

Mersin Metropolitan Municipality

CLIMATE CHANGE RISK AND VULNERABILITY ASSESSMENT REPORT-Revision II



T.C. MERSİN BÜYÜKŞEHİR BELEDİYESİ

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Mersin Metropolitan Municipality CLIMATE CHANGE RISK AND VULNERABILITY ASSESSMENT REPORT Revision II

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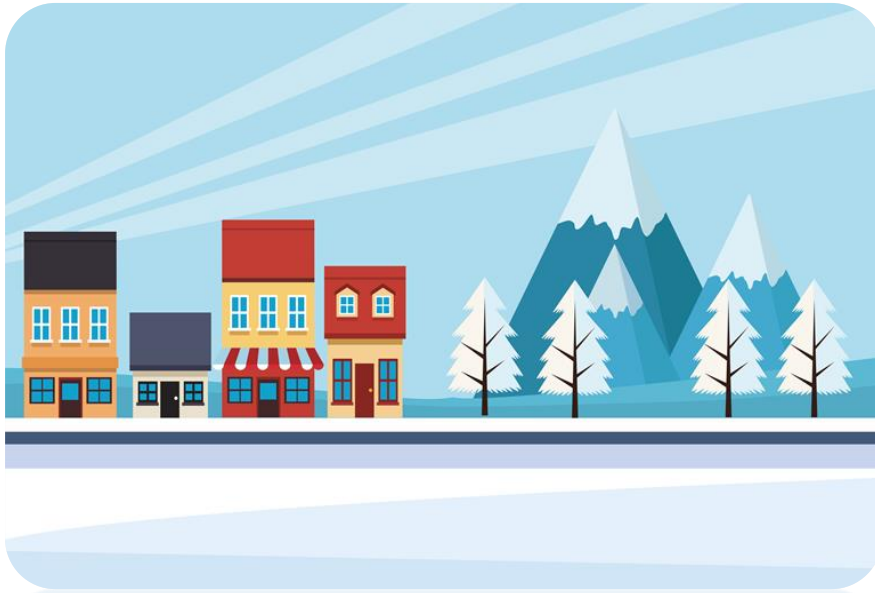
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Abbreviations and acronyms

Abbreviation / acronym	Description
AFAD	Turkish Disaster and Emergency Management Authority
CCAP	Climate Change Action Plan
CDP	Carbon Disclosure Project
CDS	Copernicus Data Store
CLIMAAX	Climate Adaptation and Risk Assessment Methodology
CORDEX	Coordinated Regional Climate Downscaling Experiment
CRA	Climate Risk Assessment
CRM	Climate Risk Management
ÇİİDB	Ministry of Environment, Urbanization, and Climate Change
DRMKC	Disaster Risk Management Knowledge Center
ET_o	Reference Evapotranspiration
EUROHEAT	A European project for heat-health risk analysis (WHO/EU-wide)
FWI	Fire Whether Index
GAEZ	Global Agro-Ecological Zones
GCM	Global Climate Model
GCoM	Global Covenant of Mayors for Climate and Energy
GIS	Geographic Information System
HDD/CDD	Heating Degree Days / Cooling Degree Days
HWI	Heatwave Index
IMS	Institute of Marine Sciences, Middle East Technical University
LST	Land Surface Temperature
MapSPAM	Spatial Production Allocation Model
MGM	Turkish General Directorate of Meteorology
MLGP	Multi-Level Governance Platform (EU4ETTR project context)
MMM	Mersin Metropolitan Municipality
MPI-ESM-LR	Max Planck Institute Earth System Model - Low Resolution
NEX-GDD	NASA Earth Exchange Global Daily Downscaled Projections

NUTS	Nomenclature of Territorial Units for Statistics
RCP	Representative Concentration Pathways
SECAP	Sustainable Energy and Climate Action Plan
SPEI	Standard Precipitation Evapotranspiration Index
SSP	Shared Socioeconomic Pathways
UHI	Urban Heat Island
UHRHO	Urban Heat Risk Hotspot Overlay
UTCI	Universal Thermal Comfort Index
WASP	Weighted Anomaly of Standardized Precipitation
WorldPop	Global population dataset developed by the University of Southampton



Executive summary

This Report presents the Phase 2 Climate Risk Assessment (CRA) for Mersin within the CLIMAAX project, applying a multi-risk approach covering heatwaves, agricultural drought, wildfires, and heavy rainfall. Phase 2 aimed to move beyond the screening-level assessment conducted in Phase 1 and provide a more spatially explicit, locally adapted, and decision-oriented understanding of climate risks affecting Mersin Metropolitan Municipality.

Mersin is one of Türkiye's most climate-sensitive Mediterranean regions due to the interaction among rapidly urbanizing coastal districts, intensive irrigated agriculture, strategic logistics and port infrastructure, and forested mountain ecosystems that extend along the Taurus range. Climate risks in the region are interconnected pressures that simultaneously affect public health, water resources, agricultural production, ecosystems, infrastructure, and vulnerable communities. Phase 2, therefore, focused on strengthening the assessment's regional relevance by integrating CLIMAAX workflows with local observations, institutional information, and stakeholder knowledge.

A key achievement of Phase 2 was the development of a regionalized multi-risk assessment framework covering four priority hazards. Heatwave analyses combined climate projections with satellite-derived surface temperatures and vulnerability indicators to identify urban heat hotspots and future changes in heatwave occurrence. Results indicate that the annual number of heatwave days may increase from approximately 18 days at present to around 44 days by mid-century under RCP8.5 conditions 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. Agricultural drought analyses highlighted increasing water stress and irrigation pressure affecting economically important production areas, particularly banana cultivation in districts such as Anamur, and Bozyazı. BIAS Adjusted-future projection (2046-2050 RCP8.5) indicates 24% increase in irrigation water demand for banana production in Anamur. Under pessimistic conditions and in case of insufficient irrigation availability, potential yield losses by 2050 were estimated as: Lemon: 31%, Banana: 45%, Tomato: 46%, Grape: 39%. Wildfires analyses identified elevated risks in forest–agriculture–settlement transition zones along the Taurus foothills. Current summer season FWI values regularly exceed extremely dangerous FWI > 40 levels even reaching 60–70 some areas in Gülnar and Mut districts. Heavy rainfall assessments showed increasing exposure of densely urbanized coastal districts to pluvial flooding and infrastructure disruption. High risk threshold of 100 mm/24h heavy rainfall events as may increase by 20–30% by 2041–2070. At the same time, return period of 100 mm of high risk threshold will decrease from 10 years to 5 years.

