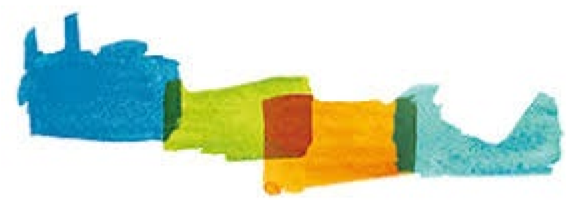
Deliverable Phase 1 – Climate risk assessment

Climate Resilient crETE (CRETE)



Greece, Region of Crete

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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

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Document Information

Deliverable Title	Phase 1 – Climate risk assessment
Brief Description	This deliverable presents the results of the first phase of the CRA for Crete under the CLIMAAX project. It provides a structured analysis of drought and flood risks, applying standardized methodologies from the CLIMAAX framework to identify hazard-prone areas, assess vulnerabilities, and inform regional adaptation strategies. The document includes an overview of the methodology, datasets used, key findings, stakeholder engagement outcomes, and identified data gaps. It highlights challenges encountered in the assessment process and outlines next steps for refining risk evaluations in future project phases.
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Region/Municipality	Region of Crete
Leading Institution	Technical Univeristy of Crete
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Table of contents

List of figures

List of tables

Abbreviations and acronyms

Abbreviation / acronym	Description
CRETE CLIMAAX	Climate Resilient crETE CLIMAAX project
CRA	Climate Risk Assessment
RAAP	Regional Adaptation Action Plan of Crete
LLRO	Local Land Reclamation Organizations

Executive summary

This report presents the results of the first phase of the Climate Risk Assessment (CRA) for Crete under the CLIMAAX project. The assessment focuses on two key climate hazards, droughts and floods, using standardized methodologies from the CLIMAAX framework. The primary goal is to identify high-risk areas, assess vulnerabilities, and provide actionable insights to support regional adaptation planning and policy development.

The analysis confirms that Crete faces increasing risks from both droughts and floods.

- Drought Risk: The assessment of relative drought and agricultural drought highlights that Heraklion and Lasithi are the most vulnerable regions. Long-term projections under high-emission scenarios (SSP585) indicate a significant increase in drought severity, affecting water availability, agricultural yields, and economic stability. Olive cultivation, a key economic sector, is particularly at risk, with estimated revenue losses exceeding €75,000 per grid cell in central and eastern Crete under future climate conditions.
- Flood Risk: Crete is highly susceptible to flash floods, particularly in urban centers near river systems and coastal tourism zones due to human intervention in stream pathways. However, due to limitations in the CLIMAAX methodology along with the island's small catchments, future flood risk projections were not feasible, and historical flood data lacked sufficient resolution to capture localized flash flood hazards. Despite these constraints, past flood events, such as the 2019 floods, provide clear evidence of the severe impact of flooding on infrastructure, economic activities, and public safety.

While the CRA successfully applied standardized risk assessment workflows, key challenges remain:

- The use of global datasets introduced uncertainties, particularly in irrigation infrastructure and socio-economic vulnerability factors for drought assessments. Similarly, the flood risk assessment lacked high-resolution hydrological modelling to capture flash flood dynamics.
- The absence of detailed human intervention in stream pathways on coastal areas and land-use data limited the accuracy of flood impact estimations. For droughts, competition over water resources from different sectors, such as tourism and agriculture, requires further integration into vulnerability assessments.
- The consultation process highlighted the need for improved risk communication and the inclusion of local expertise in refining risk models. Stakeholders emphasized the urgency of addressing water scarcity and the need for proactive land-use planning to mitigate flood risks in expanding urban and coastal areas.

The next phase of the CLIMAAX project will focus on refining risk assessments using higher-resolution local datasets, improving flood modelling techniques, and strengthening stakeholder engagement. The findings of this and subsequent reports will contribute to the revision of Crete's Regional Climate Change Adaptation Plan (2026+), ensuring that adaptation measures align with the latest climate risk projections.

The first phase of the climate risk assessment has established a critical foundation for understanding the evolving risks in Crete. The insights gained will be instrumental in guiding policy decisions, enhancing climate resilience strategies, and securing future investments in sustainable water management and flood protection infrastructure. Further refinements in methodology and data integration will ensure that the next phase of the project delivers more precise and actionable climate risk assessments.

1 Introduction

1.1 Background

Crete, the largest island in Greece, is uniquely positioned in the Mediterranean, where its climate, economy, and ecosystems are increasingly vulnerable to climate change. The island experiences a Mediterranean climate, characterized by warm, dry summers and mild, wet winters. However, long-term climate trends indicate rising average temperatures, shifting precipitation patterns, and an increased frequency and intensity of droughts (Koutroulis et al., 2011; Tramblay et al., 2020). Crete is also highly susceptible to flash floods, driven by its steep topography, localized heavy rainfall, and expanding urban areas. Climate change projections indicate an increase in the frequency and intensity of extreme precipitation events, particularly in autumn and winter (Diakakis et al., 2012; Koutroulis et al., 2010). Short-duration, high-intensity rainfall events cause rapid runoff, overwhelming drainage systems and triggering severe flash floods (Grillakis et al., 2016; Kreibich et al., 2022). These challenges pose severe risks to water resources, agriculture, infrastructure, and public safety, demanding urgent adaptation strategies (Tsanis et al., 2011).

Crete's economy is highly dependent on climate-sensitive sectors, particularly agriculture, tourism, and water resources, which are increasingly impacted by climate-related hazards. Agriculture, in example, is a key pillar of Crete's economy dominated by olive cultivation, which extends across the island's lowland and mid-altitude zones (Figure 1-1). Olive production is especially vulnerable to rising temperatures, prolonged droughts, and reduced water availability, leading to lower yields and increased irrigation demands. The 2022–2023 and 2023–2024 hydrological years have marked two successive years of severe drought, placing additional stress on agricultural productivity and rural livelihoods.

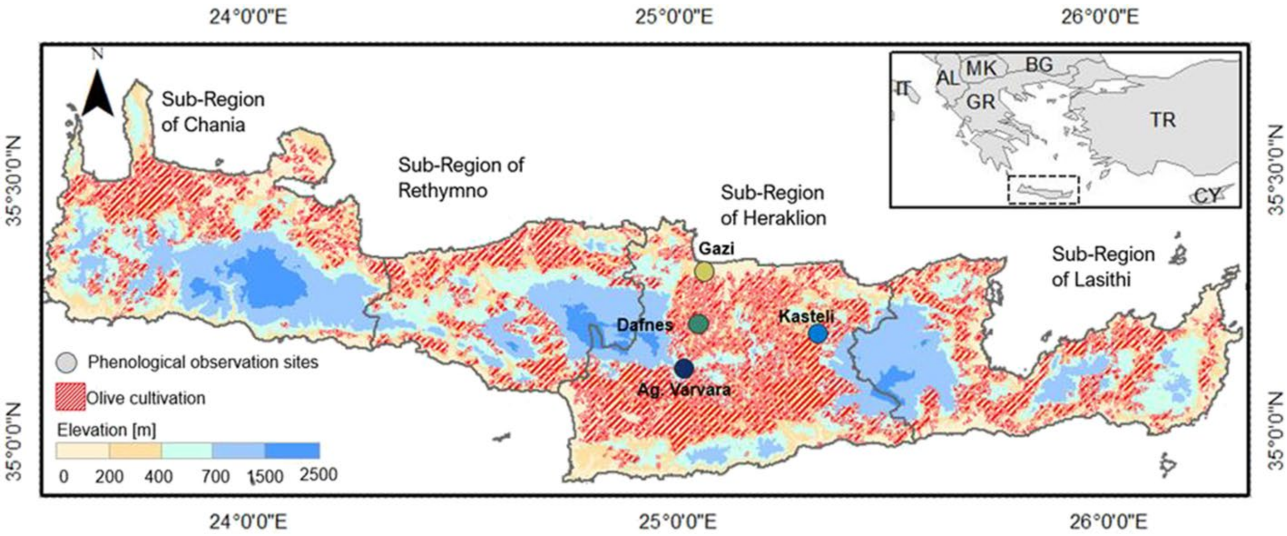


Figure 1-1: Olive cultivation zones across Crete Island (Grillakis et al., 2022)

In parallel, water security is under increasing pressure, with declining precipitation levels affecting both surface and groundwater reserves. Reservoirs have seen critically low water levels, intensifying competition between agriculture, domestic supply, and tourism demand, especially during the peak summer months. In addition to drought risks, Crete is highly susceptible to flash floods, particularly in urban and low-lying coastal areas. Flash floods have caused significant damage to infrastructure, homes, and agricultural land, disrupting local communities and leading to substantial economic losses. These extreme weather events highlight the growing risk of climate-induced disruptions across multiple sectors.

Desertification is another major concern, driven by both climate change and human activities, leading to a gradual decline in land productivity and biodiversity. This process threatens food security, economic stability, and natural ecosystems, further emphasizing the need for comprehensive climate adaptation measures.

Recognizing these escalating risks, the Region of Crete is committed to enhancing climate resilience through structured risk assessment and adaptation planning. The Crete 2030 Development Plan, a €7.7 billion initiative supported by the European Investment Bank, envisions a climate-resilient future through major infrastructure projects and investments in sustainable development. Integrating climate risk assessment into this strategy is essential to protect critical sectors, safeguard communities, and align with national and European climate adaptation objectives.

Through the CLIMAAX project, Crete is taking a proactive approach to assessing and mitigating climate risks by applying advanced methodologies and data-driven solutions.

1.2 Main objectives of the project

The main objective of the CRETE-CLIMAAX project is to enhance the region's capacity to assess and respond to climate risks, particularly focusing on droughts and floods. By leveraging the CLIMAAX Climate Risk Assessment Framework, the project aims to accelerate Crete's transformation into a climate-prepared region and contribute to the EU Mission on Adaptation to Climate Change, which targets 150 climate-resilient European regions by 2030.

