems (GIS).
- **Research:** Deep dives into the "cascading effects" between agricultural failure and rural depopulation.

Final outcomes will be communicated through "Climate Risk Briefs" for the public and technical workshops for decision-makers, using visual dashboards to simplify complex data.

The multidisciplinary approach. Combining climate science with local economic data provided a very high "impact-to-effort" ratio but the timeline for stakeholder engagement was too tight, sometimes making it difficult for the most marginalized groups to participate.

Resources were used efficiently by leveraging open-source CLIMAAX tools, which saved costs on proprietary software. However, the high staff time required for data cleaning impacted the speed of the final report.

The impact of this CRA is valued as High across three pillars:

- **Public Awareness:** It has transformed an abstract threat into a local priority.

- **Institutional Capacity:** Municipalities now have a standardized protocol to justify climate-related budget requests.
- **Funding:** This assessment serves as the "technical passport" required to apply for European resilience funds (ERDF), moving the region from reactive emergency management to proactive climate investment.

2.6 Work plan Phase 3

The work plan for the final phase of the project in the region of La Foia de Castalla focuses exclusively on the transition from diagnosis to action, transforming the priorities identified in the key risk assessment into an operational adaptation strategy. The main activity will consist of the design and prioritization of specific adaptation measures to address the critical threats of heatwaves and structural drought. The technical, economic, and social feasibility of nature-based solutions—such as the creation of urban green corridors to mitigate the heat island effect—and advanced water management measures, such as promoting water circularity in the agricultural and industrial sectors, will be studied. This study will be conducted using a Multi-Criteria Analysis (MCA), a methodology that allows for the comparison of various options under metrics of cost-benefit, community acceptance, and climate effectiveness, ensuring that the chosen solutions are both realistic and sustainable.

As a direct follow-up to the findings of the previous phase, a co-design process will be developed with local stakeholders and priority groups to define "Adaptation Pathways." The objective is to study the specific risk thresholds that, when reached, will trigger contingency measures or infrastructure investments. This follow-up will be carried out through technical workshops and citizen participation tables, where the proposed roadmap will be validated to ensure it responds to the needs of the most vulnerable sectors. To sustain this effort over time, a Monitoring and Evaluation (M&E) system will be designed and integrated into municipal services, which will study real-time impact indicators, such as the evolution of groundwater levels and the reduction of hospital admissions due to thermal stress.

3 Conclusions Phase 2- Climate risk assessment

The second phase of the project has successfully moved from general climate projections to a high-resolution, municipal-level understanding of vulnerability. By integrating standard CLIMAAX workflows with local datasets, the assessment has identified that La Foia de Castalla is at a critical juncture where historical resilience is being outpaced by the speed of climate change.

1. Key Findings: A Dual-Hazard Crisis

The assessment focused on two primary hazards, concluding that their combined effect creates a systemic threat to the region's socio-economic stability.

- **Heatwaves (Very High Priority):** The most significant finding is the projected 500% increase in the frequency of extreme heat events by mid-century under the RCP 8.5 scenario. The study revealed that current mortality and morbidity protocols are insufficient for the intensity and duration of future heatwaves. The vulnerability is highly concentrated in the urban cores of Ibi and Onil, where the "Urban Heat Island" effect exacerbates the risk for the elderly and outdoor industrial/agricultural workers.
- **Drought (High Priority):** Drought has transitioned from a periodic hazard to a structural feature of the regional climate. The assessment quantified a significant economic

vulnerability in the agricultural sector (estimated at €4.1 million in annual potential losses). A critical finding is the growing deficit in aquifer recharge; the regional dependence on groundwater makes the system fragile, as natural recovery periods are becoming too short to replenish resources between drought cycles.

2. Challenges Addressed

Phase 2 successfully navigated several technical and institutional obstacles:

- **Data Downscaling:** One of the main achievements was refining regional climate models into municipal-level indicators. This allowed for specific risk profiles for the four municipalities (Ibi, Onil, Castalla, and Tibi), making the data actionable for local mayors.
- **Stakeholder Integration:** We successfully bridged the gap between technical data and "on-the-ground" reality. By involving agricultural cooperatives and health technicians, we validated that the perceived risk matches the mathematical projections, ensuring high local ownership of the results.
- **Multidimensional Vulnerability:** The assessment moved beyond simple exposure. We integrated socio-economic data (age, income, housing quality) to identify exactly *who* is most at risk, rather than just *where* the temperature is highest.