Phase 2 strengthened the localization of the CRA through stakeholder engagement and expert consultation. A multi-stakeholder workshop held on 14 April 2026 brought together representatives from municipalities,

DSi, AFAD, forestry and agricultural institutions, universities, NGOs, and private-sector actors. Thematic expert groups focusing on heatwaves, agricultural drought, wildfires, and heavy rainfall were established to support the interpretation of results and the identification of adaptation priorities. Expert consultations continued throughout the assessment process, including a dedicated meeting held on 19 June 2026. Stakeholder feedback consistently highlighted increasing concern regarding water scarcity, urban heat accumulation, wildfire exposure, and flood risks associated with rapid urbanization and climate variability. The Key Risk Assessment process combined technical outputs with stakeholder feedback to evaluate risk severity, urgency, and resilience capacity. The evaluation demonstrated that heatwaves, agricultural drought and wildfire emerged as the highest-priority climate risks for Mersin, due to their strong interaction with vulnerable populations, urban systems, agriculture, water resources, large forest area with very high WFI and long-term socio-economic impacts. Heavy rainfall was also identified as major priority risks requiring strengthened preparedness and adaptation planning for potential pluvial floods.

Overall, Phase 2 provides Mersin with a multi-layer, action-oriented CRA package consisting of technical reports, spatial risk maps, stakeholder-informed assessments, and sector-specific analyses that improve risk communication and prioritization. The assessment also highlighted the need for higher-resolution health and socio-economic vulnerability data, stronger inter-institutional data-sharing mechanisms, and improved monitoring systems capable of addressing cascading and compound climate risks.

Institutional learning and technical capacity were further strengthened through collaboration among municipal departments and targeted capacity-building activities. In May 2026, four online training sessions on SECAP development and greenhouse gas inventories (4 × 1.5 hours) were organized for municipal staff to reinforce the links between climate adaptation, mitigation, and long-term climate governance.

In the final phase of the project, the outputs and priorities identified through the Key Risk Assessment will be translated into adaptation measures and implementation-oriented planning tools. Particular attention will be given to hotspot-based adaptation targeting, urban heat mitigation, sustainable water management, wildfire preparedness, flood resilience, and strengthening institutional coordination mechanisms across Mersin's urban, coastal, agricultural, and ecosystem-related climate risks.



1 Introduction

1.1 Background

Mersin is a metropolitan city on Türkiye's Mediterranean coast, with a population of nearly 2 million and a surface area of 15,853 km². The province combines rapidly urbanizing coastal districts, extensive agricultural production zones, forest ecosystems, industrial areas, tourism activities, and a 321 km-long coastline. Mersin also hosts Türkiye's largest container port and plays a strategic role in the Eastern Mediterranean region. The interaction between coastal urbanization, irrigated agriculture, and forested mountain systems creates compound climate pressures unique to the Eastern Mediterranean context.

Due to its Mediterranean climate, water-intensive agricultural sector, rapid urbanization, and extensive coastal and forested areas, Mersin is highly exposed to the impacts of climate change. The region faces increasing risks related to heatwaves, drought, wildfires, heavy rainfall, and coastal hazards. Climate change is expected to intensify pressure on water resources, agriculture, public health, urban infrastructure, and ecosystems in the coming decades.

The Phase 1 Climate Risk Assessment conducted under the CLIMAAX project identified heatwaves, drought, wildfires, and heavy rainfall events as the most relevant climate hazards affecting the region. Initial analyses highlighted increasing heatwave frequency, growing agricultural water stress, higher wildfire danger at forest-settlement interfaces, and increasing urban flood risks associated with more intense precipitation events.

Following the baseline assessment completed during Phase 1, the second phase of the project focused on refining and localizing the climate risk assessment by integrating higher-resolution spatial analyses, local datasets, stakeholder participation processes, and adaptation-oriented interpretation of climate risks. The Phase 2 activities aimed to strengthen the operational value of the CLIMAAX methodology for local planning and future climate resilience actions in Mersin.

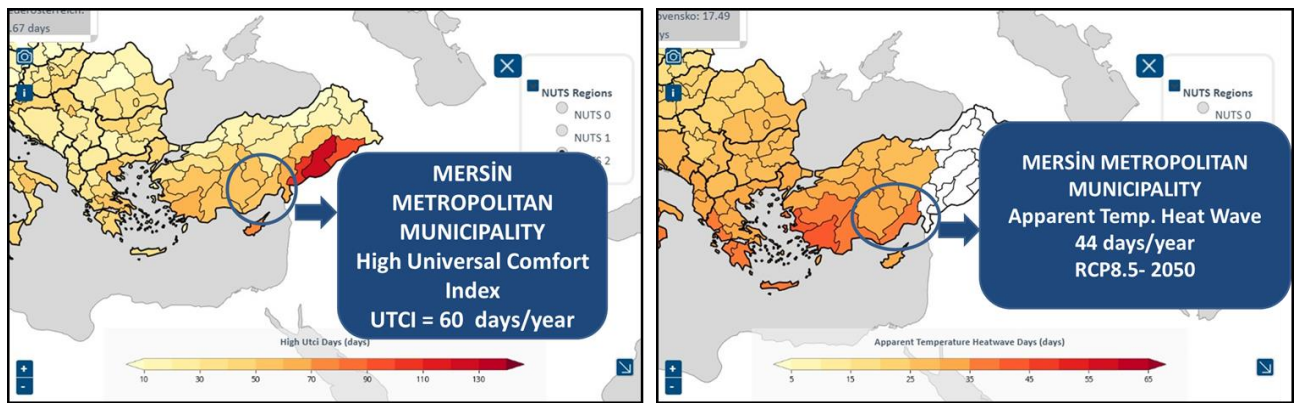


Figure 1-1 Geographic location of Mersin and heat stress in the region.

Figure source: European Environment Agency (EEA) Climate-ADAPT platform, apparent temperature heatwave days indicator. <https://climate-adapt.eea.europa.eu/en/metadata/indicators/apparent-temperature-heatwave-days>

The “Mersin Climate Ready: Multi-Risk Assessment for Urban, Coastal, and Rural Resilience (MCR-RA)” project applies the CLIMAAX methodology to develop a localized, multi-sectoral Climate Risk Assessment (CRA) framework for the MMM. While Phase 1 established the initial baseline assessment of priority climate hazards, Phase 2 focused on refining the analyses with regional data and strengthening their practical relevance for local decision-making, adaptation planning, and prioritization processes. The primary objective of Phase 2 was to transform the initial screening-level assessment into a more **operational, spatially explicit, and decision-support-oriented climate risk framework** by integrating local data, stakeholder knowledge, and refined spatial analyses. In this context, the project aimed to:

- improve the localization of CLIMAAX workflows for heatwaves, drought, wildfires, and heavy rainfall;
- refine risk analyses using local and regional datasets, including municipal data, Turkish General Directorate of Meteorology (MGM) datasets, day-time Landsat and night-time ASTER land surface temperature satellite observations, demographic indicators, regional agricultural productivity, unit prices, and growing season crop coefficients, and infrastructure-related datasets;
- identify **high-risk hotspots, vulnerable population groups, and priority intervention areas**;
- strengthen the integration of climate risk assessment outputs into municipal planning and adaptation processes;
- increase stakeholder participation and awareness through workshops, roundtable discussions, and adaptation prioritization exercises;
- support the preparation of future climate adaptation and resilience actions for MMM.