The specific objectives of the project include:

- Strengthening climate resilience across all priority sectors by integrating adaptation measures into sustainable development strategies.
- Enhancing the administrative capacity of the Region of Crete to coordinate climate risk management efforts effectively.
- Improving decision-making processes related to climate adaptation, ensuring that policies and actions are evidence-based and aligned with local needs.
- Improve risk awareness among local stakeholders.

The project is implemented in two phases:

- Phase 1 – Application of the CLIMAAX framework to conduct a multi-risk assessment, focusing on droughts, floods, heatwaves, and wildfires, while fostering community and institutional engagement.
- Phase 2 – Development of a high-resolution assessment for drought and flood risks, comparing results from Phase 1 and the Regional Adaptation Action Plan of Crete, to refine strategies based on local climate conditions and socio-economic factors.

The CLIMAAX framework and toolbox provides scientific guidance, standardized methodologies, and risk quantification tools to support the selection of adaptation measures. This structured approach helps overcome current challenges, such as limited technical expertise in climate risk assessment and the need for better coordination within Crete's administrative structures.

Community engagement is also a key pillar of the project, ensuring that local stakeholders, policymakers, and citizens actively participate in climate adaptation planning. The project involves regional directorates (e.g., Hydroeconomy, Climate Change, Civil Protection) and incorporates findings into public consultations to align with national and EU climate policies. This integration of scientific research, local data, and stakeholder engagement in the project provides actionable insights for decision-makers, contributing to a more climate-resilient Crete.

1.3 Project team

The CRETE CLIMAAX project is a collaborative effort between the Region of Crete and the Technical University of Crete (TUC), combining regional governance expertise with climate risk assessment. The Region of Crete, structured into six General Directorates and 36 Directorates, is responsible for the economic, social, and cultural development of the island. TUC, providing external services, brings extensive experience in climate risk assessment, hydrology, and adaptation planning.

The project is led by **Dr. Marinos Kritsotakis**, Director-General of Sustainable Development for the Region of Crete, who provides strategic oversight and ensures policy alignment across the project phases. His expertise in regional planning and climate policy is complemented by his past roles as Director of the Directorate of Water and the Directorate of Civil Protection Crete. **Eleni Kargaki**, Civil Engineer, is the Deputy Head of the Directorate of Environment & Spatial Planning and responsible for climate change policy and energy planning for the Region of Crete. **Evgenia Stylianou** Agronomist MSc, Team Coordinator of the Regional Climate Change Adaptation Plan Project. **Vasiliki Madoulka** Head of the Department of European & International Affairs, as Financial Manager. **Dimitra Dafnomili**, Deputy Head of the Environment Department of the Environment and Spatial Planning Directorate, with **Vavadaki Aikaterini** as deputy, Deputy Head of the Environment and Hydroeconomics Department of the Heraklion Regional Administration. The Region of Crete also engages experts from relevant directorates, such as Hydroeconomy, Civil Protection, Sustainable Development, and Infrastructure, ensuring cross-sectoral participation.
The Technical University of Crete team contributes specialized scientific knowledge in climate risk assessments and has been involved in major climate-related projects, including contributions to IPCC reports. The team is led by Associate Professor **Aristeidis Koutroulis**, an expert in hydro-climatology, hydrological extremes, and climate change impacts on water resources. **Mikaela Papa** specializes in climate hazard modelling and risk mapping, supporting the implementation of CLIMAAX methodologies. The team is responsible for applying the CLIMAAX methodology, conducting risk assessments, and refining adaptation strategies in the second phase of the project.

1.4 Outline of the document's structure

This document is structured to provide an overview of 1st phase of the climate risk assessment for the Region of Crete under the CRETE CLIMAAX project.

The document begins with an introduction, outlining the background, main objectives, project team, and the structure of the report. The core of the report focuses on Phase 1 of the Climate Risk Assessment, following a structured process that includes scoping, risk exploration, risk analysis, key risk assessment findings, and preliminary monitoring and evaluation. Each section presents data-driven insights into the primary climate hazards affecting Crete, particularly droughts and floods, and applies the standardized workflows to assess their impact, severity, and urgency.

The conclusions section summarizes the key findings from Phase 1, highlighting challenges, achievements, and areas requiring further attention. The progress evaluation section connects this deliverable to future project phases, outlining KPIs and milestones achieved.

2 Climate risk assessment – phase 1

2.1 Scoping

2.1.1 Objectives

The objective of the Climate Risk Assessment (CRA) for Crete is to systematically assess and quantify climate-related hazards, particularly droughts and floods, using the CLIMAAX framework. The purpose of this assessment is to identify vulnerabilities, exposure levels, and potential impacts on critical sectors, including agriculture, water resources, infrastructure, and urban settlements. The CRA aims to support evidence-based decision-making and policy development to enhance climate resilience in Crete, by leveraging scientific methodologies and high-resolution data.

The current Regional Adaptation Action Plan (RAAP) of Crete, developed in the framework of the National Strategy for Adaptation to Climate Change under the National Climate Law, provides a comprehensive assessment of vulnerabilities to climate hazards and their impacts on key sectors. However, it does not include a detailed climate risk analysis. Through the application of the CLIMAAX CRA methodology, the assessment will enable a quantitative evaluation of climate risks, offering a more structured approach to identifying and prioritizing high-risk areas and sectors. This is particularly significant, as the RAAP serves as a strategic guide for the Region of Crete, supporting the preparation and maturity of climate adaptation projects, ensuring their successful integration into funding opportunities in the new programming period.

The expected outcome of this CRA is to generate climate risk assessment outputs that will directly inform the revision process of the second cycle of the RAAP of Crete, scheduled for 2026+. The CLIMAAX project will provide essential data and analysis to enhance the next iteration of the RAAP, ensuring that adaptation planning is aligned with the latest climate projections, sectoral risks, and policy priorities.

Additionally, the CRA outputs will contribute to the establishment of a new Regional Climate Adaptation Support Mechanism for Crete. This mechanism is envisioned not just as a Climate Change Observatory, but as a comprehensive structure that extends beyond climate monitoring and evaluation. It will play a key role in:

- Assessing climate change related risks on Crete's key sectors and regions
- Providing scientific and technical support for policy development and implementation
- Expanding dissemination of the related climate change projects results
- Information hub for professionals and
- Awareness & citizens engagement

Through these contributions, the CLIMAAX CRA will enhance climate adaptation governance in Crete, ensuring that risk assessments translate into actionable strategies and informed decision-making at both regional and local levels.

2.1.2 Context

Climate hazards, their impacts, and associated vulnerabilities in Crete have been primarily assessed through the Regional Adaptation Action Plan (RAAP), which was developed in alignment with the National Strategy for Adaptation to Climate Change, under the framework of the National Climate Law. RAAP serves as the official planning instrument, identifying the region's key vulnerabilities to climate hazards such as droughts, precipitation extremes and floods, heatwaves, and sea level rise.

It provides strategic guidelines for adaptation planning, but it does not incorporate detailed quantitative climate risk assessments.

Beyond the RAAP, climate risk assessments and adaptation strategies have been developed in the framework of several interregional programs, in collaboration with research institutes, technical entities, and regional authorities. These projects have contributed to localized climate change impact modelling and adaptation planning. However, a lack of uniformity in methodologies, data fragmentation, and coordination challenges among stakeholders has hindered their full integration into regional policymaking.

Crete faces intensifying climate challenges, with the prolonged drought since the 2022–2023 hydrological year serving as a stark indicator of increasing climate variability. The escalating frequency of extreme events such as flash floods, heatwaves, and water shortages underscore the need for improved climate risk management. The existing RAAP provides a baseline for adaptation, but without detailed quantitative risk assessments, it is difficult to prioritize effective interventions and allocate resources efficiently. This issue is closely linked to national and European adaptation goals. The Region of Crete's climate resilience strategy must align with:

- The National Climate Law, which mandates systematic adaptation planning at the regional level.
- The EU Adaptation Strategy, ensuring coherence with European policies on climate resilience.
- The Crete 2030 Development Plan, which envisions a climate-resilient region with major infrastructure investments to support sustainable development.
- The Action Plan for Combating Drought and Water Scarcity in the Region of Crete.
- The Flood Risk Management Plan for Crete (EL13), developed under the EU Floods Directive (2007/60/EC), which informs flood mitigation and emergency response.

The Region of Crete operates within a multi-tiered governance structure that involves regional, national, and European authorities in climate risk management. Key governance mechanisms include:

- The RAAP, which outlines adaptation priorities for key sectors.
- Water Resource Management and Flood Management Plans, which focus on addressing drought and flood risk and sustainable water use.
- National and EU funding programs, supporting infrastructure development, resilience projects, and research initiatives.

The primary sectors affected by climate change in Crete include:

- Droughts have severely impacted irrigation systems, crop yields, and livestock farming. The olive-growing sector, which is economically vital, has been particularly affected.
- Increasing temperatures and water scarcity threaten summer tourism, a key economic pillar.
- Urban Infrastructure and Civil Protection as rapid urbanization has increased flood exposure, while heatwaves pose risks to vulnerable populations.
- Desertification, land degradation, and wildfires threaten natural habitats and biodiversity.

Crete's adaptation efforts are influenced by regional, national, and European climate resilience initiatives. Some key external factors include:

- European Climate Adaptation Programs, which provide funding and technical support.
- Transnational cooperation initiatives, which enable knowledge-sharing on adaptation best practices.

- Economic constraints, as Greece's financial challenges may limit large scale adaptation investments.
- Involvement of the Private Sector to fund adaptation investments

To address climate risks, the following adaptation measures are crucial:

- Water resource efficiency programs to increase water allocation optimize irrigation and reduce water loss.
- Flood risk management infrastructure, such as improved drainage systems and nature-based solutions.
- Agricultural adaptation techniques, including shifting the cultivated crops to higher elevations, drought-resistant crops, soil conservation strategies and in long terms cultivations indoors with high tech-controlled conditions.
- Expanding afforestation.
- Unsealing of urban surfaces and urban heat mitigation measures, such as increased green spaces and heat-resilient building designs.

