Deliverable Phase 2 – Climate risk assessment

CLIMAAX Risk Assessments Methodology Implementation for the Region Şanlıurfa (CRAS)

Türkiye, Southeastern Anatolia Region / Şanlıurfa Metropolitan Municipality

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Document Information

Deliverable Title	Phase 2 – Climate risk assessment
Brief Description	The second deliverable of the CRAS project presents the refined and localized implementation of the CLIMAAX methodology for climate risk assessment in Şanlıurfa, providing a detailed analysis of heatwave and drought risks using high-resolution regional data, locally adapted workflows, and expert stakeholder validation to support evidence-based adaptation planning.
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4.0	17/12/2025	Şanlıurfa Metropolitan Municipality	Final version to be submitted

Table of contents

List of figures

List of tables

Abbreviations and acronyms

Abbreviation / acronym	Description
AFAD	Turkish Disaster and Emergency Management Authority
AWC	Soil Available Water Capacity
CCAP	Climate Change Action Plan
CDP	Carbon Disclosure Project
CDS	Copernicus Data Store
CLIMAAX	Climate Adaptation and Risk Assessment Methodology
CRAS	CLIMAAX Risk Assessments Implementation for the Şanlıurfa Region
ÇŞİDB	Ministry of Environment, Urbanization, and Climate Change
DRMKC	Disaster Risk Management Knowledge Centre
ET_0	Reference Evapotranspiration
FAO	U.N. Food and Agriculture Organization
GAEZ	Global Agro-Ecological Zones
GAP	Southeastern Anatolia Project
GCM/RCM	Global Climate Model/ Regional Climate Model
GCoM	Global Covenant of Mayors for Climate and Energy
GIS	Geographic Information System
HDD/CDD	Heating Degree Days / Cooling Degree Days
LST	Land Surface Temperature
MGM	Turkish General Directorate of Meteorology
NUTS	Nomenclature of Territorial Units for Statistics
RCP	Representative Concentration Pathways
SECAP	Sustainable Energy and Climate Action Plan
SMM	Şanlıurfa Metropolitan Municipality
SPEI	Standard Precipitation Evaporation Index
SSP	Shared Socioeconomic Pathways
ŞUSKI	The Metropolitan Municipality Water and Sewerage Department
UTCI	Universal Thermal Comfort Index
WASP	Weighted Anomaly of Standardized Precipitation
WHO	World Health Organization

Executive summary

This deliverable was developed to refine and operationalise the climate risk assessment for Şanlıurfa, a metropolitan area of approximately 2.3 million people, following the baseline multi-risk screening presented in Deliverable 1. While Phase 1 identified heatwaves and drought as priority hazards using harmonised CLIMAAX workflows, it did not include detailed regional data or local validation. Phase 2 addresses this gap by providing high-resolution, locally adapted climate risk evidence to support decision-making for adaptation planning in urban systems, agriculture, water management, and public health. Readers will gain a clear understanding of where climate risks are concentrated, how they are expected to evolve toward 2050, and which risks require urgent action.

Main actions undertaken in Phase 2

Phase 2 implemented a refined Climate Risk Assessment using enhanced datasets, locally adapted methods, and structured stakeholder engagement. Two expert working groups—focused on heatwaves and drought—were established and met monthly throughout the phase, involving key regional institutions including the State Hydraulic Works (DSİ), the Metropolitan Municipality Water and Sewerage Department (ŞUSKİ), the Provincial Directorate of Agriculture, the GAP Regional Development Administration, and academic experts from Harran University.

CLIMAAX workflows were applied with improved exposure and vulnerability modelling, including the integration of night-time ASTER land surface temperature data (90 m resolution) to identify urban heat island hotspots, and refined agricultural drought hazard and risk assessments using regional crop coefficients and local unit prices. Additional analytical layers—such as crop-specific irrigation water requirement maps and comparison of current and future situations for six major crops—were also developed to strengthen the assessment of future agricultural vulnerability. Phase 2 outputs and methodological advances were also shared through the Pathways2Resilience (P2R) International Platform Group.

Main results and findings

The assessment confirms that both heatwave and drought risks in Şanlıurfa are severe and intensifying. Extreme heatwave days are projected to increase from approximately 20 to 40 days per year by 2050, placing growing pressure on densely populated urban districts with limited green space. Night-time heat-retention analysis reveals clear urban heat-island hotspots that were not clearly detectable in daytime satellite imagery. Our new data processing methodology for night-time Land Surface Temperature by Aster satellite was shared in Github/Climaax Forum.

Drought risk remains among the highest in Türkiye. By mid-century, annual precipitation is projected to decline by approximately 30%, while evapotranspiration is expected to increase, leading to higher irrigation demand. Under conditions of reduced irrigation availability, projected yield losses reach about 60% for maize, 40% for cotton and pistachio, and 25% for wheat and lentils. By 2050, yield losses in summer crops are expected to remain similar to current levels, whereas yield losses in winter crops are projected to double due to declining rainfall. Current and future revenue losses were also assessed by integrating a new local_unit_price_table into the workflow. Drought hazard workflow was further improved by integrating irrigation water requirement maps and eliminating four critical bugs affecting yield loss calculation..

Based on CLIMAAX severity, urgency, and resilience-capacity criteria, both heatwaves and agricultural drought are classified as Priority 1 (Very High) risks for Şanlıurfa.

Contribution to the overall CLIMAAX project

Phase 2 strengthens the CLIMAAX project by translating harmonised methodologies into locally validated, quantitative, and decision-ready risk information, demonstrating how CLIMAAX workflows can be adapted to semi-arid, agriculture-dependent regions.

Short conclusions – key takeaways

Climate risks in Şanlıurfa are already critical and are expected to escalate further by 2050. The projected doubling of extreme heatwave days and substantial irrigation-related yield losses indicate that delayed action will significantly increase social, economic, and environmental costs. High-resolution spatial analysis confirms the need for targeted, near-term adaptation measures.

Plans for the final phase

The final phase will translate these quantified risk priorities into adaptation pathways and an operational resilience roadmap, linking risk evidence to concrete measures, governance responsibilities, and investment needs.

1 Introduction

1.1 Background

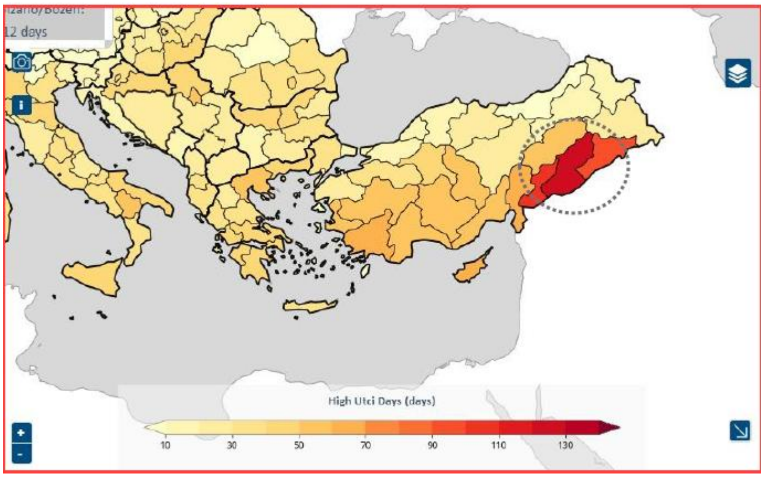


Figure 1-1 Geographic Location of Şanlıurfa

Şanlıurfa, located near the Syrian border in Türkiye's Southeastern Anatolia Region, covers 19,000 km² and hosts more than 2.1 million residents, including a large refugee population. The region's semi-arid climate produces extremely hot summers—often exceeding 40°C—and limited, irregular precipitation. Combined with low GDP per capita (below €5,000), rapid population growth, and limited institutional capacity, these conditions create chronic water stress, frequent heatwaves, and high sensitivity to climate extremes.

Deliverable 1 showed that Şanlıurfa is among the most climate-vulnerable provinces in Türkiye. It records one of the highest numbers of high-UTCI days in Europe (≈130 per year) and a Relative Drought Risk score of 4/5, the highest national category. Long-term SPEI trends indicate repeated extreme drought seasons, while projections from the national meteorological service suggest a 26–34% decrease in precipitation and a rise in evapotranspiration by mid-century.

Agriculture is one of the dominant economic sectors in Şanlıurfa, and is highly exposed to climate variability due to dependence on irrigation and extreme evapotranspiration pressures. Heatwaves pose increasing public-health risks—particularly for low-income groups, outdoor workers, elderly residents, and refugees—while limited urban green space exacerbates the urban heat island effect.

Based on these findings, Deliverable 1 identified heatwaves and drought as Şanlıurfa's priority climate hazards. The CLIMAAX CRAS project applies dedicated workflows—Heatwaves, Relative Drought, and Agricultural Drought—to generate spatial and quantitative evidence supporting climate-resilient urban planning, sustainable water management, and agricultural adaptation. This scientific foundation strengthens Şanlıurfa's climate governance and aligns with regional and national adaptation goals.

1.2 Main objectives of the project

Phase 2 aims to refine and localize the climate risk assessment developed in Phase 1 by integrating high-resolution regional data, adapting CLIMAAX workflows to Şanlıurfa's conditions, and strengthening the practical relevance of results for local decision-making.

1. Deepening and localizing climate risk assessments: Phase 2 enhances the understanding of heatwaves, drought, and water scarcity by incorporating detailed local datasets—such as regional crop coefficients, updated irrigation information, MGM climate projections, and socio-economic indicators. These additions allow risk estimates to better reflect Şanlıurfa's semi-arid climate and agricultural structure.

2. Customizing the CLIMAAX methodology to the local context: Using the CLIMAAX Handbook as the methodological foundation, Phase 2 adapts workflows to regional needs. Key improvements include the use of night-time ASTER land-surface temperature data to map urban heat islands more accurately, and refined agricultural drought modelling that compares current (2021–2025) and near-future (2046–2050) irrigation needs and yield losses.

3. Strengthening decision-making and stakeholder engagement: Two expert working groups—one for heatwaves and one for drought—meet monthly with municipal units, water authorities, agricultural institutions, and Harran University. This participatory process ensures that results are validated, interpretable, and aligned with planning needs in sectors such as agriculture, water management, public health, and urban development.

4. Supporting climate adaptation planning: The refined risk maps and indicators produced in Phase 2 provide actionable evidence for adaptation strategies, including urban greening priorities, irrigation efficiency planning, and hazard-based zoning. These outputs will also support coordination with national authorities and alignment with Türkiye's adaptation agenda.

Benefits of the CLIMAAX Handbook and local-data integration: The CLIMAAX Handbook ensures methodological consistency with European standards, while the inclusion of high-resolution local datasets—CDS climate variables, FAO/GAEZ agricultural inputs, Landsat and ASTER imagery, and regional socio-economic data—significantly improves accuracy and credibility. This combination enables a more realistic and operational assessment of heat and drought risks in Şanlıurfa.

1.3 Project team

The Phase 2 Climate Risk Assessment for Şanlıurfa is led by the Şanlıurfa Metropolitan Municipality (SMM) through its Climate Change and Zero Waste Department, which coordinates project activities and integrates results into municipal planning. Atalay Climate Consulting supports technical and methodological implementation.

A multidisciplinary team of six experts carries out the project: one project management and risk governance specialist, two climate and environmental engineers, one climate risk assessment specialist, one GIS and spatial analysis expert, and one data analysis and workflow programming specialist. In addition, two expert working groups—one on heatwaves and one on drought—meet regularly on a monthly basis to provide technical input, validate workflow outputs, and support the adaptation of CLIMAAX methodologies to local conditions.

1.4 Outline of the document's structure

This deliverable follows the CLIMAAX Phase 2 template and presents the refined climate risk assessment for Şanlıurfa. The document is organized as follows:

- Introduction provides background on the region, outlines the objectives of Phase 2, describes the project team, and explains the structure of the report.
- Climate Risk Assessment – Phase 2 details the scoping process, risk exploration, and the refined regionalized risk analysis, including the integration of local data and the adaptation of CLIMAAX workflows for heatwaves and drought.
- Key Findings and Conclusions summarize the main results of Phase 2 and discuss their implications for Şanlıurfa's climate resilience planning.
- Progress Evaluation reviews the achievements against the Key Performance Indicators and milestones defined for this phase and outlines the planned activities for Phase 3.

- Supporting Documentation lists the datasets, workflow outputs, maps, and accompanying materials that support the analysis and ensure transparency and reproducibility.

2 Climate risk assessment – phase 2

2.1 Scoping

2.1.1 Objectives

The objective of the Şanlıurfa Climate Risk Assessment (CRAS) is to generate a refined, high-resolution evaluation of the region's priority climate hazards—heatwaves and drought—building on the baseline established in Deliverable 1. Phase 2 aims to produce detailed spatial risk information tailored to Şanlıurfa's semi-arid climate, rapid urbanization, and agriculture-dependent economy. The refined assessment is intended to support evidence-based decision-making by municipal and regional authorities, guiding urban planning, water management, agricultural adaptation, public health preparedness, and climate-resilient investment planning.

The **expected outcomes** include:

- Updated, spatially explicit hazard, exposure, and vulnerability maps for heatwaves and drought;
- A clearer understanding of future risk evolution under 2050 climate scenarios;
- A structured risk narrative that can inform the Provincial Climate Change Action Plan (SECAP), municipal zoning decisions, irrigation strategies, and sectoral adaptation measures;
- Practical datasets and workflow outputs that local departments can reuse after project completion.

Limitations and boundaries: Phase 2 focuses exclusively on heatwaves and drought, identified in Phase 1 as the region's highest-priority hazards. The assessment is constrained by the limited availability of specific local datasets—particularly heat-related health and mortality records, detailed groundwater abstraction data, and district-level irrigation statistics. To address these gaps, the project team held exploratory discussions with external heat-health experts, including Madeleen Helmer, Advisor on Heat Adaptation (Adviseur Hitteadaptatie) at Klimaatverbond Nederland, as well as with the Regional Health Directorate, hospital representatives, and the Turkish Red Crescent. Although these institutions expressed interest, consistent, systematic health data on extreme heat events were not available for analysis. To compensate for these constraints, Phase 2 integrated new satellite-derived indicators (e.g., ASTER night-time LST), refined agricultural datasets, and iterative technical validation through two expert working groups. Challenges related to stakeholder availability, data quality, and technical capacity were addressed through targeted consultations, workflow demonstrations, and repeated feedback sessions.