Compared with Phase 1, Phase 2 strengthened the localization of CLIMAAX workflows through higher-resolution analyses, infrastructure-related interpretation layers, adaptation-oriented risk communication, and stakeholder-informed prioritization processes.

The CLIMAAX Handbook provided important benefits during Phase 2:

- ensuring that methods remained **standardized, transparent, and comparable** with other European regions;
- enabling analyses to be conducted in a **repeatable and open-source workflow environment**;
- supporting the translation of climate risk logic (hazard–exposure–vulnerability) into a format that can directly support municipal planning and decision-making processes.

The integration of local datasets and regional interpretation substantially improved the credibility and practical relevance of the assessment. Satellite observations, demographic indicators, agricultural impact analyses, and infrastructure-related layers helped better capture the impacts of climate hazards on vulnerable populations and critical urban and rural systems.

Stakeholder engagement was strengthened through a multi-stakeholder workshop held on 14 April 2026 and subsequent expert consultations organized around four thematic risk areas: heatwaves, agricultural drought, wildfires, and heavy rainfall. This process enabled continuous dialogue among municipal departments,

universities, technical experts, NGOs, and sectoral stakeholders and supported the identification and prioritization of adaptation measures for Mersin.

As a result, Phase 2 produced not only a refined multi-risk climate assessment for Mersin, but also a more actionable and policy-relevant CRA framework supporting future adaptation investments, planning priorities, and resilience-building activities. The project also contributes to alignment with Türkiye's forthcoming Climate Law, the EU Adaptation Mission, and broader Mediterranean climate resilient

1.2 Scoping

The scoping phase defined the objectives, implementation context, stakeholder structure, and operational boundaries of the climate risk assessment conducted for MMM under the CLIMAAX framework. While Phase 1 focused mainly on preliminary screening and the identification of priority hazards, Phase 2 expanded the assessment into a more localized, multi-risk, and action-oriented framework by integrating local datasets, stakeholder participation, refined spatial analyses, and adaptation-oriented interpretation layers.

Phase 2 focused on four priority climate hazards identified as critical for Mersin: **i) Heatwaves ii) Agricultural drought iii) Wildfires iv) Heavy rainfall**

The CLIMAAX Handbook provided important methodological benefits throughout the process. Open-source workflows, reproducible methodologies, and standardized hazard–exposure–vulnerability logic improved transparency, comparability, and traceability while allowing the integration of local datasets, regional knowledge, and stakeholder-informed interpretation into the assessment process.

1.3 Objectives

The main objective of the Phase 2 Climate Risk Assessment (CRA) was to transform the preliminary analyses from Phase 1 into a localized, operational multi-risk assessment framework to support climate adaptation and resilience planning in Mersin. Phase 2 has expanded and deepened the scope of Phase 1 in terms of scale, data, and methods. In this context, the main innovations of Phase 2 can be summarized as follows:

- New data processing methodology for night-time Land Surface Temperature by the NASA Aster satellite instead of Landsat 8 to better visualize the Urban Heat Island effect.
- Prioritisation of highly heatwave-exposed and vulnerable neighbourhoods in Mersin city centre
- Integration of up-to-date local crop productivity data instead of more generic mapSPAM data
- Integration of local “Crop_UnitPrices.csv” instead of the average GAEZ aggregated value data for more correct computation of revenue losses.
- Computation and visualisation of irrigation water requirements for main crops
- Comparison of artificial irrigation requirement for banana production in Anamur between current (2020-2024 realised) and BIAS Adjusted-future projection (2046-2050 RCP8.5)
- Definition of heavy rainfall intensity thresholds for Mersin based on past events and analysis of their future return periods.

The assessment aimed to:

- identify and spatially analyse climate-related risks across Mersin,
- determine priority hotspots and vulnerable groups,
- strengthen adaptation-oriented interpretation of risks,
- improve institutional understanding of climate hazards,
- support future municipal planning and investment prioritization.

Compared to Phase 1, Phase 2 introduced more detailed hotspot analyses, stakeholder-informed prioritization processes, and interpretation layers supporting practical municipal decision-making.

Expected outputs include:

- localized climate risk maps and the identification of priority hotspots and vulnerable groups;
- stakeholder-informed analyses supporting adaptation planning and climate resilience investments;
- improved integration of climate risks into municipal planning processes and SECAP implementation;
- support for disaster risk reduction, sustainable water management, public health preparedness, and wildfire resilience measures.

The inclusion of local datasets and regional interpretation significantly improved the practical relevance of the assessment for Mersin. Compared with standard regional climate analyses, Phase 2 integrated locally relevant spatial layers, stakeholder feedback, and municipal priorities to produce more operational outputs suitable for adaptation planning. Despite these improvements, limitations remain regarding the availability

of health-related datasets, groundwater abstraction information, irrigation statistics, and socio-economic vulnerability indicators. Differences in spatial and temporal resolution among international and local datasets also introduced methodological uncertainties, which were partly addressed through the integration of multiple data sources and stakeholder-informed interpretation. Additional uncertainties remain regarding rapid urbanization, migration dynamics, and future water availability conditions.

1.4 Context

Climate hazards and climate-related risks in Mersin have previously been addressed mainly through strategic planning, disaster management, environmental protection, and sectoral adaptation activities. MMM has already undertaken several climate-related initiatives, particularly through its **Sustainable Energy and Climate Action Plan (SECAP)**, environmental management studies, disaster preparedness activities, and planning processes related to agriculture, water management, and urban infrastructure. SECAP provides the region's first comprehensive assessment of climate hazards, identifying drought, extreme heatwaves, flash floods, and wildfires. These hazards were assessed qualitatively through stakeholder surveys on hazard severity, vulnerable sectors, and adaptive capacity. However, these earlier assessments lacked spatial detail and did not identify where risks are concentrated.