2.1.3 Participation and risk ownership

The stakeholder engagement process in the CLIMAAX Crete project was initiated through a structured consultation approach, ensuring the involvement of key actors across all levels of governance, research institutions, and sectoral associations. The first step was the stakeholder mapping, identifying key institutions and organizations relevant to climate risk management in Crete. This was followed by stakeholder consultations and a dedicated workshop, which facilitated discussions on risk identification, data gaps, and local adaptation priorities.

The stakeholders engaged represent a diverse set of governmental, research, private sector, and community organizations, ensuring that the climate risk assessment is aligned with regional development strategies and sectoral needs.

The main stakeholders involved in the risk assessment and adaptation process include:

<u>Governmental Authorities:</u>

- National Level: Ministry of Civil Protection, Ministry of Environment and Energy, Ministry of Rural Development
- Region of Crete: Directorate of Technical Works, Directorate of Environment & Spatial Planning, Directorate of Civil Protection, Directorates of Agricultural development.
- Decentralized Administration of Crete Directorate of Water and Directorate of Environment & Spatial Planning.

<u>Local Authorities and Infrastructure Agencies:</u>

- Municipalities (Technical and Civil Protection Services), particularly in high-risk flood and drought-prone areas
- Municipal Water and Sewerage Companies, responsible for water resource management and flood mitigation
- Crete Development Organization, supporting regional economic planning and infrastructure investments

<u>Research Institutions and Technical Expertise:</u>

- ADT OMEGA engineering company (developer of the flood management plan of Crete)
- ADENS S.A. company in the field of environmental studies and consulting services (developer of the water resources management plan of Crete)

- Hellenic Centre for Marine Research (HCMR): River Waters Sector (hydrological and flood modelling expertise)
- Foundation for Research and Technology – Hellas (FORTH): Coastal Erosion Monitoring Sector (assessing flood risks in coastal areas)

Sectoral and Community Organizations (Vulnerable Groups):

- Agricultural Sector: Associations of Olive Producers, Winemakers, Farmers, Livestock Breeders, Beekeepers
- Tourism and Business Sector: Hotel Associations, Technical and Commercial Chambers
- Water Management: Local Land Reclamation Organizations (responsible for irrigation management)

These stakeholders represent the primary vulnerable groups exposed to climate risks. Agricultural communities are particularly affected by droughts, while urban and coastal developments face increasing risks from flash floods and erosion.

Risk ownership is distributed across the three levels of governance (national, regional, and local), each responsible for different aspects of climate risk management:

- National level ministries set the legal and regulatory framework for climate adaptation.
- The Region of Crete implements adaptation strategies of the island, oversees/ construct major infrastructure projects, and supports municipal risk reduction efforts.
- Municipalities manage local risk reduction, emergency response, and water resources.

Each organization follows its operating regulations, defining its role in climate risk mitigation, preparedness, and response. It should be noted that the coordination between administrative levels of governance is considered of crucial importance, in particularly in flood risk management.

The acceptable risk level for the community depends on the sector and hazard type.

- For droughts, agriculture and tourism stakeholders have expressed concern over economic losses and water scarcity, making even moderate drought risk levels unacceptable without proper mitigation.
- For floods, while minor seasonal flooding is tolerated, flash floods causing infrastructure damage and economic disruption are considered highly unacceptable, requiring urgent action.

The CLIMAAX climate risk assessment outputs will help stakeholders refine risk thresholds, balancing adaptation measures with economic and social constraints.

Results from the climate risk assessment will be shared with stakeholders through multiple channels:

- Reports will be integrated into regional and municipal adaptation planning, feeding into the revision of the Regional Climate Change Adaptation Plan (RCAP 2026+).
- Risk maps and policy recommendations will be made accessible through:
    - The Region of Crete's Geospatial Portal (https://gis.crete.gov.gr/)
    - The Disaster Risk Management Knowledge Centre (DRMKC) Risk Data Hub
    - Local workshops and consultation meetings with affected communities
- Press releases and online publications will raise awareness about climate risks and adaptation needs to ensure broader community engagement.
- Findings will be disseminated through workshops and targeted briefings to guide future research and model refinement.

2.2 Risk Exploration

2.2.1 Screen risks (selection of main hazards)

Crete faces a range of climate-related hazards that have intensified in recent decades due to climate change. The primary risks include droughts, floods, heatwaves, wildfires, coastal erosion, and sea level rise, all of which have direct impacts on the island's economy, infrastructure, natural ecosystems, and human well-being.

Drought and Water Security

Recent data (Figure 2-1) highlights a clear trend of rising annual temperatures and declining rainfall, leading to increased drought frequency and severity. The 2023–2024 hydrological year marks Crete's second consecutive year of severe drought, significantly impacting dam reservoir levels, with critical sites such as Aposelemis and Faneromeni dams nearing emergency thresholds. Water shortages are particularly severe during peak summer months, when the high irrigation demands of agriculture coincide with increased tourism-related water consumption, placing immense pressure on Crete's water infrastructure. The olive-growing sector, a cornerstone of Crete's economy, has suffered extensive losses due to insufficient irrigation and prolonged dryness. These conditions highlight the urgent need for climate adaptation measures to ensure sustainable water resource management.

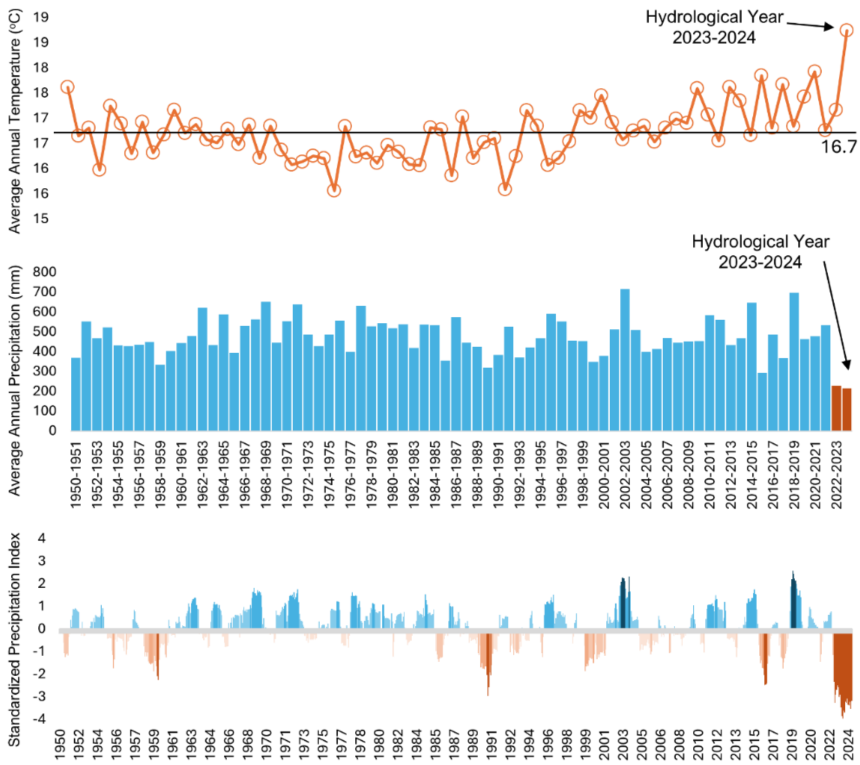


Figure 2-1 Trends in (a) average annual temperature (°C), (b) average annual precipitation (mm), and (c) Standardized Precipitation Index (SPI) for Crete indicating periods of drought and wetness, from 1950 to 2024.

Flood Risk

Crete is also highly susceptible to flash floods, driven by its steep topography, localized heavy rainfall, and expanding urban areas. Climate change projections indicate an increase in the frequency and intensity of extreme precipitation events, particularly in autumn and winter (Tsanis et al., 2011). Short-duration, high-intensity rainfall events cause rapid runoff, overwhelming drainage systems and triggering severe flash floods.

Figure 2-2 illustrates flood-prone areas and past severe flood events, highlighting high-risk zones in Heraklion, Chania, and Rethymno. The February 2019 floods demonstrated the severity of these events, resulting in bridge collapses, infrastructure damage, and transportation disruptions (Lagouvardos et al., 2020). The expansion of built-up areas, particularly along riverbanks and floodplains, has exacerbated flood risk, reducing natural infiltration and increasing surface runoff (Angelakis et al., 2020; Diakakis et al., 2012). Without targeted flood mitigation strategies, future extreme rainfall events could pose even greater threats to urban and rural communities.

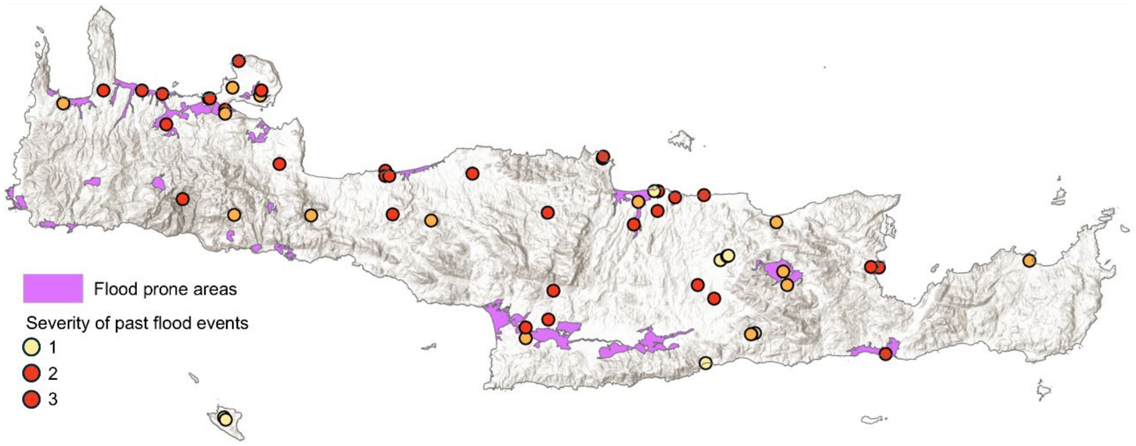


Figure 2-2 Flood-prone areas and recent past flood events in Crete.