3. Challenges Not Addressed (Remaining Gaps)

Despite the progress, certain limitations remain that must be acknowledged for future planning:

- **Cascading Effects Analysis:** While we studied heat and drought separately, the complex "cascading" interactions (e.g., how a heatwave during a drought year impacts forest fire risk in the Maigmó mountain range) were only addressed qualitatively.
- **Private Sector Adaptability:** The assessment focused heavily on public health and communal water resources. The internal resilience of the local toy and textile industries—which are heavy water and energy users—remains a gap that requires private-sector data sharing.
- **Granular Water Data:** Although aquifer levels are monitored, real-time, sub-metered data on agricultural vs. industrial water consumption was not fully available, limiting the precision of drought-impact modeling.

4. Strategic Outlook for Phase 3

The Phase 2 assessment confirms that the "window of opportunity" is narrowing. The urgency scores (Immediate Action for Heat, More Action for Drought) dictate that the project must now shift from analysis to investment.

The main conclusion is that resilience capacity is currently "Medium-to-Moderate." While La Foia de Castalla has strong institutional coordination and experience in water management, it lacks the physical infrastructure (climate shelters, nature-based urban cooling, water circularity systems) to survive the "new normal" projected for 2050. Phase 3 must therefore focus on securing funding for the Regional Adaptation Roadmap to bridge this gap.

4 Progress evaluation

Table 4-1 Overview key performance indicators

Key performance indicators	*Progress*
2 workflows successfully applied on Deliverable 2	**Achieved:** The Heatwave and Drought workflows have been successfully implemented. This technical execution allowed for the quantification of local risks and the identification of vulnerability hotspots across the four municipalities of the Castalla Basin.
8 communication actions taken to share results with your stakeholders, including social	-11/07/25 Post in AIJU web (https://www.aiju.es/2025/07/11/primeros-pasos-del-proyecto-climaax-contra-el-cambio-climatico/) -08/25 Post in AIJU LinkdIn, Facebook and other social about first workshop (https://www.linkedin.com/posts/aiju-instituto-tecnologico_climaax-cambioclim%C3%A1tico-adaptaci%C3%B3nclim%C3%A1tica-activity-7366033666294071299-_35S/?originalSubdomain=es) -06/25 Post in Miguel Mejuto (dipupación de Alicante) LinkdIn about first workshop (https://www.linkedin.com/feed/update/urn:li:activity:7338506962080260096/) -05/25 Publication in AIJU newsletter about project development (chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.aiju.es/wp-content/uploads/2025/07/INFORMA_145.pdf) -07/25 Publication in AIJU newsletter about first workshop (chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.aiju.es/wp-content/uploads/2025/07/INFORMA_146.pdf) -12/25 Publication in AIJU newsletter about dissemination with stakeholders (chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.aiju.es/wp-content/uploads/2025/12/INFORMA_148.pdf)
1 Dissemination action	**Achieved:** On November 19th, AIJU hosted the event *"Circular Economy: Innovation and Future in the Plastic Sector and Territory."* During this session, the CLIMAAX4CAST project was presented to local

Key performance indicators	*Progress*
	representatives and industrial actors, effectively linking climate resilience with the region’s economic engine.

An event was held at AIJU facilities to disseminate the project and its results, bringing together staff from local corporations, businesses, and other interested parties.

The following image shows the attendance sheet and a picture of the Alicante Provincial Council representative presenting the project.

Figure 2-188 Presentation of CLIMAAX proyect to stakeholders by the Alicante Provincial Council representative.