Many previous studies remained at strategic or sectoral level, with limited integration of hazard, exposure, and vulnerability components within a unified and spatially explicit climate risk assessment framework. Existing assessments also lacked operational hotspot identification and multi-risk comparison capacity. Phase 2 therefore aimed to strengthen these gaps by developing a data-based and decision-support-oriented assessment framework.

Mersin is one of Türkiye's most important Mediterranean metropolitan regions, characterized by rapidly urbanizing coastal districts, intensive irrigated agriculture, logistics and port activities, tourism development, forested mountain ecosystems, and increasing pressure on water resources. The interaction between coastal urbanization, irrigated agricultural systems, water stress, and forest–settlement interfaces creates compound climate pressures unique to the Eastern Mediterranean context.

Several sectors are particularly sensitive to climate change impacts in Mersin.

Table 1-1 Main climate-sensitive sectors and climate-related risks in Mersin

Sector	Main Climate-Related Risks
<i>Agriculture and water management</i>	<i>Drought, irrigation pressure, water scarcity</i>
<i>Urban infrastructure and planning</i>	<i>Heatwaves, pluvial flooding, and infrastructure stress</i>
<i>Public health</i>	<i>Heat stress and impacts on vulnerable groups</i>
<i>Forestry and ecosystems</i>	<i>Increasing wildfire risk and ecosystem degradation</i>
<i>Tourism and coastal systems</i>	<i>Thermal comfort changes and coastal pressures</i>
<i>Energy systems</i>	<i>Increasing cooling demand and peak electricity loads</i>

The governance context of the assessment is shaped by both local and national climate-related policy frameworks. At local level, SECAP implementation, municipal strategic planning, disaster management activities, and environmental policies provide the institutional basis for climate adaptation processes. At national level, climate adaptation policies, disaster risk reduction frameworks, forestry regulations, and water management policies influence the broader governance structure.

Several external drivers also influence the climate risk context of Mersin, including:

- Mediterranean-wide warming trends,
- increasing regional drought pressure,
- national climate adaptation policies,
- European resilience initiatives such as CLIMAAX and the EU Adaptation Mission.

Possible adaptation interventions identified during the assessment include:

- urban greening and cooling interventions,
- heatwave early warning systems,
- sustainable water management practices,
- irrigation efficiency improvements,
- wildfire prevention and preparedness measures,
- pluvial flood risk reduction investments,
- protection measures for vulnerable groups.

The multi-risk climate risk assessment conducted during Phase 2 provides an important evidence-based future adaptation prioritization and resilience-building activities in Mersin, such as BIAS Adjusted projection of 24% increase in artificial irrigation for banana production in Anamur region, clearly represents the need for additional water resources in the near future and the importance of efficient irrigation technologies and closed-pressurized irrigation network investments. On the other hand, a possible irrigation deficit would result in a 45% yield loss and an annual revenue loss of 181 mil USD.

1.5 Participation and risk ownership

Stakeholder participation in Phase 2 aimed to strengthen the operational relevance of the climate risk assessment, validate findings through local knowledge, and support the integration of outputs into future adaptation planning processes.

The main stakeholder engagement activity was the “**Mersin CLIMAAX Climate Risk Analysis Workshop**” organized on 14 April 2026 at the MMM Congress and Exhibition Hall. The workshop brought together 90 representatives from municipalities, public institutions, universities, NGOs, agricultural organizations, technical experts, and private sector actors.

Roundtable discussions were organized around the four priority hazards identified for Mersin.

Interactive discussions and Menti surveys were used to evaluate climate risks, vulnerable groups, adaptation priorities, and implementation barriers. Participants actively contributed to discussions regarding green infrastructure, smart irrigation, flood management, wildfire preparedness, early warning systems, and protection of vulnerable groups.

Table 1-2 Main stakeholder groups participating in the Phase 2 CRA process

Stakeholder Category	Examples
Municipalities	MMM, Akdeniz, Anamur, Tarsus, Mezitli, Bozyazı Municipalities
Public Institutions	DSİ, AFAD, Provincial Health Directorate, General Directorate of Forestry
Universities	Mersin University, Toros University, Çağ University
NGOs / Civil Society	TEMA Foundation, agricultural organizations
Private Sector	Mersin International Port, Mersin Chamber of Shipping

Following the workshop, **thematic expert groups** were established for drought, heatwaves, wildfires, and flood risks. These groups continue to meet through bi-monthly online meetings to discuss interpretation of results, local implications for Mersin, and possible adaptation pathways.

MERSIN METROPOLITAN MUNICIPALITY (Leadership)

- DECISION-MAKING BODIES**
 - Climate High Council
- CLIMATE CHANGE & ZERO WASTE DEPT. (Project Coordination and Management)**
 - Tech. Working Group
 - Climate Consultancy
- DATA PROVIDERS AND REGIONAL INVESTMENT BODIES**
 - Universities and Research Institutes (Mersin Univ., Tarsus Univ., Toros Univ., METU)
 - Institute of Marine Sciences, Akita Institute
 - MSKİ General Directorate
 - DSİ 6th Regional Directorate
 - Meteorology 6th Regional Directorate
 - Provincial Directorate of Agriculture and Forestry
 - Regional Directorate of Forestry
 - Provincial Directorate of Environment, Urbanization and Climate Change
- MUNICIPAL DEPT. (Invest./Manag.)**
 - Urban Planning
 - 13 District Municipalities
 - Disaster Affairs and Risk Manag.
 - Fire Brigade
 - Agricultural Services & Parks and Gardens
 - Urban Planning, Technical Affairs, Transportation, & Survey and Projects
 - Health Affairs, Social Services, & Mukhtar Affairs
- RISK MANAGEMENT Actors**
 - ATAF Provincial Dir. (Disaster Risk)
 - Provincial Health Directorate & Provincial Directorate of Family and Social Services
 - Chambers of Commerce, Industry, and Professions (MTSD, Chamber of Shipping, TMMOB Chamber of Agriculture)
 - Unions, Cooperatives, and Producer Representatives (Irrigation Union, Agricultural Development and Fishery Cooperatives, AİBİ)
 - Civil Society / NGOs (TEMA Foundation, Turkish Foresters Association, etc.)
 - Private Sector (Mersin Int. Port Mana, OİZ Representatives)
 - Vulnerable Groups and Neighborhood (Elderly and disabled associations, migrant and refugee NGOs, mukhtars)