According to the RAAP report and scientific literature, the most critical climate hazards in Crete include:

- Droughts: Increasing frequency and intensity due to reduced precipitation and rising temperatures.
- Floods: Particularly flash floods caused by heavy rainfall events, topography, and urban expansion.
- Heatwaves: More frequent and severe, impacting public health, agriculture, and water resources.
- Wildfires: Longer dry seasons increase the risk of forest and agricultural fires.
- Coastal Erosion & Sea Level Rise: Threatening infrastructure, tourism assets, and biodiversity in coastal zones.

The CLIMAAX CRA will focus on:

- Droughts: Including agricultural drought, with a specific focus on olive crops, as they represent the dominant agricultural activity and a major economic sector.
- Floods: Particularly flash floods, given their increasing frequency and significant damage to infrastructure, communities, and the local economy.

For droughts and floods, the currently available data include:

- Historical climate data (temperature, precipitation, drought indices).
- Hydrological data (reservoir levels, river flows, water demand for agriculture and urban use).
- Records of past drought and flood events (economic losses, affected areas, recovery costs).
- Existing vulnerability assessments from the Regional Adaptation Action Plan (RAAP).

Further data needed:

- High-resolution climate projections for future drought and flood risks at the regional scale.
- Sector-specific vulnerability assessments (e.g., impacts on agriculture).
- Improved flood hazard mapping using high-resolution hydrodynamic models and building/infrastructure exposure data.

2.2.2 Workflow selection

To assess climate risks in Crete, two risk assessment workflows were selected, corresponding to the primary hazards affecting the region: droughts and floods. The selection was based on the relevance of these hazards to Crete's socio-economic sectors and the need to quantify risk exposure and vulnerabilities.

2.2.2.1 Drought Risk Assessment Workflow

Droughts represent one of the most pressing climate hazards in Crete, affecting agriculture, water resources, and rural livelihoods. Two complementary workflows were applied:

- Relative drought assessment to identify drought-prone regions based on long-term precipitation deficits and socio-economic vulnerability indicators.
- Agricultural drought assessment to evaluate the impact of water scarcity on crop production, with a specific focus on olive groves; Crete's primary agricultural activity.

The most vulnerable groups identified include smallholder farmers relying on rain-fed agriculture, rural communities dependent on groundwater for domestic use

2.2.2.2 Flood Risk Assessment Workflow

Flash floods are a recurrent hazard in Crete, causing extensive damage to infrastructure, urban areas, and tourism facilities. Two workflows were applied:

- River flood assessment to evaluate flood hazards using precomputed flood extents for multiple return periods, assessing exposure and vulnerability in both urban and rural settings.
- Flood building damage and population exposure to estimate economic losses associated with flooding, identifying high-risk zones where infrastructure and residential buildings are exposed.

The most exposed areas include urban areas where urbanization has increased flood risk. Additionally, coastal tourism zones expanding along riverbeds face heightened risks due to inadequate land-use planning.

2.2.3 Choose Scenario

Crete faces increasing drought severity and flash floods, exacerbated by urban expansion, tourism growth, and agricultural water demand. Relevant scenario assumptions for Crete are:

- Short-term (5 years): Focus on mitigating ongoing drought and flash flood risks through water management and emergency response.
- Medium-term (20-30 years): Rising temperatures and shifting rainfall patterns will worsen water stress and increase flood exposure in expanding urban and coastal areas.
- Long-term (50-100 years): High-emission scenarios project severe droughts and increased flood risks, necessitating resilient infrastructure and sustainable land-use planning.

Scenarios Available in the Workflows

- Drought Risk: Uses SSP126, SSP370, and SSP585 for future precipitation deficits and RCP4.5 for agricultural drought impact.
- Flood Risk: Relies on historical JRC flood maps for 10-, 50-, and 100-year return periods, but lacks reliable future projections due to methodology limitations.

2.3 Risk Analysis

Risk workflows from the CLIMAAX Handbook were applied to Crete, focusing on drought and flood risk assessments. All calculations in this assessment are based on the fundamental datasets provided by the CLIMAAX workflows (Table 2-1), following the standardized methodologies outlined in the CLIMAAX Handbook. The primary goal of this first-phase analysis is to test and validate these methodologies using open-access datasets. In the second phase, the assessment will be refined with high-resolution local data, improving accuracy and ensuring alignment with regional planning needs.

2.3.1 Drought Workflows

The drought risk assessment applied two methodologies:

1. **Relative drought** assessment, which quantifies drought hazard using precipitation anomalies and evaluates exposure and vulnerability at the NUTS3 level.
2. **Agricultural drought assessment**, which estimates economic losses due to water scarcity, with a focus on olive groves, the dominant agricultural activity in Crete.

Table 2-1 Data overview Drought Risk Assessment workflow

Hazard data	***Vulnerability data***	***Exposure data***	***Risk output***
Relative Drought: Weighted Anomaly Standardized Precipitation (WASP) index, calculated using ERA5-Land reanalysis and ISIMIP3b climate projections	Socioeconomic indicators (GDP per capita, rural population share)	Cropland, livestock density, competition on water, population	Relative drought risk map for NUTS3 regions
Agricultural Drought: Yield reduction estimates under rainfed conditions based on precipitation, temperature, and evapotranspiration data	Irrigation availability distribution	Crop distribution maps (olive groves), production statistics, crop aggregated value	Estimated revenue losses due to drought

2.3.1.1 Hazard assessment

Relative drought

The hazard assessment for relative drought employs the Weighted Anomaly Standardized Precipitation (WASP) Index to quantify precipitation deficits over time. This index allows for the identification of areas that experience recurrent drought conditions, offering insights into the spatial distribution of drought severity. The WASP Index is derived from historical and projected precipitation data, normalized to highlight deviations from long-term climatic averages. The analysis incorporates multiple climate models to ensure robustness, accounting for seasonal variations and long-term precipitation trends across Crete.

According to the hazard assessment, Heraklion exhibits the highest relative drought risk compared to other prefectures on the island. This is due to a combination of moderate drought hazards and high exposure and vulnerability indicators. In contrast, Chania and Rethymno display comparatively lower risk levels, although Lasithi presents an increasing risk under high-emission future scenarios.

Agricultural drought

The agricultural drought hazard assessment focuses on estimating yield losses caused by water deficits in Crete's primary crop, olive groves. This assessment integrates crop-specific water demand calculations, including soil moisture availability, reference evapotranspiration (ET0), and crop-specific parameters such as the crop coefficient (Kc).

The Penman-Monteith equation is used to estimate ET0, incorporating variables such as temperature, solar radiation, humidity, and wind speed. This is then adjusted for olive trees to determine crop evapotranspiration (ETc), representing the actual water demand of the crop. The analysis is further refined using soil water capacity data to estimate actual evapotranspiration (ETa) and determine potential yield reductions under varying precipitation scenarios.

The hazard maps produced indicate that eastern and central Crete are particularly susceptible to agricultural drought due to a combination of lower precipitation levels and higher evapotranspiration rates. In these areas, olive groves experience significant water deficits, increasing their vulnerability to drought-induced yield losses. Conversely, western Crete exhibits more favorable conditions, with relatively higher precipitation and lower atmospheric water demand.

Projected economic impacts of agricultural drought were also assessed by estimating revenue losses under non-irrigated conditions. The results highlight substantial financial risks for olive growers, with some areas experiencing potential yield reductions of 9–11% under future climate scenarios.

2.3.1.2 Risk assessment

Relative drought

Figure 2-3 presents the relative drought risk for historical (1981–2015) and projected periods (2031–2060 and 2071–2100) under SSP126, SSP370, and SSP585 scenarios. These risk categories are calculated at the national level and depict the spatial distribution of drought susceptibility across Greece, normalized for each time period.

For the historical period, Crete shows moderate drought risk levels, with central regions, particularly Heraklion, exhibiting higher relative risk compared to other areas of Greece. These risk levels are the combined result of drought hazard, exposure, and vulnerability factors. Notably, while other regions in Greece display relatively higher hazard and exposure values and lower vulnerability levels, the combined effect positions Heraklion (and Crete overall) as the area with the highest drought risk for the historical period.

Under the SSP126 low-emission scenario, Heraklion continues to exhibit high drought risk levels relative to other regions of Greece, across both time slices. The risk distribution remains stable across the prefectures of Crete, with Heraklion consistently in a higher category. Other prefectures, such as Lasithi and Rethymno, exhibit moderate drought risk, while Chania experiences lower risk levels relative to other parts of Crete.

The intermediate emission scenario SSP370 projects moderate levels of risk in Heraklion during both time slices. Lasithi and Rethymno are classified in lower risk categories compared to other regions in Greece, while Chania experiences a relative low risk for the near future period.

Under the high-emission SSP585 scenario, Heraklion and Rethymno exhibit moderate levels of risk in the near future, while Chania and Lasithi show lower levels. For the 2071–2100 period, relative risk is projected to increase in Heraklion and Lasithi, while Chania and Rethymno are expected to remain at low and moderate risk, respectively.

It is important to note that these maps are not comparable across time periods due to the normalization approach employed in the methodology, which adjusts contributing factors independently for each period. This analysis emphasizes relative differences within each time slice, rather than trends over time or SSPs.