2.1.2 Context

Climate hazards and risk assessment to date: Şanlıurfa's Climate Change Action Plan (SECAP) provides the region's first comprehensive assessment of climate hazards, identifying drought, extreme heatwaves, soil salinization, land degradation, flash floods, and climate-sensitive diseases as key risks. These hazards were assessed qualitatively through stakeholder surveys on hazard severity, vulnerable sectors, and adaptive capacity. For example, extreme heatwaves were rated as very high severity and high probability. However, these earlier assessments lacked spatial detail and did not identify where risks are concentrated.

Phase 1 of CLIMAAX addressed this gap by introducing data-driven, geospatial analysis of heatwave and drought hazards. Phase 2 further refines this analysis using local datasets and newly developed indicators, enabling decision-makers to understand not only the risks but also where and whom they affect.

Problem definition and wider regional context: Şanlıurfa faces escalating climate pressures, including water scarcity, agricultural yield losses, ecosystem degradation, and heat-related public health risks. These impacts threaten socio-economic stability in a province whose economy is heavily dependent on irrigated agriculture and whose population includes many vulnerable households.

Regionally, Şanlıurfa is part of the GAP development corridor, where water management, agricultural productivity, energy production, and rural development are strategic priorities. Nationally, the CRA aligns with Türkiye's National Climate Change Adaptation Strategy (2024–2030) and the 2053 Net-Zero Vision. Internationally, Şanlıurfa is committed to the Global Covenant of Mayors (GCoM) and reports climate risks and progress through CDP-ICLEI Track, reinforcing the need for transparent, science-based climate information.

Governance context: The Climate Change and Zero Waste Department of Şanlıurfa Metropolitan Municipality leads local climate mitigation and adaptation work. A Climate High Council and a Climate Working Group coordinate cross-departmental planning. Land-use regulation and environmental oversight are shared with the Provincial Directorate of Environment, Urbanization, and Climate Change. Water resources and irrigation fall under the responsibility of DSİ and the municipal water utility. National ministries set overall climate policies and will be directly engaged in Phase 3.

Sectors affected by climate change

Climate impacts affect multiple sectors, mainly:

- Agriculture & Food Systems: High drought sensitivity, declining rainfall, and soil salinity threaten yields.
- Water Resources: Rising evapotranspiration and decreasing precipitation increase pressure on irrigation systems and groundwater.
- Public Health: Extreme heat events disproportionately affect the elderly, outdoor workers, low-income groups, and refugees.
- Urban Systems: Limited green space amplifies the urban heat island effect and reduces climate resilience.
- Energy: Cooling demand increases during heatwaves, heightening pressure on the electricity network.
- Ecosystems & Land: Desertification and land degradation reduce ecological resilience.

External influences and supportive initiatives: Several external initiatives shape Şanlıurfa's climate resilience landscape.

- The GAP Regional Development Program influences land, water, and agricultural planning.
- The Pathways2Resilience (P2R) project supports governance, stakeholder mapping, and identification of adaptation finance strategies.
- Partnerships with Harran University and other academic institutions strengthen scientific capacity.

- Preparations for Türkiye's forthcoming Climate Law will reshape responsibilities and increase the need for robust risk information.

Potential and ongoing adaptation interventions

Current and potential measures relevant for Şanlıurfa include:

- Modernizing irrigation systems and improving agricultural water efficiency
- Scaling green infrastructure to reduce urban heat
- Expanding treated wastewater reuse for non-potable purposes
- Strengthening early-warning systems for heatwaves and drought
- Building public awareness and providing training for farmers and municipal staff
- Coordinating climate finance through EU, national, and regional programs
- Promoting climate-resilient agriculture through crop diversification and soil restoration

Phase 2 provides the evidence base needed to prioritise these interventions.

2.1.3 Participation and risk ownership

During Phase 2, Şanlıurfa Metropolitan Municipality coordinated a structured and inclusive stakeholder engagement process to support the Climate Risk Assessment. Stakeholders were involved through workshops, bilateral meetings, technical consultations, and data-sharing sessions. The leading actors included municipal departments responsible for climate, environment, water, agriculture, transport, and urban planning; regional agencies such as the GAP Regional Development Administration and the 15th Regional Directorate of State Hydraulic Works (DSİ); the Provincial Directorates of Environment, Agriculture, and Health; AFAD's Provincial Disaster Directorate; district municipalities; and academic experts from Harran University. Civil society organizations, farmer cooperatives, and representatives of vulnerable groups also participated. The institutional roles and interactions are summarized in the organizational chart below (Figure 2-1).

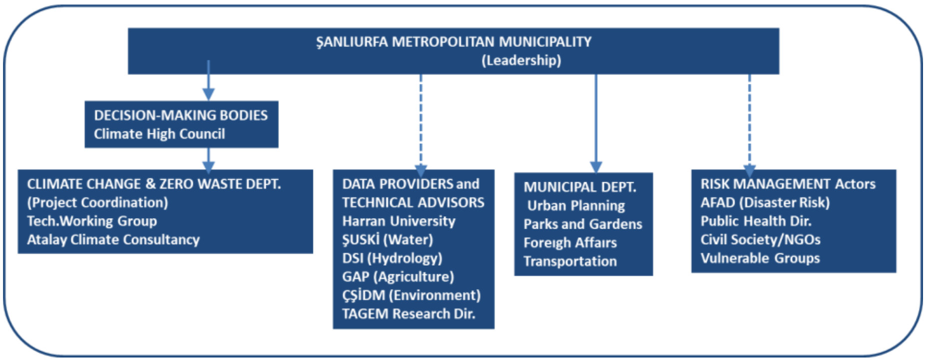


Figure 2-1 An organizational chart that maps the institutions and responsibilities

Risk ownership: In Şanlıurfa, risk ownership follows a distributed model aligned with existing governance structures.

- The Climate Change and Zero Waste Department leads climate risk identification, coordinates datasets, and integrates CRA results into planning processes.
- AFAD holds responsibility for natural hazard monitoring, early warnings, and emergency response.
- ŞUSKİ (Water Authority) and DSİ manage risks related to water scarcity, hydrology, and critical water infrastructure.

- The Provincial Agriculture Directorate and farmer organizations are responsible for agricultural drought impacts, soil degradation, and crop losses.
- Urban Planning and Infrastructure Departments manage risks related to heatwaves in dense districts and exposure of vulnerable settlements.
- The Provincial Health Directorate oversees public-health risks, including heat-related illness and climate-sensitive diseases.
- Overall coordination is facilitated through the Climate High Council and the Climate Working Group, which align responsibilities across institutions.

Vulnerable groups: Priority groups—identified through SECAP and Phase 1—include farmers and rural communities, low-income urban neighborhoods, women, children, elderly persons, disabled individuals, seasonal agricultural workers, refugees, and livestock-dependent households. These groups are represented through chambers of agriculture, local NGOs, community associations, and neighborhood leaders (muhtars).

Acceptable/tolerable risk levels: Şanlıurfa does not apply a numerical tolerable-risk threshold.

Instead, qualitative thresholds are defined through:

- the SECAP risk matrix (severity × probability),
- CRA classifications ("low", "medium", "high"),
- AFAD national disaster guidelines, and
- municipal zoning regulations.

In practice, risks categorized as high or very high—particularly in heatwave and drought maps—are considered intolerable and require immediate adaptation action.

2.1.4 Application of principles

Social justice, equity, and inclusivity: Phase 2 explicitly applied equity and social justice principles by identifying groups and locations in Şanlıurfa that face disproportionate climate risk. Şanlıurfa's social structure is highly diverse, comprising Turkish, Kurdish, and Arab communities, as well as large numbers of seasonal agricultural workers and refugees. Cultural and socio-economic conditions differ substantially from those in typical European regions: GDP per capita is nearly 10 times lower than the EU average, and access to cooling, healthcare, and safe working conditions is highly uneven across social groups.

Neighborhood-level ASTER night-time LST analysis showed that densely built central districts such as Haliliye, Eyyübiye, and Karaköprü retain significantly more heat at night, exposing low-income households and tenants who cannot afford cooling systems. In rural areas, seasonal agricultural workers in Suruç, Harran, and Akçakale — many of whom belong to Kurdish and Arab communities — experience high exposure to heat stress and water scarcity due to long outdoor working hours and limited social protection.

To ensure inclusivity, stakeholder consultations intentionally included muhtars from high-risk neighborhoods, women's associations, farmer cooperatives, refugee-support NGOs, and community groups representing Kurdish and Arab populations. The project team itself reflects this diversity, including members with Kurdish, Arab, and Turkish backgrounds, which facilitated culturally sensitive engagement and strengthened trust in discussions with different local communities.

Quality, rigour and transparency: The assessment followed the CLIMAAX Framework and maintained methodological rigour through systematic use of local datasets, including MGM climate data, ŞUSKİ water infrastructure records, agricultural production data, and TÜİK socio-economic indicators. To improve scientific accuracy, a new nighttime ASTER LST workflow was developed to detect urban heat islands, filling a critical gap not captured by daytime Landsat imagery.

Transparency was ensured through multi-stakeholder validation workshops and joint technical review sessions with AFAD, ŞUSKİ, urban planning units, agricultural directorates, and Harran University, where assumptions, uncertainties, and dataset limitations were openly discussed.

Precautionary approach: Given the high climatic uncertainty in Southeastern Anatolia—particularly the projected intensification of heat extremes and declining precipitation—the precautionary principle guided the interpretation of results. The projected doubling of extreme heatwave days justified the early prioritization of cooling corridors, shade infrastructure, and greening actions in central urban districts. Anticipated 30% declines in precipitation and rising evapotranspiration supported the evaluation of agricultural drought risks even in irrigated areas of the Harran Plain, guiding recommendations for water-saving technologies and crop diversification under uncertain future water availability.

Difficulties encountered

Challenges included:

- Lack of heat-related hospitalisation and mortality data, despite engagement with the Regional Health Directorate, hospitals, and the Turkish Red Crescent;
- Limited early participation from rural districts and vulnerable groups;
- Language and accessibility barriers affecting elderly residents, refugees, and non-Turkish-speaking communities;
- Limited availability of municipal technical staff due to overlapping obligations (SECAP, CLIMAAX, P2R).

Despite these challenges, participation remained constructive, and data gaps were mitigated through the integration of satellite indicators, refinement of agricultural inputs, and repeated validation sessions with expert working groups.

2.1.5 Stakeholder engagement

Throughout Phase 2, a structured and inclusive stakeholder engagement process was implemented to ensure that local knowledge, institutional responsibilities, and community needs were fully reflected in the Climate Risk Assessment. Engagement activities targeted municipal departments, regional authorities, academic experts, NGOs, and priority groups—including low-income neighborhoods, farmers, seasonal workers, elderly residents, and refugee communities—reflecting Şanlıurfa's multicultural social structure (Turkish, Kurdish, and Arab communities).

Engagement activities and meetings

Key engagement events included:

- CLIMAAX Local Kick-Off Meeting (19 December 2023)
- Data Needs Assessment Workshop (22 February 2024)
- Vulnerability & Prioritization Workshop with sectoral representatives
- Phase 1 Interim Consultation Meeting (Heatwaves & Drought)
- P2R Stakeholder Mapping Interview Round
- Baseline Survey Follow-Up Session with municipal units

- Technical Consultation Meeting on Hazard Maps (heatwaves and drought)
- Priority Groups Discussion (NGOs, social services, health representatives)
- Phase 2 Draft Results Verification Meeting
- UNDP Knowledge-Sharing Webinar with other Turkish municipalities
- P2R International Platform Group (IPG) meeting, where Şanlıurfa presented its CLIMAAX findings to European partners

Expert working groups (Heatwaves and Drought)

In addition to formal workshops, two expert working groups were established to ensure continuous technical validation and feedback during Phase 2:

- Heatwave Expert Group – municipal departments, health directorate, Harran University, and NGOs working on vulnerable populations.
- Drought Expert Group – agricultural directorates, DSİ, GAP Administration, farmer organizations, and water authorities.

Both groups convened monthly, reviewed workflow outputs (ASTER-based UHI mapping, irrigation requirement maps, yield loss estimates), and provided practical insights grounded in local experience. Their contributions significantly improved the interpretation of risk hotspots, social vulnerability patterns, and sector-specific implications.

Participants and communication methods: Participation ranged from 20 to 45 attendees per meeting. Municipal departments (climate, environment, urban planning, water and wastewater, agriculture, transportation), AFAD, the Provincial Directorates of Agriculture, Health, and Environment, DSİ, GAP Administration, Harran University, NGOs, and priority groups were regularly represented.

Communication relied on visual, accessible materials, including hotspot maps, exposure layers, vulnerability indices, and summary documents of the CLIMAAX methodology. Particular attention was given to presenting complex technical results in a way understandable to non-technical participants.

Feedback from participants

Stakeholders consistently responded positively to the clarity of spatial outputs.

- Municipal planners emphasized the usefulness of neighborhood-level heatwave maps for zoning decisions.
- Agricultural institutions valued the crop-specific drought and irrigation requirement analysis.
- Health authorities confirmed the relevance of heatwave thresholds and exposure patterns.
- NGOs working with refugees, women, and elderly communities requested further integration of social vulnerability data into future analyses.

Participants stated they will use CLIMAAX outputs to support urban greening decisions, agricultural drought preparedness, heat-health planning, water resource management, disaster planning (AFAD), and future EU climate funding applications.

Difficulties encountered

Stakeholder engagement faced several constraints:

- Absence of heat-related hospitalization and mortality data, despite outreach to the Regional Health Directorate and Turkish Red Crescent
- Limited early participation from rural districts
- Language barriers affecting elderly and refugee communities
- Competing workloads in municipal departments (SECAP, CLIMAAX, P2R)

Despite these challenges, engagement remained constructive, and recurring meetings with the two expert groups helped maintain momentum and continuity throughout Phase 2.