MERSIN MM -PRIORITIZED ADAPTATION STRATEGIES - HEATWAVES										
Lower priority					Higher Priority					
1	2	3	4	5	6	7	8	9	10	
Green-Blue Infrastructure (Parks, Green Corridors, Ponds) 7.8										
Early Warning System and Risk Maps 7.6										
Education and Awareness Activities 7.4										
Sustainable Settlement Regeneration 7.4										
Green Roof Applications 7.1										
Bioclimatic Gathering and Recreation Areas 6.7										
Light-Reflective and Permeable Pavements 6.6										
Citywide Drinking Fountain Network 6.0										
Social Support Programs 5.2										
Urban Hobby Gardens 4.8										

1.6 Application of principles

15

Precautionary approach: Given the substantial climatic uncertainty in the Mediterranean region, particularly regarding the projected intensification of heatwaves and extreme fire weather conditions (WFI exceeding 70), the precautionary principle was adopted in interpreting the results. The projected doubling of extreme heatwave days justified the early prioritization of cooling corridors, shade infrastructure, and greening actions in central urban districts. Gülnar is one of the most fire-prone districts in Mersin because of its extensive forests, rugged terrain, and numerous forest–settlement (wildland–urban interface) areas. Current precautionary approaches combine prevention, fuel management, preparedness, and emergency response.

1.7 Stakeholder engagement

Stakeholder engagement activities in Phase 2 focused on validating climate risk assessment outputs through local knowledge, strengthening inter-institutional coordination, and supporting adaptation prioritization processes. The main engagement activity was the “Mersin CLIMAAX Climate Risk Analysis Workshop” held on 14 April 2026. Prior to the workshop, a Turkish-language summary report presenting the preliminary CLIMAAX results was circulated to participants.

Approximately 90 representatives from municipalities, public institutions, universities, NGOs, professional organizations, and private-sector actors participated in the workshop. CLIMAAX outputs and preliminary adaptation priorities were communicated through presentations, thematic roundtable discussions, and interactive Menti surveys, which collected around 80 responses regarding vulnerable groups, adaptation priorities, institutional needs, and implementation barriers.

Overall, participants positively received the localized and spatially explicit risk maps, particularly their potential to support prioritization and adaptation planning. The main feedback themes highlighted increasing concern about drought and water scarcity, the need for stronger early warning systems, improved green infrastructure, sustainable water management, and stronger institutional coordination. Following the workshop, thematic expert groups continued stakeholder engagement through bi-monthly online meetings focusing on interpretation of results, local implications for Mersin, and possible adaptation pathways.

The outputs generated through the stakeholder engagement process are expected to support future SECAP implementation, climate adaptation planning, disaster risk reduction activities, and resilience investments in Mersin. Several challenges were encountered during the process, including differences in institutional priorities, varying technical capacities among participants, and the need to communicate technically complex analyses in an operational manner to diverse stakeholder groups. These challenges were partly addressed through interactive discussions and thematic expert groups. Further details are provided in the **Mersin CLIMAAX Workshop Outcomes Report** (MMM, 2026:

<https://www.mersin.bel.tr/dokumanlar/mersin-climaax-iklim-risk-analizi-calistayi-dokumani-raporu-900488446>) and the CLIMAAX evaluation reports available through the Municipality and Zenodo repositories.



2 QUALITATIVE CLIMATE RISK ASSESSMENT

2.1 Probability of Climate Hazards

Identifying climate risks requires knowing the frequency of events that occurred in the past. For this reason, past climatological data, reports, model results and other data sources are evaluated to determine the risks of climate change. These data also help to produce anticipations about how the climate will change in the future. Thus, identifying climate risks should be considered as a valuable input in shaping future policies and strategies.

For the probability scoring of the climate risks identified within the scope of the study, an assessment was made according to the number of times these events were encountered at least once a year in the past years and the probability of encountering these risks once a year in the coming period. This assessment is based on the frequency of events in past years and future probabilities.

This assessment is an important step to determine the likelihood of climate risks and to be prepared for them. The number of times this event has occurred in previous years shows how often it has occurred. The likelihood of encountering these risks in the coming period is a factor that should be taken into account in future planning and risk management strategies.

The probability table obtained as a result of the frequency of occurrence of climate risks for Mersin province is given in **Hata! Başvuru kaynağı bulunamadı..** Weather reports published by the General Directorate of Meteorology, meteorological station data, regional climate projections of MGM (HadGEM2-ES) and average values of the results of all global climate models were obtained and used in the studies. When the results are analyzed, temperature increase, storms and tornadoes, forest fires, excessive rainfall and flooding are identified as the most likely climate risks. Drought, on the other hand, is not seen as a serious first risk for today, but it will most likely be a risk that the Mersin will face in 2050.

Table 2-1 Probability of climate risks occurring in Mersin

Climate Risks	Evaluation Criteria	2023 Likelihood Level	2050 Likelihood Level	Change
Temperature Increase	Maximum Temperature, Warm Period Duration	5 (Very High Probability)	5 (Very High Probability)	↔
Drought	Number of Dry Days, SPEI 12	2 (Low Probability)	4 (High Probability)	↑
Extreme Rainfall and Flooding	Number of events, Number of days with more than 20mm/day rainfall, Daily max. rainfall	4 (High Probability)	5 ((Very High Probability)	↑
Storm and Tornadoes	Number of Events	5 ((Very High Probability)	5 ((Very High Probability)	↔
Hail	Number of Events	4 (High Probability)	4 (High Probability)	↔
Snow	Number of Events, Number of Icy Days and Min. Min. of Temperatures Climate Indices	1 (Very Low Probability)	1 (Very Low Probability)	↔
Lightning Strike	Number of Events	2 (Low Probability)	2 (Low Probability)	↔
Forest Fires	Fire Weather Index	4 (High Probability)	4 (High Probability)	↔
Sea Level Rise	Sea level height	1 (Very Low Probability)	3 (Possible)	↑

2.2 Identification of Sectors and Critical Infrastructures

Critical infrastructure refers to networks, assets, systems, structures or combinations thereof that may have impacts on the health, safety and economy of citizens due to the adverse effects of possible partial or complete loss of function on the environment, community order services (AFAD, 2014).

When identifying the sectors and critical infrastructures that will be affected by climate change in cities, it should be taken into account which sectors and infrastructures will be more at risk. The vulnerability of sectors and infrastructures to climate change and their role in meeting the basic needs of society and economic growth are important. The authority and capacity of local governments to adapt sectors and infrastructures to climate change and increase their resilience should also be determined.