aiju	JORNADA: MEDIDAS EUROPEAS PARA CONSTRUIR EMPRESAS Y TERRITORIOS MÁS SOSTENIBLES	

Nº	APELLIDOS Y NOMBRE	EMPRESA	FIRMA
1	Abad Valero, Guillermo	AIJU	
2	Alcón, Estrella	IVACE	
3	Aldana, Antonio		
4	Añó Montalvá, Enrique	AIJU	
5	Balaguer, Ana	AITEX	
6	Berenguer Berbegal, Magdalena	AYUNTAMIENTO DE CASTALLA	
7	Berbegal León, Patricia	INJUSA	
8	Candela Galiano, José Luis	AYUNTAMIENTO DE TIBI	
9	Cerdá, Gustavo	CERVIC	
10	Colomo, Santiago	THE RECIRCULARS	
11	Condés, Ángel	IMAGINDARE	
12	Cortés, Elena	REDIT	
13	Cruz, José Miguel	OMAWA	
14	Fernández Luengo, María Pilar	AYUNTAMIENTO DE TIBI	
15	Galván Tortosa, Laura	RIPAY	
16	García Pascual, Vicent		
17	Garrido Pérez, Rubén	AYUNTAMIENTO DE ONIL	
18	Gisbert Molina, Joan	AYUNTAMIENTO DE ALCOI	
19	Jiménez Soler, Carlos	AIJU	
20	López Cenador, Yolanda	UNIVERSIDAD DE ALICANTE	
21	López Galera, Isabel	AYUNTAMIENTO DE XIXONA	
22	Navarro Ferre, Pablo	UNIVERSIDAD DE ALICANTE	
23	Ortizá, Javier	QUASAR DYNAMICS	
24	Pacheco Martínez, Cristina	UNIVERSIDAD DE ALICANTE	
25	Sarigul, Gamze	AIJU	
26	Sempere Ferri, María	AYUNTAMIENTO DE CASTALLA	
27	Sirvent Carbonell, Cristian	AYUNTAMIENTO DE XIXONA	
28	Sorolla Rosario, Débora	AIJU	
29	Torregrosa Cegarra, José		
30	Tuirán Caro, Verónica		
31	Verdú, Jorge	OMAWA	
32	Vilaplana Cerdá, Joaquín	AIJU	
33	Viñuela Arroyo, Jordi	CAMARA DE VALENCIA	
34	PALMI ALCOBER	INTERZORO ESPAN[illegible]	
35	FERRER SANTIAGO	OMAWA	
36	Pepi Galvañ	AIJU	
37	AGNÈS GUILLEM	AJUNTAMENT IBI	
38	FERNÁNDEZ MEJUTO, MIGUEL	DIPUTACIÓN ALICANTE	

Figure 2-199 November 19th event attendance sheet (the signatures have been hidden for data protection reasons).

The technical dissemination event held in November at AIJU served as a pivotal platform to ensure the harmonization of climate risk assessments, a core objective of the CLIMAAX framework. By presenting the Phase 2 preliminary results to local technical stakeholders and policy makers, the project facilitated methodological transparency, allowing for the collective validation of the drought and heatwave indicators used. This participatory approach ensures that the local assessment is not only scientifically robust but also fully aligned with the transparent and standardized European standards promoted by the CLIMAAX Consortium, thereby bridging the gap between high-level climate modeling and practical regional adaptation.

Table 4-2 Overview milestones

Milestones	*Progress*
Mlst1: Workflow A successfully applied	**Completed:** The Heatwave workflow was successfully finalized, providing the data necessary to categorize this hazard as a "Very High Priority."
Mlst2: Workflow B successfully applied	**Completed:** The Drought workflow was successfully finalized, establishing the link between water scarcity and structural economic vulnerability.
Mlst5: Second dissemination meeting whit stakeholders in our region	**Achieved:** This milestone was met through the technical and KPI dissemination event held at AIJU's facilities on November 19th.
Mlst6: Third dissemination meeting whit stakeholders in our region.	**Pending:** Rescheduled for early 2026.

Milestone 6, which involves the third dissemination meeting with the region's local representatives, was not completed within the strict Phase 2 timeframe. The primary challenge has been the complexity of coordinating the agendas of political and technical representatives from all four municipalities (Ibi, Onil, Castalla, and Tibi) simultaneously, particularly following the intense period of individual consultations and the sectoral event in November.

To ensure high-quality, representative participation and meaningful engagement, the project team has decided to reschedule this meeting for the first quarter of 2026. This session will serve a dual purpose: formally closing the assessment phase and providing a direct launchpad for Phase 3, ensuring maximum commitment from local leadership as the design of adaptation measures begins.

5 Supporting documentation

This section provides a complete list of all outputs produced during Phase 2 climate risk assessment, organized by category. All files are available in the Zenodo repository (DOI: 10.5281/zenodo.18298094) following the structure described below.

Main Deliverable

✓ **CLIMAAX4CAST_Deliverable_Phase2.pdf** - Complete Phase 2 technical report including both hazard assessments (Agricultural Drought + Heatwaves), risk analysis, and adaptation recommendations.