2.2 Risk Exploration

Risk exploration in Phase 2 combined qualitative knowledge from Şanlıurfa's SECAP process with new quantitative evidence generated through the CLIMAAX workflows. Phase 1 identified heatwaves and drought as the two priority hazards. Phase 2 focused on improving the spatial resolution of these hazards and validating results with local expert groups.

2.2.1 Screen risks (selection of main hazards)

Relevant climate hazards in Şanlıurfa: Qualitative assessments carried out under Şanlıurfa's SECAP identified drought, extreme heatwaves/urban heat island effect, soil degradation/salinization, and flash floods as the hazards with the highest combined severity and likelihood. Sectoral vulnerability analysis also showed that agriculture, livestock, food supply, energy and water infrastructure, and public health are the most sensitive sectors to extreme heat. These early assessments provided important prioritization insights but lacked spatial detail and did not distinguish between hazard intensities across districts.

What is NEW in Phase 2 compared to Phase 1

1. High-resolution, data-driven hazard mapping

CLIMAAX workflows were applied using:

- Night-time ASTER 90m LST, which allowed detailed identification of urban heat island hotspots (e.g., Haliliye, Eyyübiye, Karaköprü) that daytime Landsat 8 imagery could not capture.
- Local crop coefficients and irrigation coverage data, enabling more realistic agricultural drought and yield-loss calculations.
- Current (2021–2025) vs. near-future (2046–2050) comparisons for precipitation, evapotranspiration, irrigation needs, and crop yield losses.

This is the main improvement beyond the Phase 1 screening, which was qualitative-only.

2. Integration with P2R governance baseline: Findings from the P2R Baseline Report—especially on institutional capacity, risk ownership, and financial constraints—were incorporated to refine risk prioritization and better align hazard screening with governance realities.

3. Stakeholder validation through two expert groups: The separate Heatwave and Drought Expert Groups met monthly and provided continuous validation of hazard maps and their interpretations. Their insights helped identify misalignment between model outputs and ground realities, especially for irrigation dependency and UHI patterns.

Hazards included in this risk assessment and why

This CLIMAAX risk assessment covers two hazards:

- **Heatwaves:** Şanlıurfa has one of the highest numbers of high-UTCI days in Europe (~130 days/year), with MGM thresholds indicating extreme heatwaves already 20 days/year and projected to double by 2050. Heatwaves strongly affect public health, energy demand, and urban livability.
- **Drought:** Şanlıurfa is historically the province with one of the highest drought risk scores (Relative Drought Level 4/5). Agricultural drought threatens food systems, irrigation demand, groundwater, and rural livelihoods.

Other hazards (e.g., hail, flash floods, vector diseases) remain relevant but are not included in this quantitative CLIMAAX analysis due to methodological scope and data limitations.

Current knowledge and remaining gaps

Available knowledge:

- SECAP qualitative surveys (hazard, vulnerability, adaptive capacity)
- CLIMAAX workflows (heatwave, relative drought, agricultural drought)
- MGM climate series and RCP projections
- Crop production, crop coefficients, and irrigation system coverage
- Landsat 8 LST (daytime), ASTER LST (night-time)
- P2R governance, vulnerability, and finance baselines

Remaining gaps:

- No systematic records of heat-related hospitalisations or mortality, despite discussions with the Regional Health Directorate, hospitals, and Turkish Red Crescent.
- Lack of spatially explicit groundwater abstraction data
- Limited availability of long historical yield-loss datasets
- Limited socio-economic vulnerability indicators at the neighborhood scale

These gaps were partially addressed using remote sensing, workflow customisation, and expert validation.

2.2.2 Choose Scenario

Future climate conditions considered: Scenario selection followed CLIMAAX guidance and Şanlıurfa's long-term climate goals.

Two scenarios were used: **1. Moderate scenario:** SSP2–RCP4.5 **2. Pessimistic scenario:** SSP5–RCP8.5

These capture both likely and high-impact warming pathways. RCP4.5 is used for agricultural drought because CLIMAAX provides consistent climate projection datasets for this scenario.

Socio-economic developments considered

Şanlıurfa's socio-economic projections were incorporated qualitatively, focusing on:

- Continued population growth (including rural-to-urban migration and refugee population)
- Expansion of irrigated agriculture
- Urban expansion in Karaköprü, Haliliye, and Eyyübiye
- Rising cooling demand and energy consumption
- Increasing water demand in the agriculture and domestic sectors

These drivers were used to interpret trends in exposure and vulnerability.

How climate and socio-economic conditions were combined: Future hazard values (precipitation, ET_0, heatwave frequency) were combined with socio-economic projections (population, land use, irrigation demand, sectoral vulnerability) to produce realistic risk narratives and adaptation implications.

Time horizons

Two time horizons were used: **1. Current period (2021–2025)** — baseline for exposure and vulnerability **2. Medium-term (2046–2050)** — consistent with CLIMAAX projections and Şanlıurfa's climate resilience target (2050)

2.3 Regionalized Risk Analysis

2.3.1 Hazard #1 – Heatwaves fine-tuning to local context

Table 2-1 Data overview for heatwave workflow

Hazard data	*Vulnerability data*	*Exposure data*	*Impact metrics/Risk output*
Daily Temp., Tmax, Tmin thresholds, MGM- Regional Climate Datasets and Projections, Heatwave Index, Heatwave Frequency, Heatwave Duration	Vulnerable Population Density dataset from WorldPop (Vulnerable groups: females>65; children <5), Maps of schools, hospitals, and social community Buildings.	Night-time LST data from the Terra ASTER satellite. Day-time LST data from the Landsat 8 satellite	Urban Heat Island and Heatwave Risk maps of the City center (More clear and prioritized maps by means of night-time visualization). "Very High" and "High" risk neighborhoods map. Heatwave risk maps of all Sanliurfa Districts.

2.3.1.1 Hazard assessment

In the CLIMAAX heatwave hazard analysis, future trends in the heatwave index, duration, and frequency were calculated under moderate and pessimistic climate scenarios (RCP4.5–RCP8.5). The CLIMAAX Heatwave XCLIM workflow was used for these calculations.

Heatwave Index projections were analyzed for 2 different cases in Sanliurfa:

Case 1: 90 percentile of max daily temperatures: 90pct Tmax> 34 °C in 3 days of duration (as threshold used in EuroHeat)

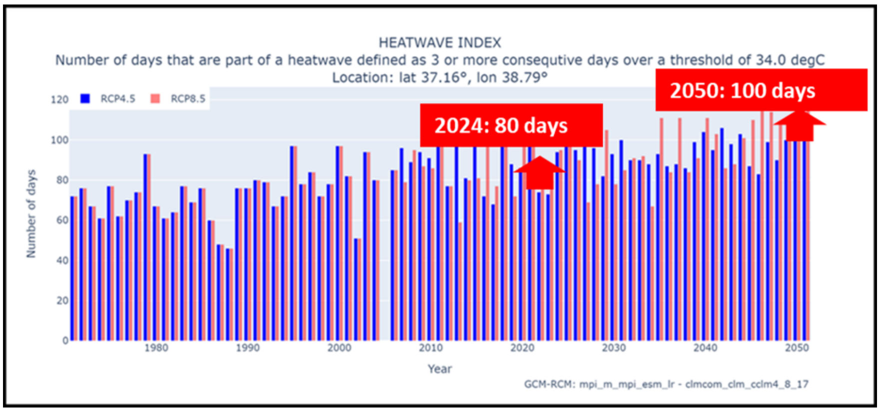


Figure 2-2 Heatwave Index graph based on 34 °C and 3 consecutive days

Heatwaves lasting>3 days and temperatures above 34 °C are projected to increase by 25% by 2050, rising from 80 days to 100 days. However, at these threshold values, the frequency of heatwaves remains the same. Extreme conditions have also been analyzed to assess whether the frequency of extreme heatwaves in Şanlıurfa will increase in the near future (by 2050). For this purpose, case 2 threshold conditions were evaluated.

Case 2: Extreme Heatwave conditions defined by the State Meteorological Department (MGM): 95 percentile of max and min. daily temperatures: Tmax > 39.5 °C, Tmin > 25.4 °C, duration > 3 days for Şanlıurfa. In Şanlıurfa, the number of days experiencing extreme heatwave threshold conditions will be projected to double by 2050, increasing from 20 days/year to 40 days/year.

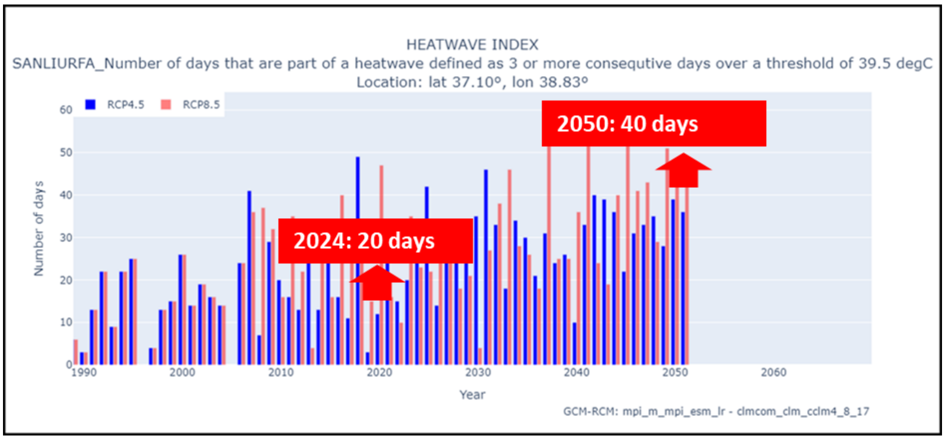


Figure 2-3 Heatwave Index graph based on 39.5 °C and 3 consecutive days

The frequency of heatwaves at extreme threshold levels, which could be highly hazardous to human health, currently occurs 1–2 times per year, but is expected to increase to 4–5 times per year by 2050.

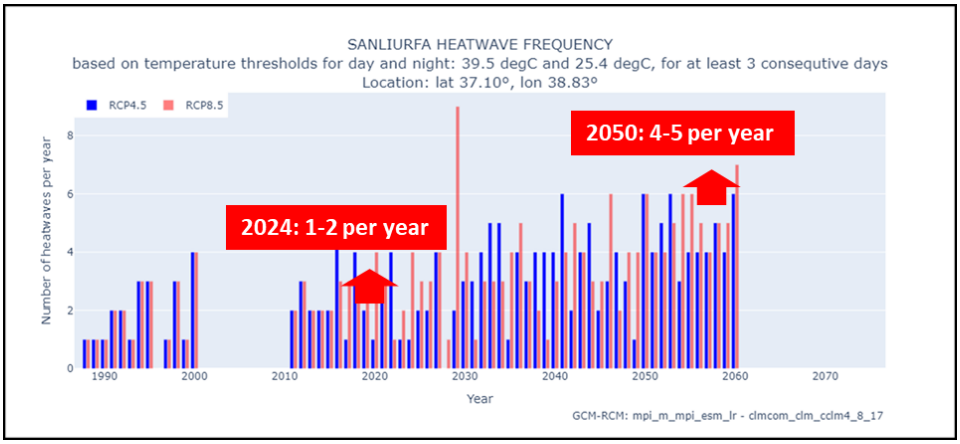


Figure 2-4 Heatwave Frequency graph based on Tmax:39.5 °C -Tmin:25.4 °C and 3 consecutive days

The frequency of heatwaves at extreme threshold levels, which could be highly hazardous to human health, currently occurs 1–2 times per year, but is expected to increase to 4–5 times per year by 2050. In our region, given the deadly impacts of extreme heatwaves, expected to occur much more frequently in the near future, it is imperative to start planning adaptation actions NOW.

2.3.1.2 Risk assessment

At the Şanlıurfa Metropolitan Municipality, Landsat 8 datasets for daytime observations during the summer season have already been applied. However, because daytime land surface temperatures often exceed 60°C and are relatively homogeneous across the city center, it was not possible to effectively visualize temperature variations or the urban heat island effect. Therefore, another data source providing nighttime LST images was searched for and found in the ASTER satellite. The Sanliurfa Climaax Team developed a new methodology for processing LST data.

Landsat 8 offers consistent global coverage and good temporal consistency, but it has fewer thermal bands and generally provides daytime-only acquisitions. For city-scale UHI studies, ASTER's 90 m thermal data is better suited to detect local temperature variations between urban structures and vegetated areas. ASTER's ability to acquire both daytime and nighttime thermal images is a major advantage. Nighttime LST helps capture residual heat storage in built-up areas and provides more apparent contrasts between urban and rural surfaces. This makes ASTER data more convenient and reliable for visualizing and quantifying the urban heat island effect, especially in densely built city centers. The new nighttime UHI data analysis method was shared with Climaax and P2R communities to be extended as a new or modified workflow.

As the first regional example of workflow applications, it was approved and shared in GitHub/Climaax: https://github.com/CLIMAAX/examples/tree/main/Heatwaves_NewDataSource

A presentation about Şanlıurfa's Heatwave risk analysis shared with P2R: https://youtu.be/lzdsMVBiyAg?si=tjQBVg1Ty6euDd0h

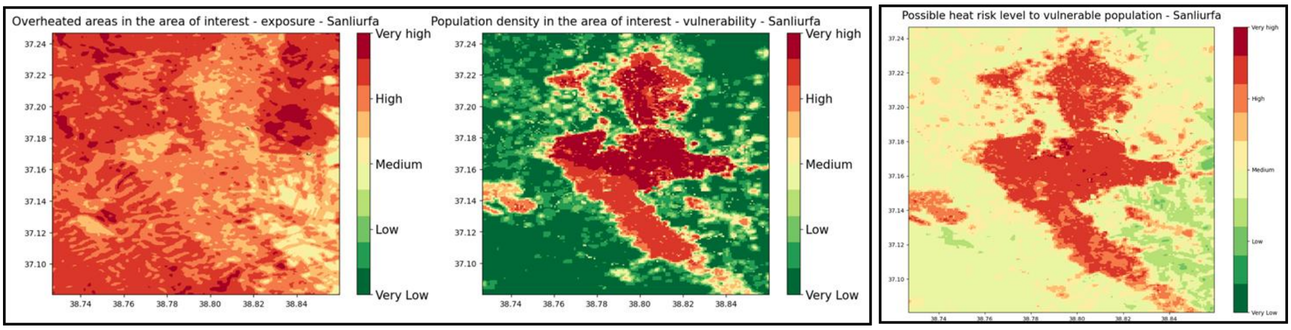


Figure 2-5 Night-time LST and vulnerability population density maps in Şanlıurfa City centre.