Considering these criteria, sectors and critical infrastructures that will be affected by climate change have been identified and given in **Hata! Başvuru kaynağı bulunamadı..**

Table 2-2 Sectors and critical infrastructures assessed within the scope of adaptation measures

Sectors	Critical Infrastructure
Urban life	- Residential buildings - Public buildings - Hospital buildings and other health institution buildings - Education buildings - Hotels - Commercial premises - Construction activities
Energy and Industry	- Thermal power plants - Renewable energy plants - Energy transmission and distribution network - Pipelines - Industrial facilities - Organized Industrial Zones - Raw material supply chain - Energy supply - Logistics

Sectors	Critical Infrastructure
	• Water use • E-Commerce • Staff
Transportation infrastructure	• Roads, bridges and tunnels • Road transportation • Rail system lines • Rail transportation • Ports and piers • Sea transportation
Solid waste and wastewater management	• Waste storage facilities • Solid waste biological processing plants • Waste incineration plants • Wastewater treatment plants • Waste recovery and recycling facilities • Medical waste sterilization facilities
Agriculture and livestock	• Animal presence • Meadow and pasture lands • Agricultural land • Agricultural enterprises
Water resources	• Surface and groundwater resources • Basins • Dams • Water tanks • Water and wastewater treatment plants • Drinking water transmission lines, sewerage system and wastewater discharge lines
Forest areas	• Forest areas • National Parks • Flora • Fauna • Land ecosystem
Coastal areas	• Ports • Other transportation structures • Marinas • Tourism facilities • Commercial buildings • Energy and industrial facilities • Water and wastewater infrastructure • Coastal settlements
Fisheries	• Fishing shelters • Fishing fleet • Fish farming facilities • Fish farms • Processing and evaluation facilities
Tourism and cultural heritage	• Accommodation facilities • Coastal areas and beaches • Historical and cultural touristic areas • Museums and cultural centers • Theaters and cinemas • Travel agencies

2.3 Assessment of the Impacts of Climate Risks by Sector

Climate change has become a rapidly increasing problem in recent years and the impacts of these changes on urban infrastructures are also increasing. These impacts vary for each sector and critical infrastructure. For example, increasing temperature and energy demand in cities can negatively affect energy infrastructure. Therefore, power generation based on renewable energy sources and infrastructure improvements can be made to increase energy efficiency. Climate change may lead to reduced water resources and increased flooding. Therefore, infrastructure improvements can be made to protect water resources in cities, strengthen water collection and storage systems, and ensure more efficient use of water. In addition, more frequent heavy rains can cause roads to become flooded. This can make it difficult to maintain safe transportation. In conclusion, the impacts of climate risks on sectors and their critical infrastructures vary considerably and may have different consequences on each critical infrastructure. The dimensions of these impacts were asked in the survey and it was requested to determine the impact of climate risks on the sector to which they relate. Impacts were evaluated on a scale of 1 (Very Low Impact) to 5 (Very High Impact) and the impact table prepared following the survey results is given in **Hata! Başvuru kaynağı bulunamadı..**

Table 2-3 Scale of impact of climate risks on sectors

	Temperature Increase	Drought	Extreme Rainfall and Floods	Storms and Tornadoes	Hail	Snow	Lightning strike	Forest Fires	Sea Level Rise
Water Resources	5	5	3	2	3	3	2	4	3
Coastal Areas	4	4	3	3	3	3	2	4	5
Waste Management	4	4	3	2	3	3	2	4	3
Public Health	4	4	3	3	3	3	3	4	3
Agriculture, Livestock and Fisheries	5	5	4	4	4	3	2	4	4
Land Use, Ecosystem and Biodiversity	5	5	4	3	3	3	2	5	4
Transportation and Logistics	4	4	4	4	4	3	2	4	4
Buildings	4	4	4	3	4	3	3	4	4
Energy Generation and Transmission	4	4	4	4	3	3	3	4	3
Industry	4	4	4	3	3	2	2	4	3
Culture and Tourism	4	4	4	4	3	3	2	4	4

2.4 Risk Assessment

Risk matrices have been prepared to assess the potential climate risks for Mersin province and their potential impacts on sectors. Climate change risk and vulnerability analysis for Mersin have been performed according to the following parameters and criteria:

Climate-related hazards: Drought, Water stress, Increased water demand, Fire weather (risk of wildfires), Urban flooding, River flooding, Coastal flooding (incl. sea level rise), Hurricanes, cyclones, and/or typhoons, Extreme wind, Storm, Heavy precipitation, Mass movement, Biodiversity loss, Loss of green space/green cover, Soil degradation/erosion, Other forms of climate-induced landscape shift/degradation, Infectious disease

Assessed Sectors or Services: Agriculture, Forestry, Fishing, Mining and quarrying, Manufacturing, Electricity, gas, steam and air conditioning supply, Water supply, Sewerage, waste treatment and remediation activities, Waste management, Administrative and support service activities, Public administration and defence;

compulsory social security, Conservation, Construction, Wholesale and retail trade; repair of motor vehicles and motorcycles, Transportation and storage, Accommodation and food service activities, Information and communication, Financial and insurance activities, Real estate activities, Professional, scientific and technical activities, Education, Human health and social work activities, Arts, entertainment and recreation

Assessed Vulnerable Population Groups: Women and girls, Children and youth, Elderly, Indigenous peoples, Marginalized/minority communities, Vulnerable health groups, Low-income households, Outdoor workers, Frontline workers

Efforts have been made to determine the potential impacts of these hazards on sectors and vulnerable community segments.

The potential impacts of evaluated climate hazards on vulnerable population groups and sectors most exposed are described in the following tables.

Table 2-4 Climate-related hazards risk definition matrix for Mersin

Climate-related hazards	Vulnerable population groups most exposed	Sectors most exposed	Description of the impacts on vulnerable populations and sectors	Proportion of the population exposed to the hazard
Extreme heat waves/ Heat stress	Elderly Outdoor workers Vulnerable health groups Low-income households	Agriculture /Livestock Water supply Electricity, gas, steam and air conditioning supply Forestry Human health and social work activities	Vital danger for chronic patients, elderly, and low income households due to energy poverty. Forest fires due to extreme heat. Increase in coolingenergy demand. Decrease in agricultural and livestock production. Reduction in dairy production.	91-100%
Drought	Indigenous peoples Low-income households Vulnerable health groups	Agriculture /Livestock Electricity, gas, steam and air conditioning supply Water supply Human health and social work activities	Decrease in agricultural production, soil degradation due to excessive irrigation. Decrease in energy production and water reserves. Food security risk.	41-50%
Heavy precipitation/ Urban/River flooding	Low-income households Outdoor workers Elderly Indigenous peoples	Agriculture /Livestock Transportation and storage Manufacturing Sewerage, waste management and remediation activities Electricity, gas, steam and air conditioning supply	Submersion of transportation lines, residential areas, and agricultural lands due to surface flooding caused by excessive rainfall. Vital risk for low income households and outdoor workers. Disruption of transportation services. Reduction in agricultural productivity.	31-40%
Fire weather (risk of forest wildfires)	Indigenous peoples Vulnerable health groups	Forestry Public administration and defence; compulsory social security	Decrease in forest areas. Fire and vital danger for settlements near forests. Decrease in bee and other insect populations. Vital danger for wild animals	≤10%