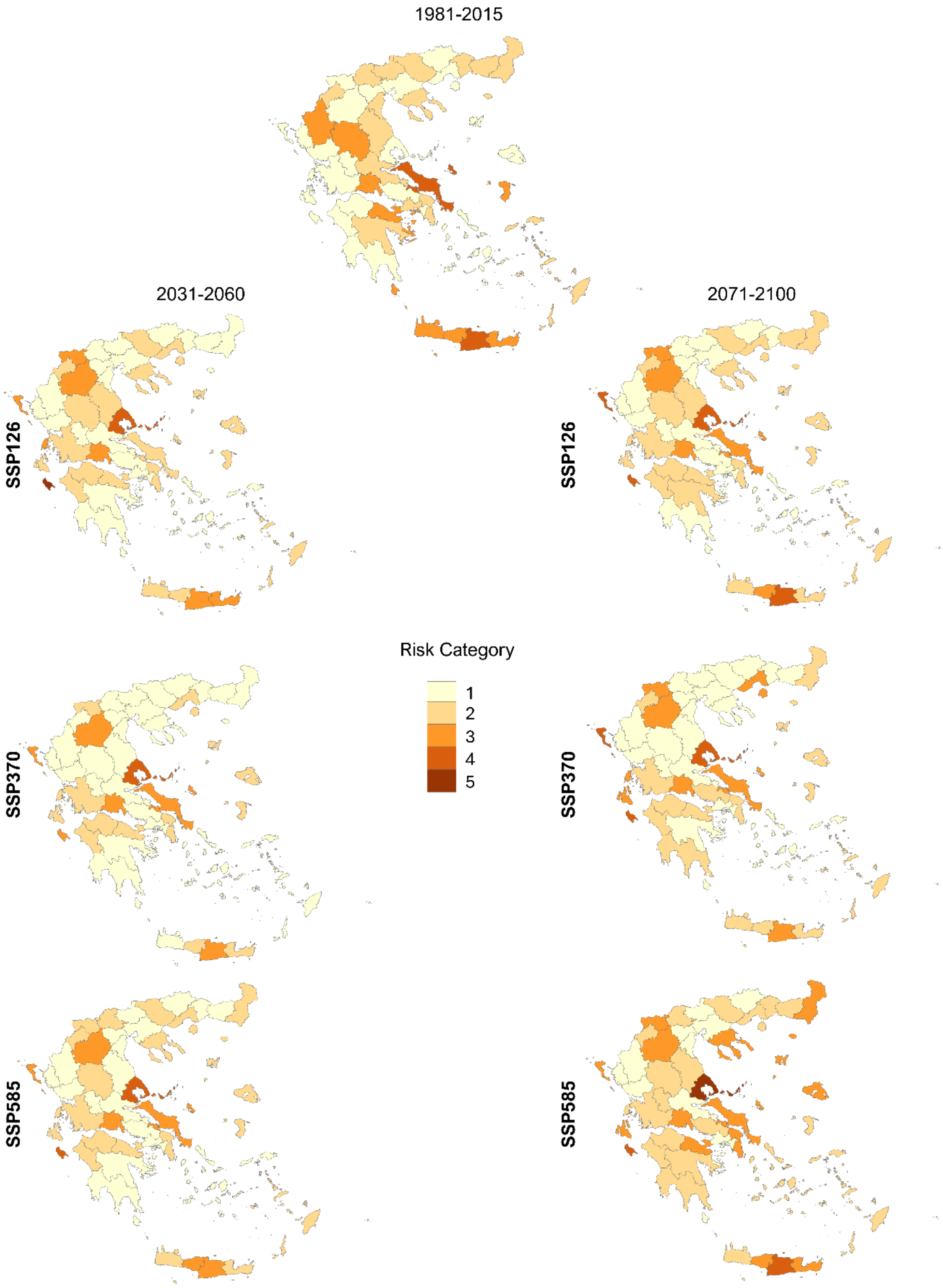


Figure 2-3 Relative drought risk for Greece during the historical period (1981–2015) and future projections (2031–2060 and 2071–2100) under SSP126, SSP370, and SSP585 scenarios.

Agricultural drought

Figure 2-4 illustrates the potential revenue losses of olive tree crops in Crete under non-irrigated conditions due to precipitation deficits, as projected for the RCP4.5 scenario during the period 2046–2050. Revenue losses are represented by red shading and expressed in thousands of euros per grid cell, showing the economic impact of water scarcity on olive grove yields. Overlaying the revenue loss data, the patterned hatches indicate the percentage of cropland equipped with irrigation systems in 2010, providing a critical vulnerability measure. Areas with lower irrigation coverage are more exposed to precipitation deficits, while regions with higher irrigation coverage exhibit reduced vulnerability.

All four regional climate models (NORESM1-REMO2015, MPI-RCA4, CNRM-RACMO22e, NORESM1-RCA4) indicate similar spatial distributions of revenue losses, with the highest impacts concentrated in central and eastern Crete. Revenue losses exceeding €75,000 per grid cell are consistently observed in these regions, while lower losses are evident in western Crete. There are no noticeable variations in the projected patterns or severity of revenue losses among the models. The consistent patterns across all models highlight central and eastern Crete as the most economically vulnerable regions to precipitation deficits under non-irrigated conditions. The patterned overlays representing the percentage of irrigated cropland further emphasize the vulnerability of areas with limited irrigation infrastructure.

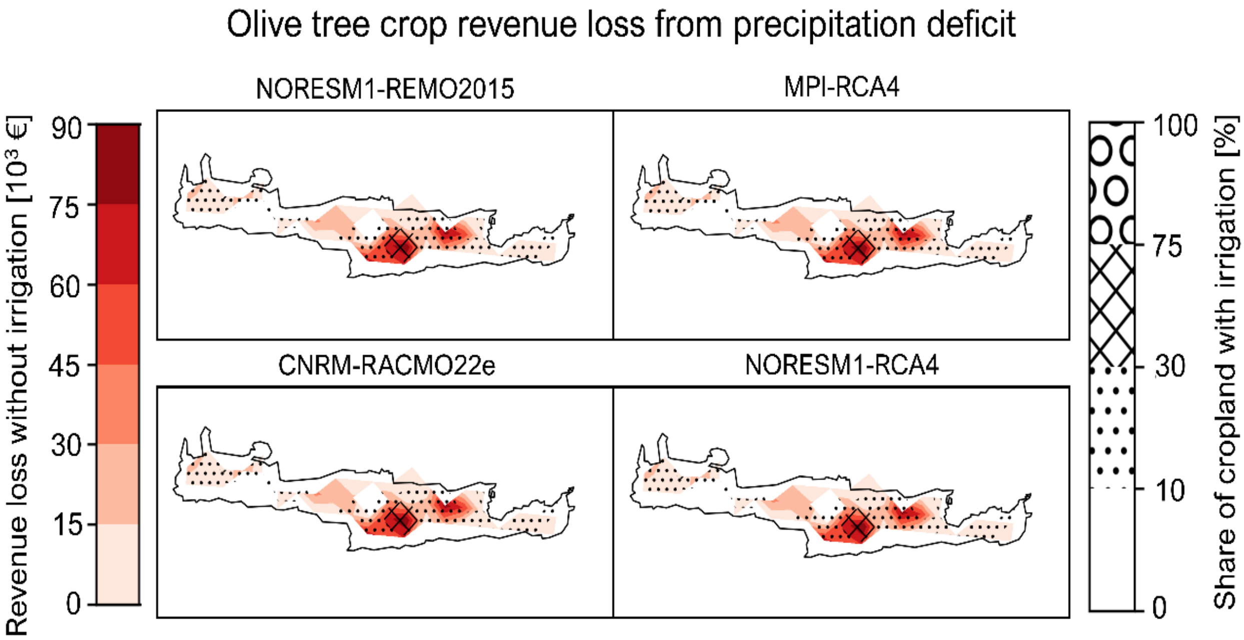


Figure 2-4 Projected revenue loss (in € thousands per grid cell) for olive tree crops in Crete under the RCP4.5 scenario (2046–2050) due to precipitation deficits.

2.3.2 Flood Workflows

The flood risk assessment applied two methodologies:

1. River flood assessment, which evaluates flood hazards based on precomputed flood extents for multiple return periods and assesses exposure and vulnerability using population and infrastructure data.
2. Flood building damage and population exposure, which quantify the potential economic losses and population displacement due to flooding.

Table 2-2 Data overview Flood Risk Assessment workflow

Hazard data	***Vulnerability data***	***Exposure data***	***Risk output***
River Flooding: JRC historical river flood hazard dataset and Aqueduct Floods future river flood hazard maps for multiple return periods (10, 50, 100 years).	Depth-damage relationships for different land-use categories	LUISA land use map	River flood risk maps indicating expected damages and exposure at different return periods
Flood Damage and Population Exposure: JRC historical river flood hazard dataset for multiple return periods (10, 50, 100 years).	Depth-damage relationships for different building categories	Building footprint data from OpenStreetMap (OSM), building damage fraction, reconstruction costs, and the value of its contents. Critical infrastructure. Population data JRC GHS-POP	Estimated financial losses and displaced population due to flooding

2.3.2.1 Hazard assessment

River Floods

The flood hazard assessment was conducted using the JRC global river flood hazard dataset, which provides precomputed flood extents and depths for various return periods (10, 50, 100 years). These high-resolution maps illustrate the extent of potential flooding under present climatic conditions. However, the dataset has limitations, particularly in underrepresenting small basins prone to flash floods, which are dominant in Crete due to its steep topography.

The hazard maps indicate that major urban areas such as Heraklion, Chania, and Rethymno are at the highest risk of river flooding, especially in low-lying coastal areas and river floodplains. The data suggests that Heraklion is the most flood-prone region, with significant exposure to floodwaters under the 100-year return period scenario. However, some areas might exhibit overestimated flood depths, exceeding 30 meters in some cases, which is unrealistic given the island's topography.