The heatwave risk map, "very high-risk" neighborhoods, and socially vulnerable areas (schools, hospitals, and social community buildings) are shown below at a 100×100-meter resolution within an area of approximately 18×18 km.

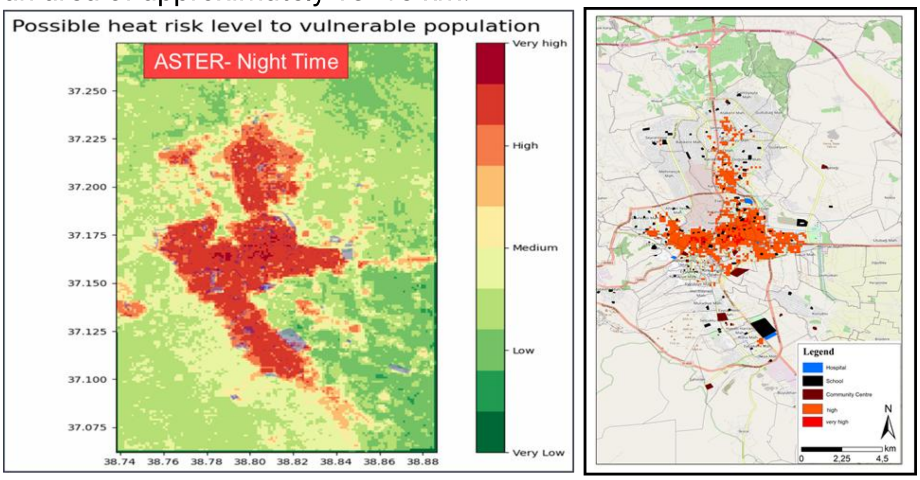


Figure 2-6 Possible Heatwave Risk Map and the geographic location of neighborhoods and socially vulnerable buildings

The geographic location of some neighborhoods, which will be exposed to "Very High" Heatwave Risk and high priority for adaptation actions, is determined as follows: Cengiz Topel, Bahçelievler, Sultan Fatih, Paşabağı, Şair Nabi, Yenişehir, Ulubatlı, Yeşildirek

Calculation of the priority green areas that need to be increased in the central neighborhoods against Heatwaves by the year 2035:

- Current Green Area: 10 hectares
- Additional Green Area Required: 31 hectares

Table 2-2 Assessment of Urban Greening in High-Priority Neighborhoods

Neighborhoods in Şanlıurfa City Center	Risk Level	Greenland, hectare	Population, cap.	Vulnerable Population <5, >65 %	Greenland per capita		Additional GreenLand Required, hectare
					Current m^2/cap.	2035 Target m^2/cap.	
CENGİZ TOPEL	Very high	0.00	2,666	15%	0.0	9.0	2.40
BAHÇELİEVLER	Very high	0.00	1,341	18%	0.0	9.0	1.21
SULTAN FATİH	Very high	0.71	877	16%	8.1	9.0	0.08
PAŞABAĞI	Very high	1.95	5,501	15%	3.5	9.0	3.00
ŞAİR NABİ	Very high	1.69	8,842	16%	1.9	9.0	6.27
YENİŞEHİR	Very high	0.79	10,532	14%	0.7	9.0	8.69
ULUBATLI	Very high	4.56	7,259	16%	6.3	9.0	1.97
YEŞİLDİREK	Very high	0.53	8,331	15%	0.6	9.0	6.96
TOTAL		10 hectare					31 hectare

2.3.2 Hazard #2 – Drought finetuning to local context

Drought hazard and risk assessments were conducted using both the Climaax Relative Drought and the Agricultural Drought workflows.

Table 2-3 Data overview for drought workflow

Hazard data	Vulnerability data	Exposure data	Impact metrics/Risk output
Climate data from CDS (Daily precipitation, max/min temp, humidity, solar rad., wind speed), Soil AWC, Elevation, Thermal Climate Zone; Regional Crop Coefficients and growing season lengths (for cotton, maize, wheat, pistachio, lentil, and chickpea)	Irrigation availability from GAEZ (percentage of cropland in each grid-cell equipped with irrigation systems) at 11 km res.	Crop production (ton) data from MapSPAM-2020, (at 5 arc-min res.) Regional Crop Unit Prices Crops Aggregated Value from FAO Global Agro-Ecological Zones (GAEZ) at 11 km res.	Maps showing crop yield loss due to irrigation deficit, for local main crops (cotton, maize, wheat, pistachio, lentil, and chickpea) Maps showing irrigation requirements (mm) for all local main crops. Comparison of annual precipitation, ET0, yield loss, and irrigation requirements. Between 2021-25 and 2046-50 temporal periods, Revenue losses for each main crop per grid cell based on the absence of irrigation system coverage

2.3.2.1 Hazard assessment

CLIMAAX Relative Drought risk scores were obtained as the product of the hazard, exposure, and vulnerability components, which were normalized across all NUTS3 regions of Türkiye. For relative drought, the hazard component was analyzed using the Weighted Anomaly Standardized Precipitation (WASP) index, which accounts for seasonal variability and represents precipitation deficits.

For Şanlıurfa, the risk was analyzed using the WASP index (hazard), exposure indicators (cultivated land, population, and water stress), and vulnerability data (rural population ratio and GDP per capita).

The figures below show the current and future relative drought risks. The relative drought risk score for the Şanlıurfa Region is currently at level 4 out of 5 (High), the highest level observed across Türkiye, and is expected to remain at level 4 until 2050. However, it is also observed that drought risk in regions such as southern Marmara, the Aegean, and Central Anatolia will reach levels similar to those currently seen in Şanlıurfa.

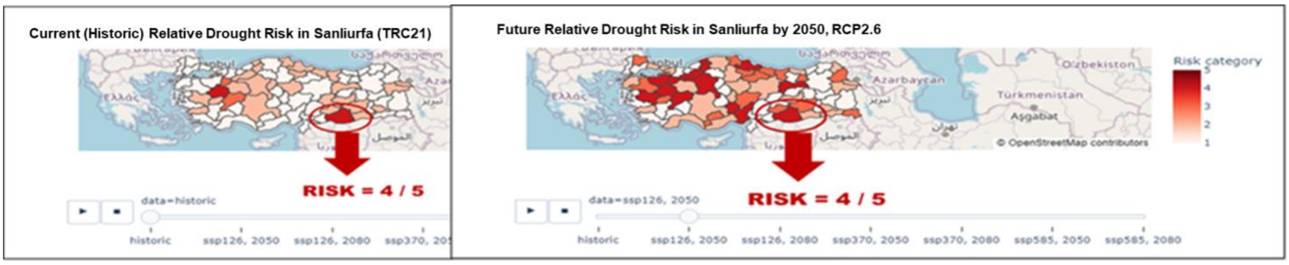


Figure 2-7 Relative Drought maps of Turkey and Şanlıurfa's risk scores.

The agricultural drought hazard was assessed using climate projection datasets from the EU CDS for the RCP4.5 scenario covering the temporal periods of both 2021-2025 and 2041–2045for comparison and for the regional main crops of the TRC21 region (Cotton, Maize, Wheat, Pistachios, Lentil, and Chickpea) parameterized in the regional crop coefficients as shown in the table below. The analysis focused on cumulative seasonal precipitation, available soil water capacity, and standard evapotranspiration to evaluate the water balance affecting crop productivity in the Şanlıurfa region.

Table 2-4 Regional crop coefficients of Şanlıurfa's main crops

FAO Code	Crop	Clim	Kc_in	Kc_mid	Kc_end	lgp_f1	lgp_f2	lgp_f3	lgp_f4	Season start	Season End	RD1	RD2	DF	Type	Ky
111	Wheat	Regional	0.66	1.14	0.26	0.137	0.522	0.183	0.137	286	139	0.2	1.25	0.55	1	1
112	Maize	Regional	0.29	1.25	0.37	0.177	0.25	0.339	0.234	141	281	0.2	1	0.55	1	1.25
9211	Cotton	Regional	0.32	1.25	0.62	0.166	0.274	0.31	0.25	120	301	0.2	1.35	0.65	1	0.85
365	Pistachio	Regional	0.4	1.1	0.45	0.089	0.292	0.354	0.266	71	297	1.25	1.25	0.4	0	0.85
201	Lentil	Regional	0.67	1.09	0.31	0.143	0.524	0.19	0.143	310	155	0.2	0.7	0.5	1	1
191	Chickpea	Regional	0.86	0.97	0.34	0.193	0.387	0.29	0.129	317	107	0.2	0.8	0.5	1	0.6

Source: The Ministry of Agriculture and Forestry- Turkish Agricultural Research Center (TAGEM)

https://www.tarimorman.gov.tr/TAGEM/Belgeler/yayin/Tu%CC%88rkiyede%20Sulanan%20Bitkilerin%20Bitki%20Su%20Tu%CC%88ketimleri.pdf

The region currently receives an average of 610 mm of total annual precipitation, but by 2050, total annual precipitation is projected to decrease by 30%, to 424 mm. On the other hand, evapotranspiration, already at an extremely high level of around 1734 mm, is expected to increase further, reaching approximately 1853 mm by 2050. The declining precipitation and increasing evapotranspiration rates indicate a strong dependency on intensive irrigation in the region.

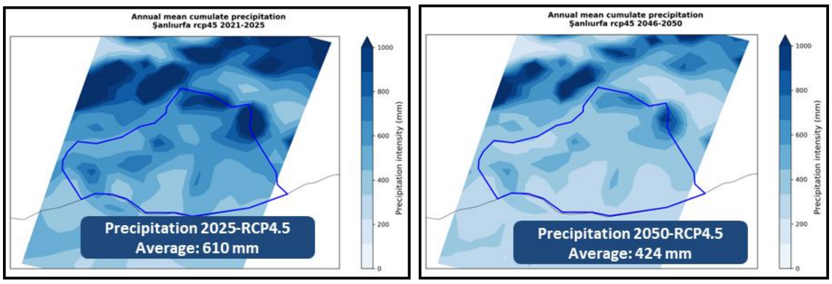


Figure 2-8 Comparison of Projected Annual Precipitation Change between 2025 and 2050

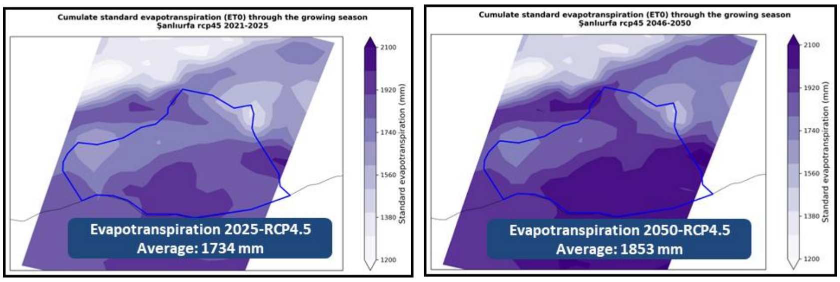


Figure 2-9 Comparison of Projected Annual Evapotranspiration Change between 2025 and 2050

If agricultural drought leads to reduced irrigation capacity and forces reliance solely on rainfall, it is estimated that, under the medium-emission scenario (RCP4.5), by 2050 the region will experience average yield losses of 60% in maize production, around 40% in cotton and pistachio production, 25% in wheat, 27% in lentils, and approximately 11% in chickpeas.

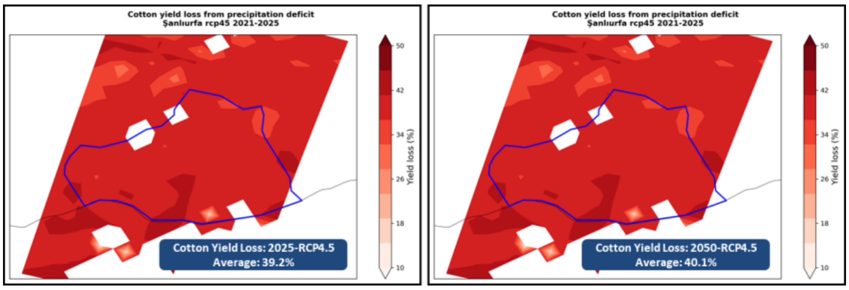


Figure 2-10 Comparison of the Yield Loss change in Cotton between 2025 and 2050

To better analyze the impact of agricultural drought in Şanlıurfa, crops planted in the summer and winter seasons were analyzed separately. Summer crops such as maize and cotton are completely dependent on artificial irrigation due to low precipitation and extremely high evaporation. For these crops, irrigation dependency will remain constant between 2025 and 2050, and yield losses under water scarcity conditions will not change.

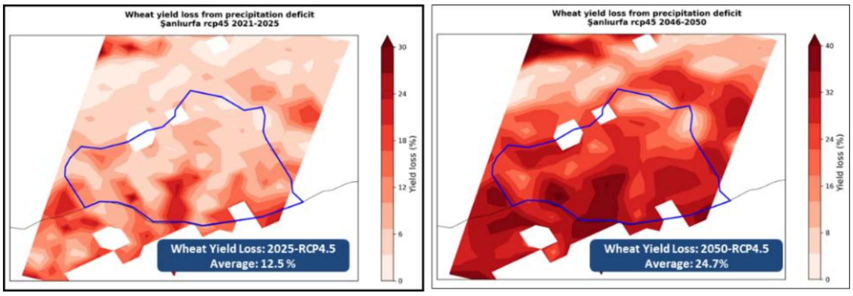


Figure 2-11 Comparison of the Yield Loss Change in Wheat between 2025 and 2050

On the other hand, winter crops such as wheat, lentils, and chickpeas—which receive relatively more rainfall and experience lower evapotranspiration—will become more dependent on irrigation due to a projected 30% decrease in precipitation. As a result, yield losses from insufficient irrigation are expected to increase by an average of 100%.