	Low-income households	Agriculture /Livestock Electricity, gas, steam and air conditioning supply		
Storm/ Extreme wind/Tornadoe	Low-income households Outdoor workers Indigenous peoples	Accommodation and food service activities Agriculture /Livestock Human health and social work activities Transportation and storage Construction	Roof damages in buildings due to excessive wind and storms. Damage to seedlings during flowering season. Vital danger for low income households due to CO poisoning. Damages in energy supply lines.	11-20%
Hail Storm	Low-income households Outdoor workers Frontline workers	Agriculture /Livestock Transportation and storage Accommodation and food service activities	Impact on fruit and vegetable production during flowering season due to excessive hail. Reduction in agricultural yield. Damage to vehicles.	≤10%
Sea level rise/ Coastal flooding and other events	Low-income households Indigenous peoples Elderly	Transportation and storage Manufacturing Accommodation and food service activities Agriculture /Livestock Sewerage, waste management and remediation activities	Submersion of residential, agricultural and industrial lands next to the coastal areas	≤10%
Extreme cold/Snow and ice	Low-income households Indigenous peoples Elderly	Transportation and storage Manufacturing Accommodation and food service activities Agriculture /Livestock Sewerage, waste management and remediation activities	Disruption of transportation due to severe winter conditions. Disruption in energy/water supply. Decrease in agricultural yield due to spring frosts	≤10%
Lightning Strike	Low-income households Outdoor workers Frontline workers	Transportation and storage Electricity, gas, steam and air conditioning supply Accommodation and food service activities Agriculture /Livestock	Disruption of energy supply. Vital danger for outdoor workers.	≤10%

A risk matrix is used to assess risk by considering the likelihood of an event occurring and weighing it against its corresponding impact. When creating a risk matrix, each potential impact is assigned a risk rating based on its likelihood of occurrence and what the consequences (severity) would be if it were to occur. In the risk matrix prepared within the scope of the study, the risk is classified in 3 categories as High, Medium and Low. **Hata! Başvuru kaynağı bulunamadı.** shows the 2023 risk matrix and **Hata! Başvuru kaynağı bulunamadı.** shows the 2050 risk matrix obtained as a result of the probability-impact assessment conducted for Mersin. As a result of the risk and vulnerability analysis, temperature increase, storms and tornadoes, hail, heavy rainfall and flooding create high risks on critical infrastructures. In 2050, drought is categorised under high risk category for the region. Heavy snowfall and lightning strikes are climate events in the low risk category for the region. Sea level rise, which is defined as low risk in the current situation analysis, increases to medium risk class in the 2050 analysis. It has been determined that urban life, transport infrastructure, agriculture and animal husbandry are the sectors most affected by climate events today. However, it is predicted that coastal areas will also be included in this class in the future. All sectors are at high risk of being affected by different climate events. Therefore, actions to mitigate these risks should be implemented by local administrations. For this purpose, actions that will strengthen the adaptation capacity of Mersin province against climate change and increase its resilience are proposed for all sectors included in the analysis.

Table 2-5 Climate-related hazards risk assessment risk matrix for Mersin

Climate-related hazards	Current probability of hazard	Current magnitude of impact of hazard	Expected future change in hazard intensity	Expected future change in hazard frequency	Timeframe of expected future changes
Extreme heat waves/ Heat stress	High	High	Increasing	Increasing	Medium-term (2026-2050)
Drought	Medium	Medium	Increasing	Increasing	Medium-term (2026-2050)
Heavy precipitation/ Urban/River flooding	High	High	Increasing	Increasing	Medium-term (2026-2050)
Fire weather (risk of forest wildfires)	High	High	Increasing	Increasing	Medium-term (2026-2050)
Storm/ Extreme wind/Tornadoe	Medium Low	Medium	Increasing	Increasing	Medium-term (2026-2050)
Hail Storm	Medium Low	Medium High	Increasing	Increasing	Medium-term (2026-2050)
Sea level rise/ Coastal flooding and other events	Low	Low	None/Remains the same	None/Remains the same	Long-term (after 2050)
Extreme cold/Snow and ice	Low	Low	None/Remains the same	None/Remains the same	Long-term (after 2050)
Lightning Strike	Low	Low	None/Remains the same	None/Remains the same	Long-term (after 2050)

Table 2-6 Current situation risk matrix for Mersin

Climate Risks	Sectors									
	Urban Life	Energy and industry	Transportation infrastructure	Solid waste and wastewater management	Agriculture and livestock	Water resources	Forest areas	Coastal areas	Fisheries	Tourism and cultural heritage
Extreme Heat Waves	High	High	High	High	High	High	High	High	High	High
Drought	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Heavy Rainfall and Flooding	High	High	High	Medium	High	Medium	High	Medium	High	High
Storms and Tornadoes	High	High	High	Medium	High	Medium	High	High	High	Medium
Hail	High	Medium	High	Medium	High	Medium	Medium	Medium	Medium	Medium
Snow Extreme winter Cond.	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Lightning Strike	Medium	Medium	Low	Low	Low	Low	Low	Low	Low	Low
Forest Wildfires	High	High	High	High	High	High	High	High	Medium	High
Sea Level Rise	Low	Low	Low	Low	Low	Low	Low	Medium	Low	Low

Table 2.1: Risk matrix for Mersin in 2050

Climate Risks	Sectors									
	Urban Life	Energy and industry	Transportation infrastructure	Solid waste and wastewater management	Agriculture and livestock	Water resources	Forest areas	Coastal areas	Fisheries	Tourism and cultural heritage
Temperature Increase	High	High	High	High	High	High	High	High	High	High
Drought	High	High	High	High	High	High	High	High	High	High
Heavy Rainfall and Flooding	High	High	High	High	High	High	High	High	High	High
Storms and Tornadoes	High	High	High	Medium	High	Medium	High	High	High	High
Hail	High	Medium	High	Medium	High	Medium	Medium	Medium	Medium	Medium
Snow	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Lightning Strike	Medium	Medium	Low	Low	Low	Low	Low	Low	Low	Low
Wildfires	High	High	High	High	High	High	High	High	Medium	High
Sea Level Rise	Medium	Medium	Medium	Medium	Medium	Medium	Medium	High	Medium	Medium

2.5 Sectoral Vulnerability Analysis Against Climate Hazards

The adaptive capacities of service sectors against primary (major) climate hazards were evaluated through Survey 3. Sectors resilient or vulnerable to these prioritized hazards were identified and shown in the table and chart below. The assessment was based on the potential future impacts (PI) of climate hazards on the

service/sector and the current adaptive capacity (AC) of the service or sector. The evaluation criteria are defined as follows:

Potential Impact (PI)

- PI5-High-Sector/Service collaps. Unmanageable.
- PI4- Medium High- Sector/service disrupts
- PI3-Medium: Shows a tendency to deteriorate.
- PI2 - Sector/sector temporarily interrupt.
- PI1-Low- Sector/Service is not affected.