Flood building damage and population exposure

This assessment integrates flood hazard maps with exposure and vulnerability indicators to estimate flood-related damages and population displacement. Vulnerability functions are applied to estimate damage costs based on flood depth, land-use categories, and critical infrastructure exposure.

Population exposure was assessed using the JRC GHS-POP dataset, which provides high-resolution population distribution estimates. The results indicate that 917 people per year are at risk of flood exposure, while 484 individuals may be displaced annually due to extreme flood depths exceeding 1 meter. The expansion of urban areas along riverbanks and floodplains has exacerbated flood exposure, particularly in rapidly growing population centers. The lack of adequate drainage infrastructure in some urban areas further increases vulnerability to flooding.

2.3.2.2 Risk assessment

River Floods

The flood risk assessment combines hazard maps with exposure and vulnerability data to estimate the potential economic damage caused by river flooding. The risk maps for the 10-year (Figure 10) and 50-year (Figure 2-5) return periods illustrate the spatial distribution of expected flood damages across Crete, highlighting regions where economic losses are most significant. These maps integrate flood depth data with land-use vulnerability functions to quantify damage costs per hectare (€ per ha).

The results show that higher return periods result in greater flood damage, though the increase between the 50-year and 500-year return periods is less pronounced, falsely indicating a limited expansion of high-damage areas beyond a certain flood threshold. The economic losses are concentrated along major river valleys and urbanized floodplain areas, where exposure to flooding is highest due to built infrastructure and economic activities.

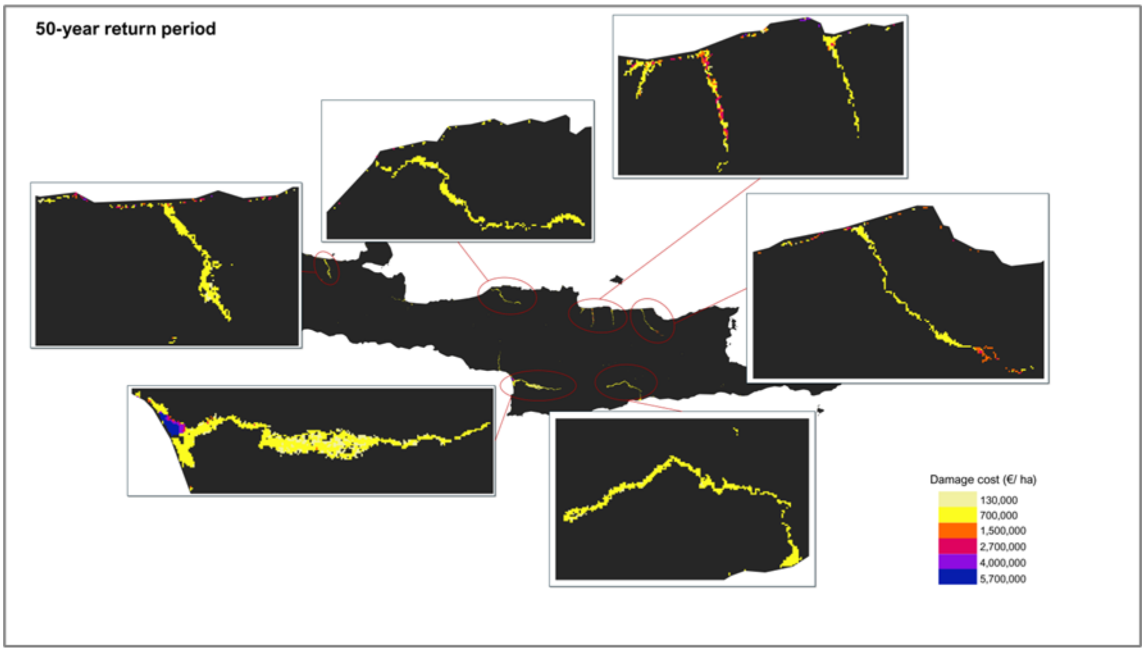


Figure 2-5 Estimated flood damages for a 50-year return period in Crete. The map highlights areas with different levels of expected economic loss per hectare (€ per ha).

Flood building damage and population exposure

Figure 2-6 illustrates the estimated building damage in Heraklion for two flood scenarios: the 10-year return period (RP) (top panel) and the 500-year RP (bottom panel). The damage assessment is based on mean flood depth at building locations, with damage values categorized into four classes: €0–10k, €10–50k, €50–100k, and >€100k per building. While the 500-year RP scenario results in slightly higher damage values, the overall increase is not as significant as expected. Again, it is important to note that incomplete OSM building data results in missing structures, leading to an underestimation of actual flood-induced damages.

Figure 2-7 presents the estimated displaced population due to a 10-year return period (RP) flood event in Crete. Displacement is defined as people residing in areas where flood depths exceed 1.0 meters, necessitating relocation or emergency evacuation. The results show that displacement is concentrated in flood-prone river valleys and low-lying coastal areas, where population centers intersect with high flood depths. While most displacement occurs in sparsely populated rural areas, some higher-density urban areas are also affected. Figure 2-7 presents the estimated displaced population in Crete across different flood return periods (10, 50, 100, and 500 years), based on population projections for the year 2025. The Expected Annual Population Displaced (EAPD) is estimated at 484 people, representing the average yearly number of individuals expected to be forced from their homes due to flooding.

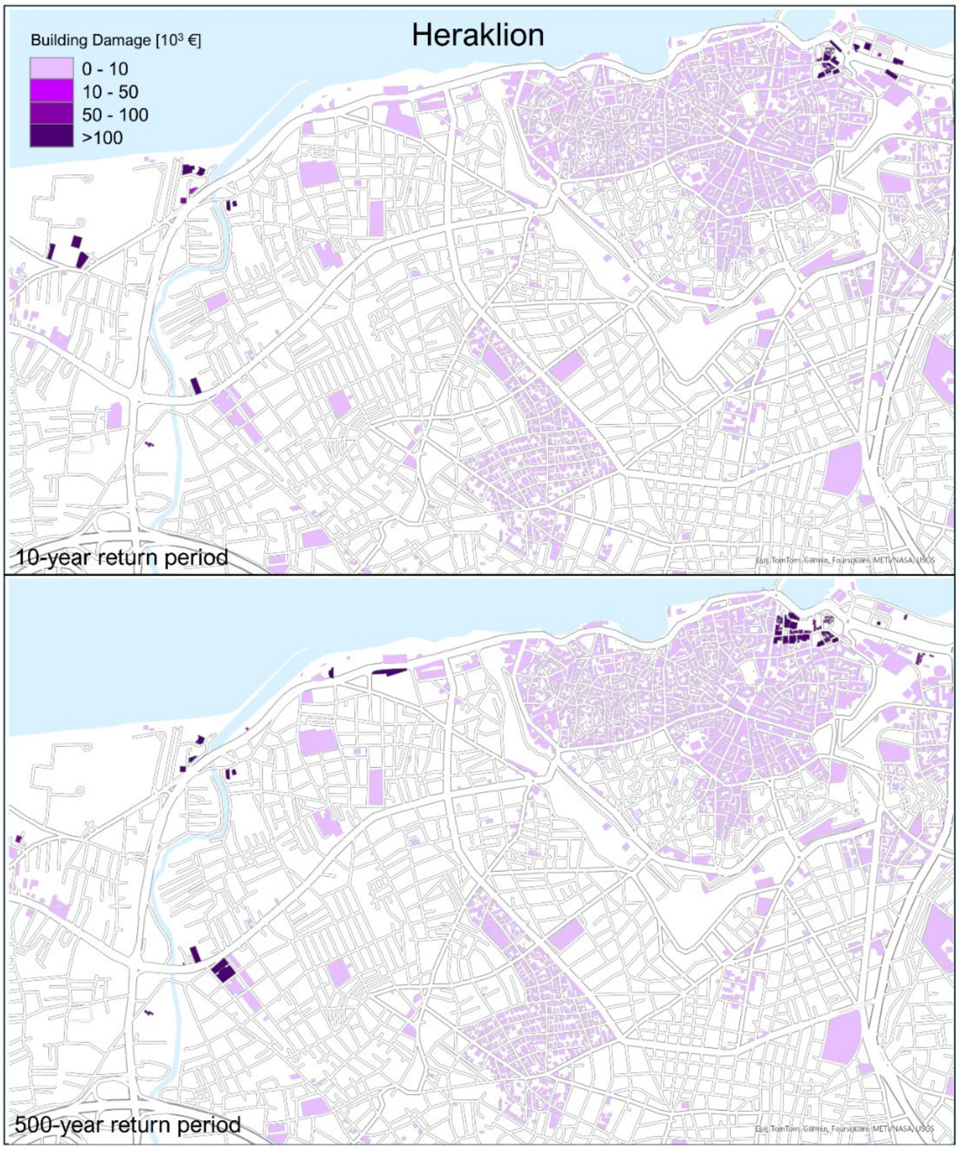
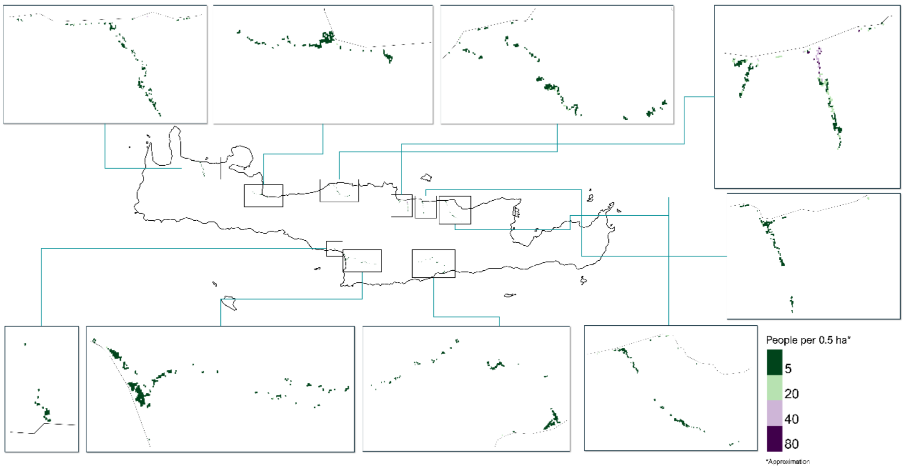


Figure 2-6 Estimated building damage in Heraklion based on mean flood depth for the 10-year return period (top) and 500-year return period (bottom)



Displaced population of 10y RP flood

Figure 2-7 Estimated displaced population due to a 10-year return period (RP) flood event in Crete. The map highlights areas where flood depths exceed displacement thresholds, requiring relocation. Population displacement is categorized by density (people per 0.5 ha), with green representing lower displacement levels and purple indicating higher levels.