2.3.2.2 Risk assessment

The revenue losses resulting from reduced crop yields due to precipitation scarcity and the absence of irrigation were visualized in the following maps. Calculation of total revenue and revenue losses was improved by using local crop unit prices rather than rough estimates based on GAEZ Aggregated Values, which are the total of all crops. Additionally, total revenues for each main crop were calculated based on the 2019-21 average production (ton) and local unit prices (USD/ton) using exported CSV files, and the results were visualized as revenue-per-pixel maps. For this purpose, we have created a new "crop_unitprice.csv" file and modified the workflow's data pr accordingly.

Table 2-5 Regional unit prices of some main crops are used for revenue and revenue loss calculations.

Crop_ID	*WHEA*	*MAIZ*	*COTT*	*LENT*	*CHIC*	*APPL*	*BANA*	*TOMA*	*POTE*	*CITR*	*SUGB*
Unit_Price_USD_per_ton	343	288	789	738	1018	950	764	400	300	1782	79

The margin of error between the workflow in the current version (using the GAEZ Aggregated values) and the modified workflow with local unit prices was also compared based on total revenues within Şanlıurfa's geographical boundaries. For crops such as cotton, lentils, and chickpeas—where the unit price is significantly higher than the average unit price—the margin of error is 100–200%. Therefore, as shown in the table below for crop-based evaluations, GAEZ provides a relatively coarse and misleading result.

Table 2-6 Comparison of Revenue calculations based on GAEZ aggregated value and Local Unit Prices

	Wheat	*Cotton*	*Maize*	*Lentil*	*Chicpea*	*Total*
Total Revenue_mil Euro_Local_Data	498.1	276.1	143.3	22.7	23.0	963.2
Total Revenue_mil Euro_GAEZ_Aggregated	538.0	134.4	194.4	9.2	8.0	884.0
Difference, %	-7.4%	105.4%	-26.3%	146.7%	187.5%	9.0%

Thus, the maps representing the comparison of current/historic revenues and revenue losses in the near future (2046-50 RCP4.5) due to the absence of an irrigation system were calculated (as the total of the region) and visualized as follows:

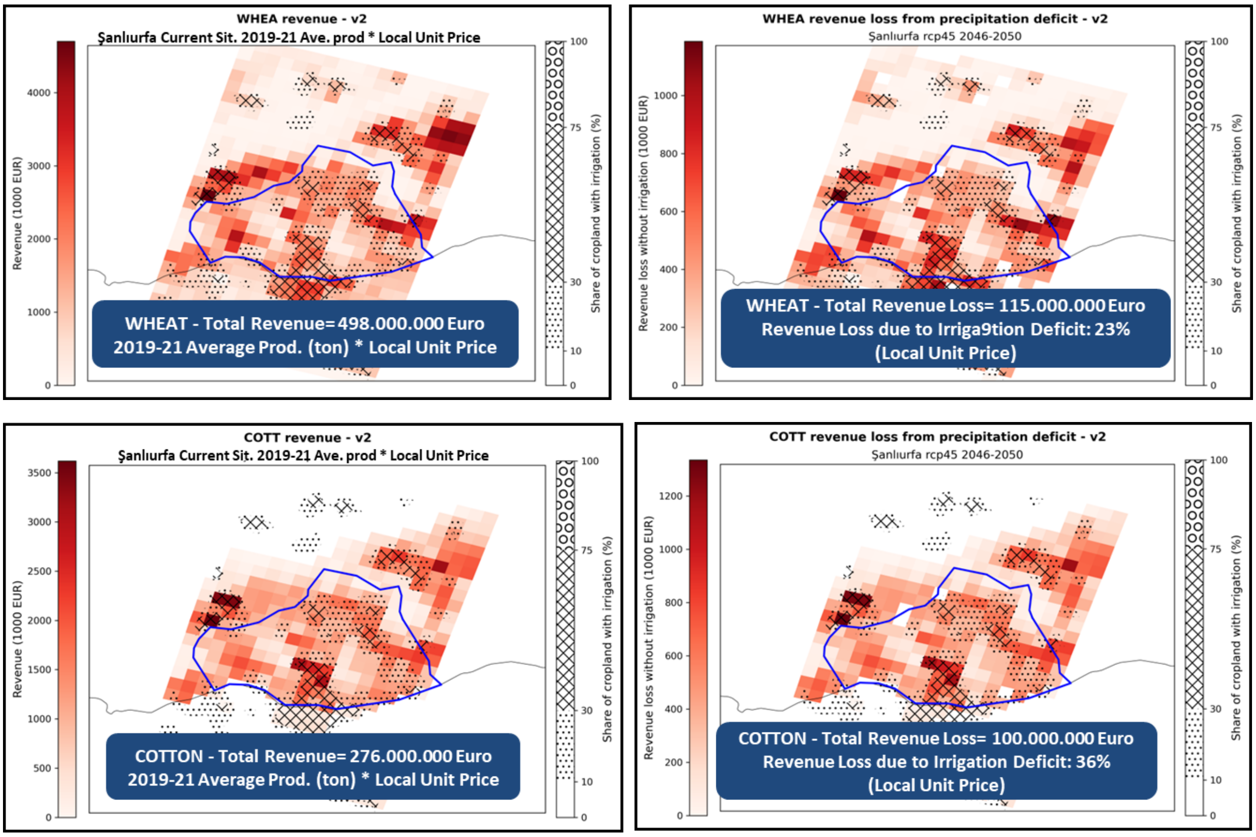


Figure 2-12 Maps of agricultural revenue and revenue losses for Wheat and Cotton

Based on local unit prices and average production quantities for the 2019–2021 period, the comparative maps indicate that agricultural revenue from wheat and cotton production will decrease by 23% and 36%, respectively, by 2050. The total annual revenue loss resulting solely from insufficient irrigation for these two crops is estimated to be approximately 215 million Euros. Moreover, these maps reveal the specific areas where revenue losses will be more significant, thereby providing valuable insights for identifying priority zones for additional irrigation investments and supporting feasibility assessments.

2.3.3 Additional assessments based on local models and data

2.3.3.1 Hazard assessment

In the agricultural drought hazard analysis, although yield losses resulting from insufficient irrigation are assessed, it is also necessary to understand whether water resources will be sufficient to compensate for these losses in the near future, and to develop preventive and adaptation actions accordingly. In this context, as the Şanlıurfa CLIMAAX team, we modified and improved the CLIMAAX agricultural drought hazard assessment workflow and calculated and visualized the irrigation water requirements for each crop. During this improvement process, we also identified and committed four critical bugs affecting the yield loss computations. (New version of agricultural drought workflow is in progress.)

The maps below illustrate the projected 2050 irrigation water requirements for major crops in the Şanlıurfa region based on the RCP4.5 scenario.

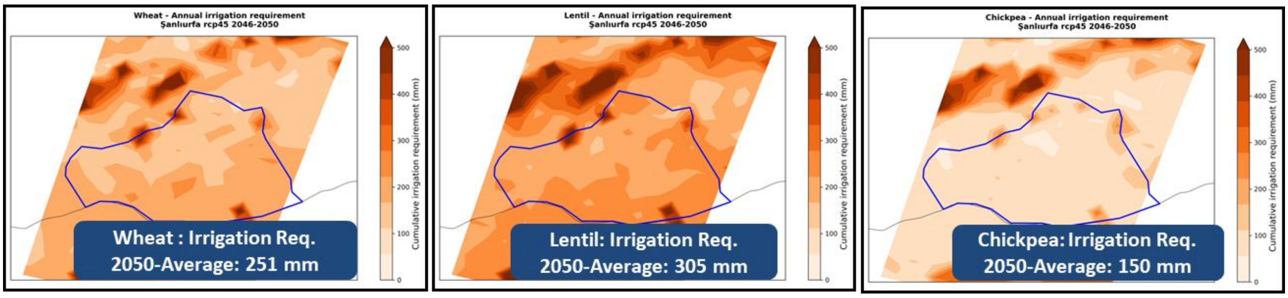


Figure 2-13 Irrigation water requirements of winter-season crops (Wheat and Lentil).

While winter crops such as wheat, lentil, and chickpea will require less irrigation water (150–300 mm), summer-season crops such as cotton, maize, and pistachio will need much more irrigation water (630–930 mm) due to higher evapotranspiration by 2050-rcp4.5. This analysis highlights the importance of crop diversification in situations of irrigation water scarcity. (Average irrigation requirements defined in the maps below are the average of all grids of the region computed by an exported CSV file.)

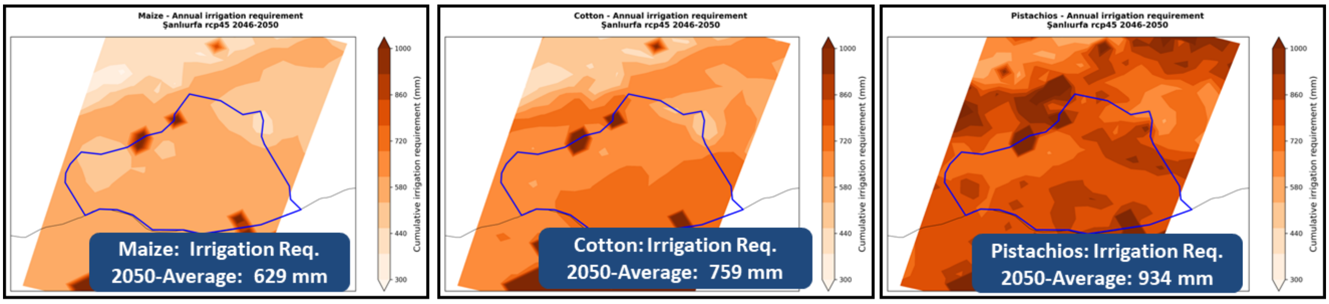


Figure 2-14 Irrigation water requirements of summer season crops (Maize and Cotton).

2.3.3.2 Risk assessment

In Şanlıurfa, the existing heatwave risk assessment workflow was enhanced by integrating night-time land surface temperature (LST) data to improve representation of the urban heat island (UHI). ASTER L2 Surface Kinetic Temperature (V003) night-time imagery was introduced and systematically compared with Landsat 8 daytime LST over the same spatial extent and time period (July–August, 2020–2025).

The ASTER night-time data required additional pre-processing, including temperature conversion from Kelvin to Celsius, spatial clipping to the study area, and coordinate system harmonisation to ensure compatibility with population exposure datasets. These steps were performed using ArcMap (v10.8).

The comparative analysis demonstrated that night-time ASTER imagery provides a substantially more transparent and more representative depiction of urban heat island patterns than daytime Landsat data, particularly in densely built-up areas where nocturnal heat retention is critical for assessing heat-related health risks. However, the ASTER-based workflow involves greater processing complexity than the Landsat-based approach.

Future workflow optimisation is recommended to automate temperature conversion and spatial preprocessing steps, reducing reliance on manual GIS operations and improving scalability.

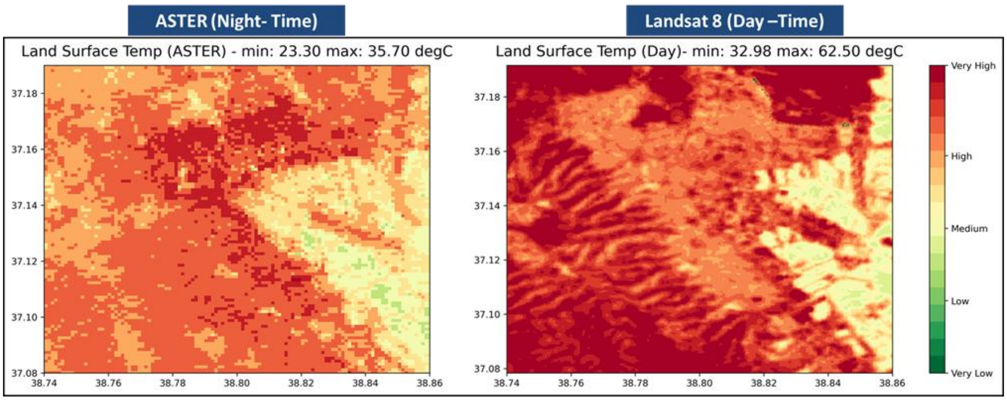
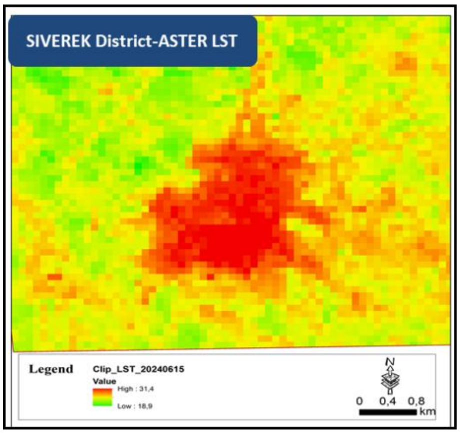
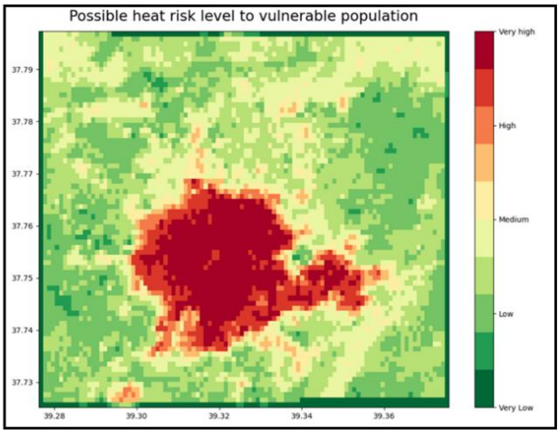


Figure 2-15 Comparison of LST maps of Şanlıurfa city center obtained from Aster (night time) and Landstat 8 (day time)

Our new data processing methodology was shared as "the first regional example of workflow applications" in Github/Climaax Forum: https://github.com/CLIMAAX/examples/tree/main/Heatwaves_NewDataSource

Şanlıurfa Metropolitan Municipality is a metropolis of 2.3 million people, with 10 districts comparable in size to cities. We applied the CLIMAAX heatwave workflows with ASTER LST, not only in Şanlıurfa city center but also across all districts, and we shared the results with the relevant district-level decision-making authorities. Below are two example district risk maps (Siverek: 245,000 cap.; Halfeti: 45,000 cap).