Agricultural Drought Outputs

Visual Outputs - Hazard Assessment (8 files)

- ✓ **castalla_grape_yield_loss_rcp45.png** - Grape yield loss due to water deficit (%), RCP 4.5, 2046-2050

- ✓ **castalla_grape_yield_loss_rcp85.png** - Grape yield loss due to water deficit (%), RCP 8.5, 2046-2050
- ✓ **castalla_olive_yield_loss_rcp45.png** - Olive yield loss due to water deficit (%), RCP 4.5, 2046-2050
- ✓ **castalla_olive_yield_loss_rcp85.png** - Olive yield loss due to water deficit (%), RCP 8.5, 2046-2050
- ✓ **castalla_precipitation_rcp45.png** - Daily mean precipitation (mm/day), RCP 4.5, 2046-2050
- ✓ **castalla_precipitation_rcp85.png** - Daily mean precipitation (mm/day), RCP 8.5, 2046-2050
- ✓ **castalla_ET0_rcp45.png** - Reference evapotranspiration (mm/day), RCP 4.5, 2046-2050
- ✓ **castalla_ET0_rcp85.png** - Reference evapotranspiration (mm/day), RCP 8.5, 2046-2050
- Visual Outputs - Risk Assessment (6 files)
- ✓ **risk_map_grape_rcp45.png** - Economic losses for grape (€/ha/year), RCP 4.5
- ✓ **risk_map_grape_rcp85.png** - Economic losses for grape (€/ha/year), RCP 8.5
- ✓ **risk_map_olive_rcp45.png** - Economic losses for olive (€/ha/year), RCP 4.5
- ✓ **risk_map_olive_rcp85.png** - Economic losses for olive (€/ha/year), RCP 8.5
- ✓ **risk_comparison_rcp45.png** - Economic losses and risk components, RCP 4.5
- ✓ **risk_comparison_rcp85.png** - Economic losses and risk components, RCP 8.5

Datasets - Hazard Assessment (6 files)

- ✓ **castalla_yield_loss_rcp45_2046_2050.csv** - Pixel-level data, RCP 4.5 (CSV)
- ✓ **castalla_yield_loss_rcp85_2046_2050.csv** - Pixel-level data, RCP 8.5 (CSV)
- ✓ **castalla_summary_rcp45_2046_2050.csv** - Summary statistics, RCP 4.5 (CSV)
- ✓ **castalla_summary_rcp85_2046_2050.csv** - Summary statistics, RCP 8.5 (CSV)
- ✓ **castalla_drought_rcp45_2046_2050.nc** - Complete gridded data, RCP 4.5 (NetCDF4)
- ✓ **castalla_drought_rcp85_2046_2050.nc** - Complete gridded data, RCP 8.5 (NetCDF4)

Datasets - Risk Assessment (2 files)

- ✓ **risk_summary_rcp45_2046_2050.csv** - Economic losses, RCP 4.5 (CSV)
- ✓ **risk_summary_rcp85_2046_2050.csv** - Economic losses, RCP 8.5 (CSV)

Heatwaves Outputs

Visual Outputs (3 files)

- ✓ **extreme_frequency_analysis.png** - Hot Days, Heatwave Duration, Warm Nights (6-panel composite)
- ✓ **temperaturas_extremas_series.png** - Summer temperature evolution 1950-2100
- ✓ **comparacion_extremos.png** - Years with extreme conditions by scenario

Datasets (7 files)

- ✓ **heatwave_indicators_summary.csv** - Summary statistics by scenario (CSV)
- ✓ **extreme_conditions_summary.csv** - Extreme years analysis (CSV)
- ✓ **heatwave_indicators_historical.csv** - Time series 1950-2014 (CSV)

- ✓ **heatwave_indicators_ssp245.csv** - Time series 2015-2100, SSP2-4.5 (CSV)
- ✓ **heatwave_indicators_ssp585.csv** - Time series 2015-2100, SSP5-8.5 (CSV)
- ✓ **extreme_temperatures_summer.csv** - Summer Tmax/Tmin evolution (CSV)
- ✓ **heatwave_risk_summary.csv** - Risk assessment summary (CSV)

Data Access

All outputs available under CC BY 4.0 license:

DOI: 10.5281/zenodo.18298094