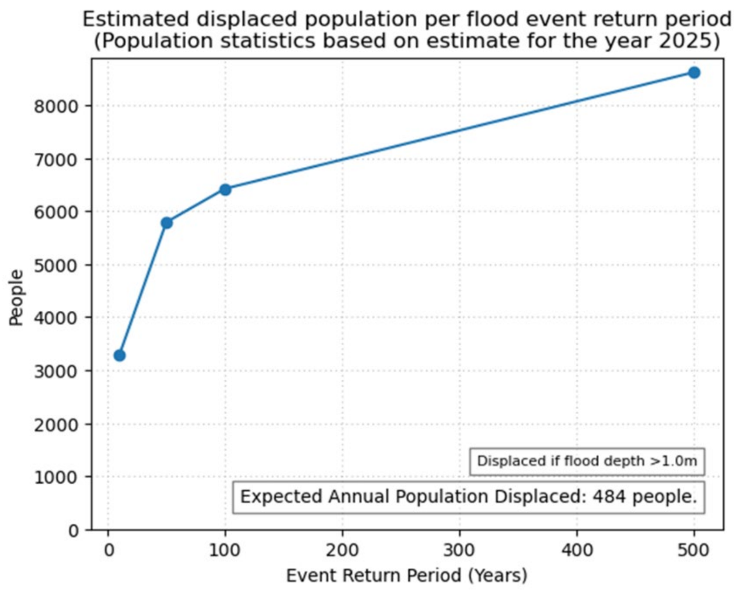


Figure 2-8 Estimated displaced population in Crete for different flood return periods (10, 50, 100, and 500 years), based on population estimates for the year 2025. Displacement is defined as exposure to flood depths exceeding 1.0 meters.

2.4 Preliminary Key Risk Assessment Findings

2.4.1 Severity

The key results of the risk analysis highlight that Crete faces severe and escalating climate risks, primarily related to droughts and floods. The island has experienced consecutive years of drought (2022–2024), leading to critically low water reservoir levels and economic losses in agriculture, particularly in olive groves. The increasing frequency of flash floods, exacerbated by extreme precipitation events and rapid urban expansion, poses a substantial threat to infrastructure, human safety, and economic stability.

For drought risk, the relative drought assessment shows that Heraklion and Lasithi are the most vulnerable prefectures, with significant exposure to prolonged precipitation deficits. More specifically, Crete has already experienced moderate to high drought risk between 1981 and 2015, particularly in Heraklion and Lasithi, due to natural precipitation variability and high water demand. In the near future (2031–2060), drought risk remains high across all emission scenarios (SSP126, SSP370, SSP585), with worsening conditions in Heraklion and expanding impacts across the island, emphasizing the urgent need for adaptation measures. By the end of century (2071–2100), Heraklion and Lasithi face the greatest drought severity, especially under SSP585, while even under low-emission scenarios (SSP126), drought risk remains significantly elevated, underscoring the necessity for long-term water conservation, irrigation efficiency improvements, and climate-resilient agricultural strategies.

The agricultural drought risk analysis further emphasizes that central and eastern Crete, where olive cultivation is most concentrated, are highly exposed to revenue losses due to water scarcity. The economic implications are severe, with projected revenue losses exceeding €75,000 per grid cell in some areas under future climate scenarios.

For flood risk, the risk analysis confirms that flash floods are the primary flood hazard in Crete, posing a significant threat to urban areas near rivers, expanding coastal tourism zones, and critical infrastructure. However, due to methodological limitations, the CLIMAAX framework did not effectively capture flash flood dynamics, and historical flood risk analyses lack the resolution needed for precise risk assessments. Additionally, future flood risk projections were not usable, making it difficult to quantify how climate change may alter flood patterns over time. Despite these challenges, past flood events, such as the February 2019 floods, provide clear evidence of the severity of the threat, with major infrastructure damage, bridge collapses, transportation disruptions, and economic losses. Additionally, coastal tourism developments built on former river routes face heightened risks, as natural flood pathways have been altered or obstructed by construction, leading to unpredictable floodwater accumulation and runoff issues.

Overall, these climate risks threaten key economic sectors, including agriculture, water supply, and tourism. Without targeted adaptation measures, the severity of impacts is expected to increase in the coming decades, particularly under high-emission climate scenarios.

2.4.2 Urgency

The urgency of action varies depending on the hazard type. Drought risk is a slow-onset hazard, with prolonged dry periods gradually depleting water resources and affecting agriculture. The current drought emergency in Crete, now in its second consecutive year, underscores the immediate need for improved water management strategies, including irrigation infrastructure upgrades and more efficient water allocation. Future implications for drought urgency based on CLIMAAX CRA include:

- Short-term (2025–2030): Immediate action is required to enhance water resource management, particularly for agriculture, as drought risk is already impacting economic stability.
- Medium-term (2030–2050): Strategic investments in climate-resilient agriculture and water infrastructure should be implemented to mitigate worsening drought conditions.
- Long-term (2050+): Crete must prepare for persistent, high-impact droughts, requiring integrated adaptation strategies across all economic sectors to ensure long-term sustainability.

The progressive increase in drought risk reinforces the critical need for urgent intervention, aligning with the upcoming revision of the Regional Climate Change Adaptation Plan (2026+) to ensure that long-term drought resilience is embedded in regional policies.

Flood risk in Crete is primarily driven by flash floods, which develop rapidly following intense rainfall. However, the existing CLIMAAX framework does not effectively capture flash flood dynamics, and the resolution of historical flood risk analyses is too coarse to provide valuable insights for localized flood risk assessment. Additionally, the methodology did not yield usable results for future flood risk projections, limiting the ability to assess how climate change may influence flood patterns over time.

Despite these limitations, immediate action is needed, particularly in urban centers near river systems, where rapid urban expansion into flood-prone areas is increasing exposure. Furthermore, coastal areas with extensive tourism infrastructure development along former river routes are also at high risk of flash flooding, as these flood pathways are often disregarded in land-use planning. Given the unpredictable and destructive nature of flash floods, flood mitigation efforts should focus on existing vulnerabilities, including enhancing drainage infrastructure, enforcing stricter flood zoning regulations, and implementing nature-based solutions to reduce runoff and improve water retention in flood-prone regions.

2.4.3 Capacity

<u>Existing Climate Risk Management Measures:</u>

- Crete has implemented financial, social, human, physical, and natural measures to manage drought and flood risks, but challenges persist in water resource management, urban resilience, and agricultural adaptation.

- Regarding financial capacity, climate resilience projects in Crete are primarily funded through ESPA 2021–2027, which is co-funded by the EU and national resources. ESPA provides targeted funding for water infrastructure, flood protection, and sustainable agriculture. Additional financing sources include LIFE, Horizon Europe, and ESIF, but gaps remain in irrigation modernization, groundwater management, and alternative water sources
- As for social capacity, climate awareness is increasing across all actors in the region. Farmers and rural communities face severe drought impacts, requiring enhanced early warning systems for both droughts and flash floods.
- Regarding physical infrastructure, while dams and reservoirs help mitigate drought, storage is insufficient due to the current prolonged drought period, and groundwater over-extraction is a major issue. Flood defenses exist in urban areas but are inadequate for sudden/extreme flash floods, especially in expanding coastal tourism zones. The limited irrigation network is worsening the agricultural drought.
- Natural and ecosystem-based solutions such as reforestation and wetland restoration projects aim to mitigate floods and enhance water retention, but nature-based solutions are underutilized. Artificial aquifer recharge and drought-resistant agriculture remains a priority.

<u>Opportunities for Climate Risk Management:</u>

- ESPA 2021–2027 provides critical funding for flood defenses, irrigation upgrades, and water conservation projects. Private localized actions like rainwater harvesting and public-private partnerships in water recycling could further reduce water stress.
- Strengthening drought early warning systems for farmers, community-based water conservation programs, and better urban flood preparedness can enhance social resilience.
- Upgrading irrigation and domestic supply networks to reduce water loss, expanding flood defenses, and integrating green infrastructure in flood-prone areas can improve physical resilience.
- Scaling aquifer artificial recharge projects, promoting drought-resistant crops, and restoring wetlands for flood and drought mitigation will enhance natural resilience.
- Expanding training for local authorities in drought management, risk modelling, and flood prevention will build institutional capacity. A Regional Climate Adaptation Support Mechanism would enhance policy coordination.
- Leveraging ESPA 2021–2027 and other funding mechanisms, Crete can strengthen resilience to both droughts and floods and ensuring economic, social, and environmental sustainability.

2.5 Preliminary Monitoring and Evaluation

The first phase of the climate risk assessment provided valuable insights into drought and flood risks in Crete, while also highlighting key challenges and methodological limitations that need to be addressed in the next phase.

For drought risk, the CLIMAAX methodology effectively assessed relative and agricultural drought hazards, providing spatial insights into areas most affected by precipitation deficits and agricultural losses. However, the use of global datasets introduced uncertainties, particularly in irrigation availability and agricultural vulnerability factors, which require refinement using local datasets in the second phase. Additionally, the methodology did not fully account for small-scale hydrological processes affecting water availability, making it difficult to capture localized drought impacts on agriculture and water supply systems.