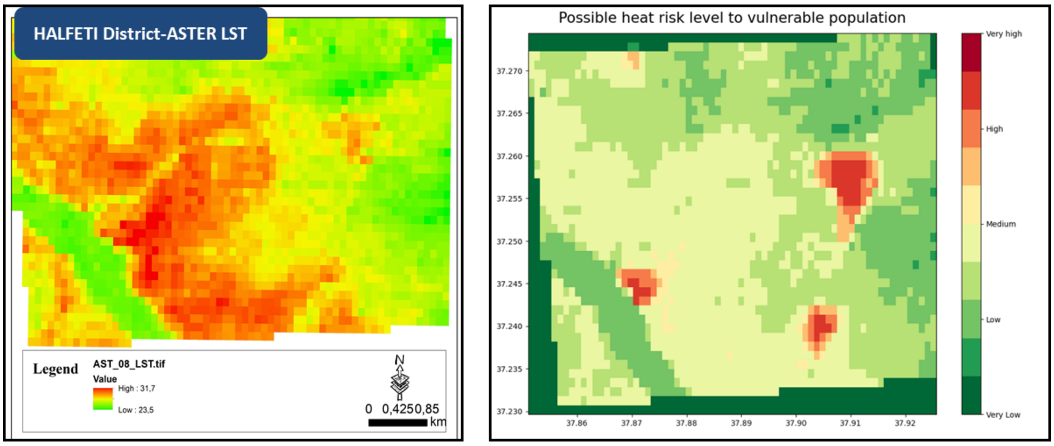


Figure 2-16 Heatwave risk maps of some Sanlıurfa Districts (Siverek and Halfeti)

2.4 Key Risk Assessment Findings

The key hazards dashboard below was supported by stakeholder and community surveys, reflecting local perceptions of climate risks and their prioritization:

Risk Workflow	Severity C	Severity F	Urgency	Capacity Resilience/ CRM	Risk Priority
River flooding	N.A	N.A	N.A	N.A	N.A
Coastal flooding	N.A	N.A	N.A	N.A	N.A
Heavy rainfall					Moderate
Heatwaves					Very High
Drought					Very High
Fire	N.A	N.A	N.A	N.A	N.A
Snow	N.A	N.A	N.A	N.A	N.A
Wind					Low

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

Figure 2-17 Key Hazard Dashboard of Sanliurfa

2.4.1 Mode of engagement for participation

The evaluation of heatwave and drought risks in Phase 2 was carried out through focused consultations with institutional experts and priority groups. Building on the general engagement process described in Section 2.1.5, these meetings focused on interpreting the CLIMAAX risk results and validating their relevance to Şanlıurfa.

Two expert groups met monthly during Phase 2:

- **Heatwave Expert Group**: municipal technical units, the Provincial Health Directorate, Harran University researchers, and NGOs representing vulnerable populations (elderly, refugees, women).
- **Drought Expert Group**: the State Hydraulic Works (DSİ), responsible for regional irrigation infrastructure, GAP Regional Development Administration (agriculture and water programs), the Provincial Agriculture Directorate, farmer cooperatives, and the municipal water utility ŞUSKİ.

Additional risk-evaluation consultations included AFAD, Türkiye's Disaster and Emergency Management Authority, which is responsible for hazard monitoring and emergency response. AFAD reviewed the heatwave severity and urgency scores and provided operational insights based on recent extreme-temperature events.

During the evaluation sessions, stakeholders examined the CLIMAAX outputs—heatwave index trends, ASTER-based nighttime UHI maps, exposure layers, irrigation-requirement maps, and crop yield-loss projections. Their feedback confirmed that the spatial patterns of high heatwave risk in central districts and the drought impacts on key crops matched field observations and recent extreme-weather experiences.

Participants emphasized the practical value of:

- neighborhood-level heatwave maps for zoning and greening,
- crop-specific drought indicators for irrigation planning,
- and revenue-loss maps for prioritizing agricultural investments.

Overall, the engagement process ensured that the risk severity, urgency, and priority levels reflected both scientific evidence and the lived experience of local institutions and communities.

2.4.2 Gather output from Risk Analysis step

For the risk evaluation phase, we used all relevant hazard, exposure, and vulnerability outputs generated during the CLIMAAX Risk Analysis step. These outputs provide both spatial and quantitative evidence necessary for assessing risk severity, urgency, and response capacity. The following datasets and indicators were included in the evaluation:

a) Heatwave Risk Assessment Outputs

- Current and future Heatwave Index
- Current and future heatwave frequency (days >34°C lasting >3 days
- Extreme heatwave thresholds Tmax > 39.5 °C; Tmin > 25.4 °C; Duration > 3 days
- Projected change in extreme heatwave days (20 → 40 days/year)
- Number of extreme heatwave events per year (1–2 increasing to 4–5)
- Land Surface Temperature and Urban Heat Island (UHI) maps derived from night-time ASTER data
- Vulnerable Population Density maps (city-wide and district-specific
- Heatwave risk maps of Şanlıurfa and all its districts at 100×100 m resolution)
- Critical infrastructure exposure: health facilities, schools, and social community buildings.
- Socio-economic indicators: income levels, housing quality
- Green space availability : 4.6 m2/cap., 2035 target: 9 m2/cap.
- Health sensitivity indicators (chronic illness prevalence)

b) Drought Risk Assessment Outputs

- Relative drought hazard index (WASP-based)
- Current and future drought severity (2050, RCP4.5)
- Precipitation trends (610 mm → 424 mm)
- Evapotranspiration trends (1734 mm → 1853 mm)
- Yield loss due to irrigation deficit maps
- Current(2025) and future (2050) yield loss trend for all main crops

- Comparison of winter and summer season crops' yield losses and irrigation water requirements
- Revenue losses of all main crops due to the irrigation system deficit.

2.4.3 Assess Severity

Overall approach: Severity was assessed by combining historic and current climate trends, future projections (2050, RCP4.5), potential impacts on human health, critical infrastructure, water resources, agriculture, and ecosystems, consultations with municipal authorities, district-level decision-makers, and sectoral stakeholders.

Severity was classified according to the four categories in the CLIMAAX Key Risk Assessment Protocol: Limited, Moderate, Substantial, and Critical.

1. Heatwave Risk Severity Assessment
Current Severity (2021–2025) → Substantial to Critical
Historical and Recent Trends: Heatwaves in Şanlıurfa already exhibit extreme characteristics; up to 80 days per year above 34°C for >3 days; extreme heatwaves (Tmax > 39.5°C, Tmin > 25.4°C) occurring 20 days per year; and 1–2 extreme heatwave events per year currently. These climatic conditions have already resulted in;

- Increased heat-related illness (hospital admissions rise during summer peaks), repeated stress on livestock, power outages, Severe energy demand surges (cooling needs), and disruptions in outdoor work.
- Intensified Urban Heat Island effect in central districts (confirmed via nighttime ASTER analysis)
- Considering the large exposed population (2.3 million), the severity is already high.
- Potential Impacts & Irreversible Consequences: Human mortality, especially among the elderly and chronically ill, and the Public health system overload
- Damage to ecosystems, drying urban vegetation, and declining biodiversity
- Occasional social stress (migration from the hottest districts)

Stakeholder Perspectives: District municipalities, health authorities, and urban planning departments consistently view heatwaves as a top-priority risk. Vulnerable groups (elderly, low-income households, outdoor workers) report increasing difficulty coping with heat. Decision-makers have basic awareness but limited capacity to understand heatwave risk systematically.
This pushes severity toward the critical category.

Assessment :
Current heatwave severity: Critical
Future Severity (2050, RCP4.5) → Critical
Projected Changes: Heatwave days >34°C increase from 80 to 100 days/year (+25%), Extreme heatwave days double (20 → 40 days/year), Extreme events increase from 1–2 to 4–5 per year
This places Şanlıurfa among regions with the highest heat stress in Türkiye.
Cascading Effects: Major human health emergency risks (heat stroke, mortality); Critical infrastructure strain (electricity, water distribution); Loss of habitability in some districts during peak summer; Severe impact on economic sectors, especially agriculture, industry, and construction. These cascading, irreversible impacts warrant a critical severity rating.

2. Drought Risk Severity Assessment
Current Severity → Substantial

Historic and Current Trends: Precipitation: ~610 mm, Evapotranspiration: ~1734 mm. Şanlıurfa currently has one of the highest relative drought risk scores in Türkiye (Level 4/5). Heavy dependence on irrigation for major crops (cotton, maize, pistachio)
Impacts include: Local water scarcity during peak irrigation—soil degradation/salinization due to excessive irrigation and extreme evapotranspiration. Severity is already substantial, especially for the agricultural sector.
Stakeholder Perspectives: Provincial agriculture directorates, farmers, and irrigation associations all confirm drought as their most pressing climate concern. They report increasing conflict over water allocation. Decision-makers understand the issue but lack sufficient tools for long-term planning, increasing perceived severity.

Assessment
Current drought severity: Critical
Future Severity (2050, RCP4.5) → Critical
Projected Trends: Precipitation decreases by 30% (610 → 424 mm), Evapotranspiration increases by 7% (1734 → 1853 mm), Irrigation needs for summer crops reach 630–930 mm, Water scarcity becomes structurally unavoidable.
Potential Impacts & Irreversible Consequences affecting large areas.

- Major agricultural yield losses if irrigation water declines: Maize: –60%, Cotton & Pistachio: –40%, Wheat: –25%, Lentil: –27%, Chickpea: –11%
- Loss of agricultural livelihoods and rural out-migration, Permanent decline in soil quality, salinization risk, Potential collapse of some irrigation-dependent production systems

2.4.4 Assess Urgency

The urgency of heatwave and drought risks was assessed using the four CLIMAAX categories—no action needed, watching brief, more action required, and immediate action needed—based on changes in hazard severity, timing of significant impacts, and stakeholder perspectives.

a) Change in severity from current to future
Both hazards show an apparent and significant worsening toward 2050.

- Heatwaves: Extreme heatwave days (Tmax > 39.5 °C, Tmin > 25.4 °C) are projected to double, increasing from ~20 to ~40 days per year.
- Drought: Precipitation is expected to fall by ~30%, evapotranspiration to rise (1734→1853 mm), and irrigation requirements for major crops to increase sharply.

This escalation in hazard intensity justifies a high-urgency category.

b) Timing of major impacts
Major impacts are expected within the next 10–20 years, not only after 2050.

- Heatwaves causing health emergencies already occur 1–2 times per year and will increase to 4–5 events annually.
- Crop yield losses and irrigation deficits will intensify well before mid-century, affecting livelihoods and water systems.

Therefore, preparation and adaptation actions are required now.

c) Near-future worsening of hazards
Model outputs show:

- Higher frequency and duration of heatwaves,
- Significant reductions in rainfall,

- Increasing irrigation deficits for cotton, maize, pistachio, wheat, lentil, and chickpea.

Because both hazards worsen in the short term and medium term, urgency falls between "more action needed" and "immediate action needed."

d) Sudden vs. slow-onset characteristics

- Heatwaves: Sudden-onset events that can quickly cause hospitalizations, worker safety risks, and energy shortages.
- Drought: Slow-onset but persistent, with cumulative impacts on water resources, soil moisture, and crop productivity.

The combination of acute (heatwaves) and chronic (drought) pressures increases overall urgency.

e) Persistence of hazards

Both hazards show long-term persistence:

- Heatwaves become a regular annual threat,
- Drought conditions intensify due to climate change and groundwater pressure.

Persistent hazards require proactive adaptation.

f) Stakeholder and vulnerable-group perspectives

Local experts, DSİ, agricultural associations, and farmers emphasized:

- Rapidly rising irrigation costs,
- Water shortages during peak season,
- Declining viability of water-intensive crops,
- Limited adaptation capacity of small-scale rural producers.

Municipal and health stakeholders highlighted the increasing difficulty in protecting vulnerable populations (elderly, refugees, outdoor workers) during extreme heat. These perspectives support higher urgency scores.

Final Urgency Ratings

- Heatwaves → Immediate Action Needed (because of rapid onset, rising frequency, extreme thresholds, and acute health risks)
- Agricultural drought & irrigation deficits → More Action Needed (because impacts will intensify steadily and require long-term adaptation of crops, irrigation systems, and water governance)

2.4.5 Understand Resilience Capacity

The resilience capacity of Şanlıurfa to cope with heatwave and drought risks was assessed using the CLIMAAX categories—low, medium, substantial, high—and informed by findings from the SECAP and Pathways2Resilience Baseline Report. These sources provided insight into governance structures, available resources, infrastructure conditions, and social vulnerability.

Existing climate risk management measures: Şanlıurfa's SECAP identifies climate adaptation as a priority and outlines actions such as improving irrigation efficiency, mitigating urban heat, and promoting climate-resilient agriculture. AFAD (Disaster and Emergency Management Authority) provides emergency coordination during extreme heat events, while DSİ (State Hydraulic Works) and the GAP Regional Development Administration invest in irrigation modernization. Municipal departments conduct awareness campaigns on water saving and heat protection, and universities contribute through climate research. However, progress in implementing major adaptation measures remains limited, especially in densely built districts with insufficient green space.

Capacity across key dimensions

- Financial capacity: Funding for drought response, irrigation upgrades, and heatwave preparedness is constrained. Heavy dependence on national funds and donor programs limits flexibility. Rating: Low
- Human capacity: Awareness of climate risks is increasing, and technical staff and universities contribute expertise. However, capacity gaps remain in municipal departments and agricultural directorates, as well as among smallholder farmers. Rating: Medium
- Natural capacity: Very low precipitation, extremely high evapotranspiration, soil degradation, and dominance of water-intensive crops limit natural resilience. Rating: Low
- Physical capacity: Although irrigation networks exist, modern pressurized systems are incomplete, canal losses remain high, and cooling infrastructure in cities is limited. Rating: Low
- Social capacity: High poverty rates, large vulnerable populations (elderly, refugees, seasonal agricultural workers), and limited community-level adaptation awareness reduce resilience. Rating: Low

Weak spots identified

Key limitations include:

- Heavy dependence on irrigation amid declining water availability
- Fragmented coordination between agriculture, water, and urban planning sectors
- High exposure to extreme temperatures in central neighborhoods
- Limited adaptive capacity of small farmers
- Absence of local drought early-warning systems
- Insufficient neighborhood-level heat-health preparedness

Existing and planned interventions: Ongoing initiatives include modernizing irrigation systems, training farmers in climate-smart agriculture, expanding green and blue infrastructure, improving water distribution efficiency, and developing district-level hazard maps under CLIMAAX. While these indicate growing commitment, implementation remains slow relative to the pace of climate change.

Final resilience capacity rating: Considering all dimensions, Şanlıurfa's overall resilience capacity to both heatwave and drought risks is assessed as Low. Existing measures provide a foundation for action, but substantial strengthening of financial, institutional, physical, and social capacities is required to address escalating climate pressures.

2.4.6 Decide on Risk Priority

Risk prioritization was conducted using the CLIMAAX evaluation dashboard, which combines severity, urgency, and resilience capacity into an integrated assessment. The process followed the Key Risk Assessment Protocol and incorporated both quantitative outputs from the heatwave and drought workflows and qualitative insights from stakeholders and expert groups.

Step 1 — Review dashboard results: Severity and urgency scores were derived from the CLIMAAX analysis (current and 2050 projections), supported by local climate data, agricultural statistics, socio-economic indicators, and expert validation.

Step 2 — Compare current vs. future risks: Both heatwaves and drought show clear worsening under the 2050 scenario (RCP4.5). Hazards with increasing severity and urgency were automatically identified as high-priority risks.

Step 3 — Integrate resilience capacity: Low resilience capacity—particularly in financial resources, infrastructure, and social vulnerability—further elevated the priority of both hazards. Risks with high severity, high urgency, and low capacity were classified as Priority 1 (Very High Priority) according to CLIMAAX guidelines.

Final Priority Ranking for Şanlıurfa

Heatwaves — Priority 1 (Very High)

Severity: Substantial (current) → Critical (future) **Urgency:** Immediate action needed **Resilience Capacity:** Low

Extreme heatwave days are projected to double by 2050, causing major risks to public health, energy systems, and densely populated urban areas. Limited cooling infrastructure, insufficient green spaces, and high exposure of vulnerable groups justify assigning heatwaves the highest priority.

Agricultural Drought — Priority 1 (Very High)
Severity: Substantial (current) → Critical (future) **Urgency:** More action needed (approaching immediate by 2050) **Resilience Capacity:** Low

Projected rainfall decline (~30%), rising evapotranspiration, and increased irrigation demand will intensify yield losses across key crops. Because agriculture underpins Şanlıurfa's economy and food security, and because resilience capacity is constrained by water scarcity, agricultural drought is also ranked as a top priority.

Other hazards (qualitative screening only)

Based on SECAP and stakeholder perception surveys:

- Coastal and river flooding: Not applicable.
- Heavy rainfall/flash floods: Moderate priority; relevant but not dominant.
- Snow: Not relevant.
- Wildfire: Low priority due to limited forest area.
- Wind: Low; no significant historical events reported.

These hazards were not included in the quantitative CLIMAAX workflows and therefore receive lower priority.

2.5 Monitoring and Evaluation

The second phase of the Climate Risk Assessment (CRA) strengthened Şanlıurfa's understanding of its key climate risks—particularly extreme heatwaves and agricultural drought—and improved institutional processes for tracking and evaluating these risks.

a) Key lessons learned and difficulties encountered: Phase 2 showed that heatwaves are intensifying more rapidly than previously expected, with extreme events projected to double by 2050. Neighborhood-level analysis using ASTER night-time LST greatly improved the identification of urban heat island hotspots. For drought, the CRA confirmed that future impacts depend heavily on irrigation availability; summer and winter crops require different adaptation pathways due to differences in rainfall and evapotranspiration trends. Main difficulties included the lack of heat-related health data, limited information on groundwater abstraction, and the need to integrate local crop production and irrigation system data to improve drought revenue-loss modeling.

b) Role of stakeholders and their feedback: Stakeholders played a central role in validating CRA outputs. Municipal departments, DSİ, AFAD, agricultural institutions, and NGOs reviewed heatwave and drought maps, confirmed their consistency with field conditions, and identified priority adaptation needs for 2035 and 2050.
Feedback emphasized:

- the usefulness of neighborhood-level heatwave maps for zoning and greening;
- the need for continuous drought monitoring for irrigation scheduling;

- the importance of simplified communication materials for non-technical users;
- alignment of CRA outputs with ongoing SECAP work (green areas, shading, and water-saving measures).

c) Learning processes: Learning was ensured through continuous cross-departmental involvement, repeated expert-group review sessions, and integration of CRA findings into SECAP and P2R activities. Improved workflow components (e.g., nighttime UHI mapping and irrigation requirement modules) were shared with the CLIMAAX community, contributing to collective learning across regions.

d) New data and remaining needs: Phase 2 generated new high-resolution datasets, including ASTER night-time LST maps, crop-specific irrigation water requirement maps, and district-level heatwave exposure layers. Remaining needs include access to heat-related hospitalization data, more detailed irrigation system maps, and improved revenue-loss models calibrated to local production statistics.

e) Communication of outcomes: Final CRA outputs will be communicated through presentations to municipal and district councils, public-friendly booklets and infographics, workshops with farmer groups and irrigation managers, and sharing of methods through CLIMAAX and national knowledge-exchange platforms.

f) Current monitoring systems: Şanlıurfa already benefits from MGM real-time climate alerts, DSİ water allocation monitoring, and annual CDP-Cities reporting. However, local drought early-warning and neighborhood-level heat-health monitoring systems require further development. CRA findings highlight the need for periodic review of vulnerable neighborhoods and climate-sensitive populations.

g) What worked well and what did not: High-resolution mapping (especially ASTER-based UHI analysis), coordination through expert groups, and integration with SECAP and P2R processes worked effectively. Improvements are still needed in agricultural drought modeling—particularly incorporating detailed irrigation system data—and in obtaining health-related impact data.

h) Resource efficiency and overall impact: Despite limited staff and competing workloads, the CRA was delivered on time and within budget. Workflow enhancements increased accuracy with minimal additional costs, and stakeholder meetings maximized cross-sectoral input. Overall, Phase 2 significantly strengthened institutional capacity, improved understanding of climate risks, and laid the foundation for future adaptation investments and funding applications.

2.6 Work plan Phase 3

Phase 3 (Months 17–22) will focus on converting the CRA findings into practical adaptation strategies and updating Şanlıurfa's risk management plans. This phase aligns with the official CLIMAAX work plan and milestones defined in the IFUP.

Main activities:

- Validation of key risks (M17–M18): Present and review Phase 2 results with municipal departments, DSİ (water authority), AFAD (disaster management), agricultural and health directorates, district municipalities, and relevant NGOs to confirm priority risks.
- Identification of adaptation measures (M17–M20): Define heatwave and drought adaptation options (e.g., cooling corridors, green spaces, irrigation efficiency, crop diversification) and integrate them into Şanlıurfa's SECAP and sectoral strategies.
- Feasibility assessment (M18–M20): Evaluate administrative, financial, institutional, and technical feasibility of proposed actions through targeted consultations with responsible agencies.

- Monitoring & Evaluation framework (M19–M21): Establish indicators, data sources, responsibilities, and reporting cycles for tracking heatwave and drought risks, including early-warning mechanisms.
- Finalization of outputs (M21–M22): Prepare the Phase 3 deliverable (D3), including prioritized adaptation measures, adaptation pathways, an implementation roadmap, an updated risk management plan, and communication materials for decision-makers and the public.

Milestones & Deliverables:

- M5: Adaptation strategies identified and proposed (Month 20)
- M6: Final deliverable prepared and results disseminated (Month 22)
- D3: Contribution to local adaptation strategies and improved risk management plans (due Month 22)

Scope limitations: Phase 3 will not include detailed planning for low-priority hazards (e.g., snow, wildfire, storms), as these risks are marginal for Şanlıurfa and are outside the quantitative focus of the CLIMAAX workflows.

3 Conclusions Phase 2- Climate risk assessment

Phase 2 of the Şanlıurfa Climate Risk Assessment (CRAS) significantly advanced the understanding of the region's two highest-priority climate hazards—heatwaves and drought—by integrating high-resolution local datasets, refining CLIMAAX workflows, and validating outputs through structured expert engagement. This phase addressed several methodological challenges encountered in Phase 1, developed new risk metrics, and generated actionable insights to guide adaptation planning in Phase 3.

Challenges Addressed and Remaining Gaps

Challenge 1 – Limited visibility of the Urban Heat Island (UHI) effect using daytime imagery

Daytime Landsat-8 LST values frequently exceed 60°C and show little spatial differentiation across the city, preventing meaningful visualization of UHI patterns.
Solution: A new night-time LST workflow was developed using 90 m ASTER data, enabling precise identification of heat-retaining neighborhoods. This method was shared with CLIMAAX and P2R partners and included in the CLIMAAX GitHub repository as a regional example.

Challenge 2 – Absence of heat-related hospitalization and mortality data

Despite discussions with the Regional Health Directorate, hospitals, and the Turkish Red Crescent, no systematic health-impact data on extreme heatwaves were available.
Solution: This limitation remains unresolved and represents a key data gap for improving future public-health risk assessments.

Challenge 3 – Missing regional crop types in FAO/GAEZ datasets

Certain crops specific to Şanlıurfa were not represented in global datasets.
Solution: A regional crop table was created, incorporating locally validated crop coefficients for wheat, maize, cotton, pistachio, lentil, and chickpea.

Challenge 4 – Need to quantify additional irrigation requirements under climate change

Yield-loss calculations alone were insufficient for planning water allocation.
Solution: The Agricultural Drought workflow was modified to compute and map crop-specific irrigation water requirements for both current (2021–2025) and future (2046–2050) periods.

Challenge 5 – Rough revenue-loss estimates using GAEZ aggregated values

Using aggregated economic values masked crop-specific economic impacts.
Solution: A new crop_unitprice.csv file and data-processing step were developed, allowing calculation of revenue and revenue-loss maps per crop using local production volumes (2019–2021) and regional unit prices.

These improvements significantly enhanced the realism, policy relevance, and usability of the CRA outputs.

Key Findings of Phase 2

Heatwaves

- Heatwaves above the EuroHeat threshold (Tmax > 34°C for ≥3 days) are projected to increase by ~25% by 2050, rising from ~80 to ~100 days per year.

- Extreme heatwaves at MGM thresholds (Tmax > 39.5°C, Tmin > 25.4°C) will double from ~20 days/year in 2024 to ~40 days/year by 2050.
- The number of extreme heatwave events is expected to rise from 1–2 per year to 4–5 per year, significantly increasing health and energy risks.
- Neighborhood-level UHI mapping identified eight districts—Cengiz Topel, Bahçelievler, Sultan Fatih, Paşabağı, Şair Nabi, Yenişehir, Ulubatlı, and Yeşildirek—as having "very high" heat-exposure risk, overlapping with schools, hospitals, and social facilities.
- To meet the 2035 urban-greening target (9 m²/capita), these neighborhoods require 31 hectares of additional green space, beyond the current 10 hectares.

Drought and Agricultural Impacts

- Annual precipitation is projected to decrease by ~30% (610 mm → 424 mm), while evapotranspiration increases from 1734 mm → 1853 mm by 2050, intensifying water scarcity.
- Summer crops (maize, cotton, pistachio) remain entirely dependent on artificial irrigation, with little change in projected yield-loss levels because they already rely on irrigation.
- Winter crops (wheat, lentil, chickpea) become significantly more vulnerable: yield losses due to insufficient irrigation are projected to double by 2050, due to reduced rainfall and increased water deficits.
- Revenue-loss analyses using regional unit prices show that by 2050:
  Wheat revenue decreases by ~23%,
  Cotton revenue decreases by ~36%,
  The total estimated annual economic loss for these crops due to irrigation scarcity is ~€215 million.
- Spatial revenue-loss maps reveal concentrated high-loss zones, helping agencies such as DSİ and GAP prioritize irrigation investments and modernization.

Overall Conclusions of Phase 2

Phase 2 provided a scientifically robust, high-resolution picture of Şanlıurfa's climate risks. Heatwaves and drought—already severe in Phase 1—are confirmed to intensify significantly by mid-century. Urban heat stress will intensify in densely populated central districts with limited green infrastructure, while agricultural drought will threaten livelihoods and regional food security.

The methodological advances introduced in Phase 2—such as the ASTER night-time UHI method, crop-specific irrigation requirement modeling, and revenue-loss mapping—created a much more accurate and actionable evidence base than previously available to local authorities. Stakeholder engagement throughout the process ensured that findings reflect real-world conditions and institutional priorities.

Remaining gaps, particularly in health-impact data, groundwater information, and crop-specific economic datasets, highlight areas for future improvement. Nevertheless, the Phase 2 CRA establishes a solid scientific and institutional foundation for Phase 3, which will focus on designing adaptation pathways, feasibility assessments, and an updated risk-management plan.

4 Progress evaluation

Connection between Deliverable 2 and the next project phase

Deliverable 2 provides the refined, high-resolution climate risk assessment for Şanlıurfa and represents the core analytical foundation for Phase 3. By integrating night-time ASTER LST data, locally calibrated agricultural parameters, crop-specific irrigation requirements, and revenue-loss models, Phase 2 generated risk outputs directly usable for adaptation planning. These results enable the identification of priority neighbourhoods for heat-wave adaptation, high-loss agricultural zones for irrigation modernization, and vulnerable population groups requiring targeted interventions.

Deliverable 2, therefore, ensures that Phase 3 can concentrate on adaptation design, feasibility assessments, monitoring frameworks, and updates of Şanlıurfa's regional planning instruments (SECAP, development plans, drought preparedness strategies). The monthly expert groups established during Phase 2 (heatwaves & drought) will continue in Phase 3 and form the core governance mechanism for validating proposed adaptation measures.