For flood risk, the assessment faced significant challenges. The CLIMAAX framework did not provide usable results for future flood risk projections, limiting the ability to quantify climate change impacts on flooding. Additionally, flash floods – the dominant flood hazard in Crete – were not adequately captured due to limitations in resolution and the lack of fine-scale hydrological modelling. Existing historical flood hazard data were also too coarse to assess flood risk at the local level, particularly in urbanized and rapidly developing coastal areas.

Beyond technical limitations, a key challenge was data availability and compatibility. The reliance on open-access datasets resulted in gaps in exposure and vulnerability assessments, especially for critical infrastructure, agricultural systems, and land-use changes. The integration of high-resolution local data in the next phase will be crucial to improving the accuracy of climate risk assessments.

Overall, the first phase successfully tested methodologies and identified high-risk areas, but highlighted the need for refining datasets, improving flood modelling capabilities, and incorporating localized socio-economic and hydrological information to produce more actionable risk assessments in the next iteration.

<u>Stakeholder feedback and future involvement</u>

The stakeholder workshop provided critical feedback on the usability and applicability of the climate risk assessment results. Stakeholders, including representatives from regional authorities, municipalities, and sectoral organizations, highlighted key concerns regarding data accuracy, risk communication, and policy integration.

Stakeholders emphasized the need for higher-resolution local data, particularly regarding irrigation and agricultural vulnerability. They highlighted the availability of olive tree yield data, while regional authorities stressed the importance of implementing master plans for LLROs to improve water distribution. Concerns were raised about competing water demands, particularly from tourism expansion. Civil protection authorities noted the lack of structured water-saving initiatives and the growing risk of water shortages for firefighting. A major concern was desertification risk, especially in Lasithi (eastern Crete), where olive tree losses are escalating due to extreme drought. Stakeholders also suggested reactivating abandoned private water retention facilities and expanding the reuse of treated water to enhance water availability for agriculture.

For flood risk, civil protection authorities and municipal representatives raised concerns about the lack of localized flood information, particularly for flash floods, which remain the most damaging flood type in Crete. Urban planners raised concerns about rapid urban expansion into flood-prone areas, particularly in coastal tourism zones. Stakeholders also identified data gaps in exposure assessments. The next phase must incorporate localized flood models and exposure datasets, ensuring better risk informed decision making for land use planning and emergency response.

Based on this feedback, the next phase of the project will require closer collaboration with municipal technical services, local water management authorities, and emergency response agencies to refine the exposure and vulnerability components of the climate risk assessments.

<u>New data availability and gaps</u>

Several potential sources of higher-resolution data were identified for integration into the next phase:

- The Department of Agricultural Production provides olive tree yield records and drought impact reports, improving economic loss estimations for agricultural drought assessments.
- The 2023 update of the Flood Risk Management Plan includes higher-resolution flood maps, refining hazard identification and exposure assessments.

- Building footprint maps and land-use zoning data from Municipal Planning Authorities and the National Cadastre will enhance flood risk assessments, particularly in expanding urban and coastal areas.
- Local flood impact reports and emergency response records from Civil Protection Authorities will support validation of flood risk models.

The next phase of the CLIMAAX project will focus on refining risk quantification through localized data integration, validating model outputs with field observations, and enhancing engagement with key decision-makers to ensure that climate risk information is effectively translated into adaptation planning and disaster risk reduction policies.

3 Conclusions Phase 1- Climate risk assessment

The first phase of the climate risk assessment for Crete provided valuable insights into regional drought and flood risks, while also highlighting methodological limitations and data gaps that need to be addressed in the next phase.

Key Findings

- Drought risk assessment successfully identified Heraklion and Lasithi as the most vulnerable regions, with increasing drought severity projected in high-emission scenarios. The agricultural drought analysis confirmed that central and eastern Crete face the highest revenue losses, particularly for olive groves, due to prolonged precipitation deficits and water scarcity.
- Flood risk assessment confirmed that flash floods pose the greatest flood hazard in Crete, affecting urban centres near rivers and coastal tourism developments expanding along former river routes. However, the CLIMAAX methodology did not provide usable results for future flood projections, and existing historical flood hazard data lacked the resolution to assess local flood risks accurately.

Challenges Addressed

- The CLIMAAX framework provided a structured methodology for conducting climate risk assessments, allowing for the identification of key risk areas and the integration of exposure and vulnerability indicators.
- Open-access datasets were effectively used for drought risk assessment, generating relative drought risk maps and economic impact estimates for agriculture.

Challenges Not Addressed

- Flash floods were not adequately captured in the flood risk assessment, as the methodology relies on global datasets that do not account for small, steep river basins characteristic of Crete's topography.
- Future flood risk projections could not be assessed, limiting the ability to evaluate climate change impacts on flooding.
- Drought vulnerability assessments require refinement, particularly in irrigation infrastructure data and socio-economic exposure indicators, which were limited by the resolution of global datasets.
- The integration of high-resolution local data is necessary to improve the accuracy and relevance of risk assessments, especially for flood modelling, agricultural drought projections, and infrastructure exposure analysis.

Next Steps

The next phase will focus on enhancing the assessment methodologies by incorporating local datasets, refining drought and flood risk models, and addressing identified data gaps. Additionally, stakeholder engagement will be expanded to ensure that risk assessment results align with regional adaptation planning and policy development. These improvements will be critical for the upcoming revision of the Regional Climate Change Adaptation Plan (2026+) and for developing more targeted climate resilience strategies for Crete.

4 Progress evaluation and contribution to future phases

This deliverable covers the first phase of climate risk assessment for Crete, focusing on drought and flood risk workflows. The results provide a baseline understanding of climate hazards, exposure, and vulnerability, informing both scientific refinement and regional adaptation planning in the following project phases. Despite methodological limitations - particularly in flood risk projections - the first phase successfully tested workflows, identified key data gaps, and set the foundation for enhancing risk assessments using local datasets in the second phase.

The insights from this phase will directly contribute to the refinement of methodologies and integration of localized data in the next stage of the project. Key next steps include:

- Refining the drought and flood risk assessments with high-resolution regional datasets to improve accuracy.
- Addressing flood modelling limitations, particularly regarding flash floods, by incorporating local hydrological data and improving exposure mapping.
- Strengthening stakeholder engagement, integrating feedback into the revised Regional Climate Change Adaptation Plan (2026+).
- Expanding communication and dissemination efforts, ensuring that findings inform policy-making, local decision-making, and public awareness.

4.1 Key Performance Indicators and Milestones

The progress made in this phase is summarized in the tables below, highlighting achievements and pending actions:

Table 4-1 Overview key performance indicators

Key performance indicators	***Target until the end of the project***	***Progress***
KPI1 - Number of workflows successfully applied on Deliverable 1	2	2 + wildfires still resolving issues
KPI2 - Number of stakeholders involved in the activities of the project	25+	31 stakekeholders during the 1st consultation meeting and 1st Workshop
KPI3 - Number of communication actions taken to share results with your stakeholders	4	1
KPI4 - Number of publications and dissemination actions	2 - (M3.5)	0

Key performance indicators	*Target until the end of the project*	*Progress*
KPI5 - Number of reports available for policy makers	3 - (D1, D2, D3)	1 (D1) + 2 technical reports for drought and floods (see sup. doc.)
KPI6 - Number of articles in regional media mentioning the project	3	4 (media and press release, see sup. doc.)

Table 4-2 Overview milestones

Milestones	*Progress*
M1.1 - Test of the Drought Risk Workflow made	Completed Nov 2024
M1.2 - Test of the Flood Risk Workflow made	Completed Nov 2024
M1.3 - Drought Risk Workflow successfully applied	Completed Feb 2025
M1.4 - Flood Risk Workflow successfully applied	Completed Feb 2025
M1.5 - Consultations and Workshop with Directorates done	Completed (1 Consultation meeting on 15 Jan 2025, 1 Workshop with Stakeholders 19 Mar 2025)

5 Supporting documentation

The outputs generated in this phase include the main climate risk assessment deliverables, technical reports, and communication materials. All outputs are uploaded to the Zenodo repository for open access.

1.Main report

- Deliverable 1: Climate Risk Assessment for Crete (PDF) – This report presents the methodology, results, and key findings from the first phase of the CLIMAAX project in Crete.

2.Technical reports

- 2a.Drought Hazard and Risk Assessment for Crete – Technical Report (PDF) – This document provides an in-depth assessment of drought risk applied in the CLIMAAX-CRETE 1st phase, including relative drought and agricultural drought methodologies, hazard assessments, and economic impact estimations.
- 2b.Flood Hazard and Risk Assessment for Crete – Technical Report (PDF) – This report details the river flood risk assessment applied in the CLIMAAX-CRETE 1st phase, highlighting exposure, vulnerability, and potential damages.

3.Communication outputs

Press releases and media coverage – A series of communication materials published on official platforms (Region of Crete, Technical University of Crete) and media outlets to disseminate the project's progress and findings.

- Two Official Press Releases on crete.gov.gr – Announcing Crete's participation in the CLIMAAX project and its objectives.

- Coverage on Cretalive.gr – Highlighting the scientific collaboration and significance of climate risk assessment for regional adaptation.
- Press Release from the Technical University of Crete – Discussing the role of hydrological modelling and climate projections in supporting regional policy.

4.Workshop agenda

As part of the CLIMAAX-CRETE 1st phase, a stakeholder workshop was conducted bringing together key representatives from regional authorities, municipalities, technical consultancies, sectoral organizations, and civil protection agencies. The workshop aimed to present preliminary climate risk assessment findings, gather expert feedback, and identify data gaps for the next project phase.

All outputs are publicly available through the Zenodo repository

https://doi.org/10.5281/zenodo.15075885

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