Table 4-1 Overview key performance indicators

Key performance indicators	*Progress*
KPI 1 – One project report in Turkish (M14)	Achieved. A Turkish-language high-resolution risk report summarizing Phase 2 outputs (heatwave hotspots, ASTER-based UHI maps, drought and yield-loss maps) was prepared by Month 14 and shared with >40 stakeholders in an online meeting. This meeting also clarified the structure and roles of the Heatwave and Drought Expert Groups, which now meet monthly.
KPI 2 – Four vulnerable sectors and populations identified (M16)	Achieved. The CRA identified vulnerability across key groups: low-income urban populations in heatwave-intensive districts, farmers and irrigators exposed to agricultural drought, refugee communities with limited adaptive capacity, and elderly populations sensitive to heat stress. These groups are fully represented in the risk maps and stakeholder consultations feeding into Phase 3.

Note: Other KPIs originally listed under Deliverable 2 (e.g., 150 stakeholders trained; 5 municipalities informed; 8 communication actions) have due dates after Month 16 and are therefore part of Deliverable 3. They are not reported here.

Table 4-2 Overview milestones

Milestones	*Progress*
M3 – High-resolution local data integrated into the project (M10)	Achieved. High-resolution datasets were successfully integrated, including ASTER night-time LST (90 m), locally validated crop coefficients, crop-specific irrigation water requirements, and updated socio-economic vulnerability indicators. These datasets significantly improved workflow accuracy and spatial relevance.
M4 – Refined risk assessment completed and second deliverable submitted (M16	Achieved (ahead of schedule). Although the contractual due date was 31/01/2026, Deliverable 2 was completed in mid-December 2025. The refined assessment includes new heatwave and drought metrics, neighbourhood-scale risk maps, irrigation requirement analysis, and revenue-loss maps.

Summary of Phase 2 Achievements

Phase 2 successfully delivered:

- High-resolution, localized climate risk maps for heatwaves and drought.
- Novel methodologies (e.g., ASTER night-time LST workflow; crop-specific irrigation requirement analysis; local revenue-loss modelling).
- Comprehensive identification of vulnerable neighbourhoods and priority agricultural zones.
- Strengthened stakeholder engagement, including the creation of two expert groups meeting monthly.
- Completion of the two Phase 2 milestones ahead of official deadlines.

These achievements ensure that Phase 3 (M17–M22) can build directly on a robust evidence base to design targeted adaptation pathways, update risk management plans, and develop an actionable monitoring & evaluation framework.

5 Supporting documentation

Main Report

Phase 2 – Climate Risk Assessment – Sanliurfa (PDF): Comprehensive documentation of methodology, analysis, findings, and conclusions.

1 Sanliurfa Heatwave Hazard Analysis (XCLIM)

1_1_heatwave_hazard_assessment_xclim_Sanliurfa_34C.ipynb
1_2_heatwave_hazard_assessment_xclim_Sanliurfa_39_5C.ipynb
1_3_Sanliurfa_hwd_34C.png
1_4_Sanliurfa_HWF_34C.png
1_6_Sanliurfa_HWI_34C.png
1_6_Sanliurfa_HWD_39_5.png
1_7_Sanliurfa_HWF_39_5.png
1_8_Sanliurfa_HWI_39_5.png

2 Sanliurfa Heatwave Risk & Vulnerability Analysis (LST-based)

2_1_Sanliurfa_Heatwave_Risk_Assessment.ipynb
2_2_Sanliurfa_Overheated_Area_and_Population_Density_Maps.png
2_3_Sanliurfa_Possible_Heatwave_Risk_to_Vulnerable_Population.png
2_4_Sanliurfa_LST_by_Aster.jpg
2_5_Sanliurfa_LST_of_Neighborhoods_by_Aster_1.jpg
2_6_Sanliurfa_LST_of_Neighborhoods_by_Aster_2.jpg
2_7_Sanliurfa_LST_of_Neighborhoods_by_Aster_3.png
2_8_Siverek_District_Overheated_Area_and_Population_Density_Maps.png
2_9_Siverek_District_Possible_Heatwave_Risk_to_Vulnerable_Population.png
2_10_Siverek_District_LST_by_Aster.jpg
2_11_Halfeti_District_Overheated_Area_and_Population_Density_Maps.png
2_12_Halfeti_District_Possible_Heatwave_*Risk_to_Vulnerable_Population.png*
2_13_Halfeti_District_LST_by_Aster.jpg

3 Sanliurfa Relative Drought Analysis

3_1_Sanliurfa_RELATIVE_DROUGHT_Hazard_assessment.ipynb
3_2_Sanliurfa_RELATIVE_DROUGHT_Risk_assessment.ipynb
3_3_Sanliurfa_RELATIVE_DROUGHT_Risk_visualization.ipynb
3_4_Sanliurfa_RELATIVE_DROUGHT_WASP_TR_ssp585_nf.csv

4 Sanliurfa Agricultural Drought & Water Demand Analysis

4_1_Sanliurfa_AGRICULTURE_DROUGHT_Hazard_2025_RCP45.ipynb
4_2_Sanliurfa_AGRICULTURE_DROUGHT_Hazard_multicity_2050_rcp45.ipynb
4_3_Sanliurfa_Regional_crop_table.csv
4_4_Sanliurfa_AWC.png
4_5_Sanliurfa_2025_Precipitation.png
4_6_Sanliurfa_2025_ET0.png

4_7_Sanliurfa_2025_yield_loss_SPREADSHEET.csv
4_8_Sanliurfa_2025_Wheat_yield_loss.png
4_9_Sanliurfa_2025_Wheat_irrigation_requirement.png
4_10_Sanliurfa_2025_Cotton_yield_loss.png
4_11_Sanliurfa_2025_Cotton_irrigation_requirement.png
4_12_Sanliurfa_2025_Maize_yield_loss.png
4_13_Sanliurfa_2025_Maize_irrigation_requirement.png
4_14_Sanliurfa_2025_Pistachios_yield_loss.png
4_15_Sanliurfa_2025_Pistachios_irrigation_requirement.png
4_16_Sanliurfa_2025_Lentil_yield_loss.png
4_17_Sanliurfa_2025_Lentil_irrigation_requirement.png
4_18_Sanliurfa_2025_Chickpea_yield_loss.png
4_19_Sanliurfa_Chickpea_irrigation_requirement.png
4_20_Sanliurfa_2025_irr_req_Wheat.csv
4_21_Sanliurfa_2025_irr_req_Cotton.csv
4_22_Sanliurfa_2050_Precipitation.png
4_23_Sanliurfa_2050_ET0.png
4_24_Sanliurfa_2050_yield_loss_SPREADSHEET.csv
4_25_Sanliurfa_2050_Wheat_yield_loss.png
4_26_Sanliurfa_2050_Wheat_irrigation_requirement.png
4_27_Sanliurfa_2050_Cotton_yield_loss.png
4_28_Sanliurfa_2050_Cotton_irrigation_requirement.png
4_29_Sanliurfa_2050_Maize_yield_loss.png
4_30_Sanliurfa_2050_Maize_irrigation_requirement.png
4_31_Sanliurfa_2050_Lentil_yield_loss.png
4_32_Sanliurfa_2050_Lentil_irrigation_requirement.png
4_33_Sanliurfa_2050_Chickpea_yield_loss.png
4_34_Sanliurfa_2050_Chickpea_irrigation_requirement.png
4_35_Sanliurfa_2050_irr_req_Wheat.csv
4_36_Sanliurfa_2050_irr_req_Cotton.csv

5 Sanliurfa Agricultural Economic Risk Analysis

5_1_Sanliurfa_AGRICULTURE_DROUGHT_Risk_Assessment_multicity_MODIFIED.ipynb
5_2_Sanliurfa_revenue_loss_1000euro_GAEZAgregated.csv
5_3_Sanliurfa_revenue_loss_1000euro_LocalData.csv
5_5_Sanliurfa_WHEA_revenue_EUR_LocalData.png
5_6_Sanliurfa_WHEA_revenue_loss_GAEZAggregated.png
5_7_Sanliurfa_WHEA_revenue_loss_LocalData.png
5_8_Sanliurfa_COTT_revenue_EUR_LocalData.png
5_9_Sanliurfa_COTT_revenue_loss_GAEZAggregated.png
5_10_Sanliurfa_COTT_revenue_loss_LocalData.png
5_11_Sanliurfa_MAIZ_revenue_EUR_LocalData.png
5_12_Sanliurfa_MAIZ_revenue_loss_GAEZAggregated.png
5_13_Sanliurfa_MAIZ_revenue_loss_LocalData.png
5_14_Sanliurfa_LENT_revenue_EUR_LocalData.png
5_15_Sanliurfa_LENT_revenue_loss_GAEZAggregated.png
5_16_Sanliurfa_CHIC_revenue_EUR_LocalData.png
5_17_Sanliurfa_CHIC_revenue_loss_GAEZ_Aggregated.png
5_18_Sanliurfa_CHIC_revenue_loss_LocalData.png
5_19_Crop_UnitPrices.csv
5_20_Sanliurfa_LENT_revenue_loss_LocalData.png

6 Sanliurfa Communication_Outputs

6_1_Aster_LST_v4.pdf
6_2_Improving_Land_Surface_Temperature_Maps_rev04.pdf
6_3_P2R_IPG_Presentation_Sanliurfa.pdf
6_4_SanliurfaBB_CLIMAAX_Climate_Risk_Analysis_Results_Sep25_v00.pdf (Turkish)

7 Sanliurfa Data_Sets

7_1_Regional_Climate_Data_MGM_Formal_Letter.pdf
7_2_Turkiyede_Sulanan_Bitkilerin_Bitki_Su_Tuketimleri.pdf
7_3_MGM_Dataset_20250123387B-Gunluk_Guneslenme_Suresi_(saat).xlsx

7_4_MGM_Dataset_20250123387B-Gunluk_Maksimum_Ruzgar_Hizi_(m_sn).xlsx
7_5_MGM_Dataset_20250123387B-Gunluk_Toplam_Global_Gunes_Radyasyonu_(kWh_m2).xlsx
7_6_MGM_Dataset_20250123387B-Gunluk_Toplam_Guneslenme_Siddeti_(cal_cm2).xlsx
7_7_MGM_Dataset_20250123387B-Gunluk_Toplam_Guneslenme_Siddeti_Global_(W_m2).xlsx
7_8_MGM_Dataset_20250123387B-Gunluk_Toplam_Yagis_(mm)_MANUEL.xlsx
7_9_MGM_Dataset_20250123387B-Gunluk_Toplam_Yagis_(mm)_OMGI.xlsx

Media coverage and outreach:

1. National Media & Web Coverage
This tier includes major Turkish news outlets, signifying the project's reach beyond the local context.

- **Habertürk:** Coverage of climate change applications and adaptation practices in Şanlıurfa (11.11.2025). https://www.haberturk.com/sanliurfa-haberleri/39681250-sanliurfada-iklim-degisikligi-uygulamalari-anlatildi
- **Haberler.com:** Feature on Şanlıurfa's climate projects being presented as a model for other provinces (11.11.2025). https://www.haberler.com/guncel/sanliurfa-iklim-degisikligi-uygulamalari-diger-illere-tanitildi-19243073-haberi/

2. Local & Regional Media Engagement
Sustained coverage in Şanlıurfa-based news portals focused on project milestones and municipal leadership.

- Primary themes included: the project launch announcement by Mayor Mehmet Kasım Gülpınar (26.05.2025), the commencement of field activities (21.02.2025), and the development of 2050 climate risk maps (21.02.2025).

3. Official Technical Publications & PDFs
The production of formal documents underlines the project's technical and methodological rigor.

- **Pathways2Resilience Baseline Assessment Report**: A foundational technical document (Published 08.10.2025).
- **CLIMAAX & Pathways2Resilience Project Information Brochure:** Official public-facing project description (Published 07.07.2025).

4. Digital & International Outreach
Strategic use of professional and international platforms to share progress and build networks.

- **Podcast:** Feature on **BABLE Smart Cities** podcast #145, discussing resilience planning and implementation (22.10.2025). https://smart-in-the-city-the-bable-podcast.castos.com/episodes/145-sanliurfa-pathways2resilience
- **Professional Networks:** Project updates and achievements shared via official **CLIMAAX and Pathways2Resilience LinkedIn** pages (17.10.2025) and by affiliated experts.
- **Municipal Social Media:** Continued dissemination of workshop highlights, risk assessment results, and official statements through the Municipality's YouTube, Twitter (X), Instagram, and Facebook channels.

Zenodo access : All Phase 2 outputs, including the final report and supporting materials, have been uploaded in ZIP format to the Zenodo repository and are accessible via the CLIMAAX community at: 🔗 https://doi.org/10.5281/zenodo.18009759

6 References

1. Şanlıurfa Metropolitan Municipality (2022). Climate Change Risk and Vulnerability Assessment Report, Climate Change and Zero Waste Department

2. Şanlıurfa Metropolitan Municipality (2022). Sustainable Energy and Climate Action Plan Report.

3. CLIMAAX Consortium (2024). CLIMAAX D1.4: Climate Risk Assessment Framework. Horizon Europe Project. Available at: https://climaax.eu/

4. Turkish State Meteorological Service (TSMS) (2023). Regional Climate Data for South-eastern Anatolia. TSMS Publications, Ankara, Türkiye.

5. The Ministry of Agriculture and Forestry- Turkish Agricultural Research Center (TAGEM) https://www.tarimorman.gov.tr/TAGEM/Belgeler/yayin/Tu%CC%88rkiyede%20Sulanan%20Bitkilerin%20Bitki%20Su%20Tu%CC%88ketimleri.pdf

6. Carbon Disclosure Project https://myportal.cdp.net/guidance/questionnaire?tags=&outputType=REPORTING&type=CSTAR&locale=en

7. MUNICIPALITY, S. M. (2025). *Climate Change Risk Analysis and Adaptation Strategies Report (Revision II).* Şanlıurfa, Türkiye: Climate Change and Zero Waste Department.