Adaptive Capacity (AC)

- AC5-Low- Very High investment required
- AC4-Medium Low- High investment Required
- AC3-Medium- Additional investment required
- AC2-Medium High- Additional improvement may be necessary.
- AC1-High- No improvement needed

Table 2-7 Sectoral Vulnerability Analysis for Mersin

Climate-Related Hazards	Most Exposed Sectors	Potential Impact on Sector (PI1 Low - PI5 High)	Sector's Adaptive Capacity (AC1 Low – AC5 High)
Extreme Heatwaves / Heat Stress	Agriculture /Livestock	PI4- Medium High- Sector/service disrupts	AC2-Medium High- Additional improvement may be necessary.
	Water supply	PI2 - Sector/sector temporarily interrupt.	AC2-Medium High- Additional improvement may be necessary.
	Electricity, gas, steam and air conditioning supply	PI3-Medium: Shows a tendency to deteriorate.	AC2-Medium High- Additional improvement may be necessary.
	Forestry	PI2 - Sector/sector temporarily interrupt.	AC2-Medium High- Additional improvement may be necessary.
	Human health and social work activities	PI4- Medium High- Sector/service disrupts	AC4-Medium Low-High investment Required
Drought	Agriculture /Livestock	PI4- Medium High- Sector/service disrupts	AC3-Medium- Additional investment required
	Electricity, gas, steam and air conditioning supply	PI3-Medium: Shows a tendency to deteriorate.	AC2-Medium High- Additional improvement may be necessary.
	Water supply	PI3-Medium: Shows a tendency to deteriorate.	AC2-Medium High- Additional improvement may be necessary.
	Human health and social work activities	PI2 - Sector/sector temporarily interrupt.	AC2-Medium High- Additional improvement may be necessary.
Heavy Rainfall and Floods	Agriculture /Livestock	PI5-High-Sector/Service collaps. Unmanageable.	AC3-Medium- Additional investment required
	Transportation and storage	PI4- Medium High- Sector/service disrupts	AC3-Medium- Additional investment required
	Manufacturing	PI2 - Sector/sector temporarily interrupt.	AC2-Medium High- Additional improvement may be necessary.
	Sewerage, waste management and remediation activities	PI5-High-Sector/Service collaps. Unmanageable.	AC4-Medium Low-High investment Required
	Electricity, gas, steam and air conditioning supply	PI4- Medium High- Sector/service disrupts	AC2-Medium High- Additional improvement may be necessary.
Forest Wildfire	Forestry	PI5-High-Sector/Service collaps. Unmanageable.	AC3-Medium- Additional investment required
	Public administration and defence; compulsory social security	PI5-High-Sector/Service collaps. Unmanageable.	AC3-Medium- Additional investment required
	Agriculture /Livestock	PI2 - Sector/sector temporarily interrupt.	AC2-Medium High- Additional improvement may be necessary.

	Electricity, gas, steam and air conditioning supply	PI4- Medium High-Sector/service disrupts	AC3-Medium- Additional investment required
Storm/ Extreme wind/Tornadoe	Accommodation and food service activities	PI2 - Sector/sector temporarily interrupt.	AC2-Medium High- Additional improvement may be necessary.
	Agriculture /Livestock	PI2 - Sector/sector temporarily interrupt.	AC2-Medium High- Additional improvement may be necessary.
	Human health and social work activities	PI2 - Sector/sector temporarily interrupt.	AC1-High- No improvement needed
	Transportation and storage	PI2 - Sector/sector temporarily interrupt.	AC1-High- No improvement needed
	Construction	PI2 - Sector/sector temporarily interrupt.	AC1-High- No improvement needed
Hail Storm	Agriculture /Livestock	PI3-Medium: Shows a tendency to deteriorate.	AC2-Medium High- Additional improvement may be necessary.
	Transportation and storage	PI2 - Sector/sector temporarily interrupt.	AC1-High- No improvement needed



3 QUANTITATIVE RISK ANALYSIS

The risk screening step refined the hazards identified during Phase 1 using updated climate projections, quantitative evaluations of past events, stakeholder feedback from climate surveys, and preliminary spatial analyses. Consistent with findings from the MGM Climate data (historical and projections), Copernicus Climate Change Service (C3S), EURO-CORDEX projections, and regional Mediterranean climate assessments, four priority hazards were selected for detailed assessment in Mersin: **heatwaves, agricultural drought, wildfires, and heavy rainfall.**

Table 3-1 Main climate hazards and associated risks identified for Mersin

<i>Climate Hazard</i>	<i>Main Risks</i>
<i>Heatwaves</i>	<i>Public health impacts, thermal discomfort, livestock and infrastructure stress</i>
<i>Agricultural drought</i>	<i>Irrigation deficits, crop productivity losses, and water scarcity</i>
<i>Wildfires</i>	<i>Ecosystem degradation, settlement exposure, and infrastructure damage</i>
<i>Heavy rainfall</i>	<i>Pluvial floods, drainage overload, and infrastructure damage</i>

These hazards were retained because they affect different but interconnected systems across Mersin. Heatwaves increasingly affect densely populated districts such as Akdeniz, Mezitli, Yenişehir and Toroslar, agricultural drought threatens irrigated production systems in Erdemli, Anamur and Bozyazı, wildfire danger is increasing in forest–settlement interface areas in districts such as Gülnar and Mut, and heavy rainfall events create recurrent pressures on drainage systems, transport infrastructure, and densely urbanized coastal districts.

Current observations already indicate increasing thermal stress in densely urbanized districts, growing pressure on water resources that support agricultural production, rising wildfire danger in forest–settlement interface areas, and increasing exposure to short-duration, intense rainfall events that can overwhelm urban drainage systems. Vulnerable groups include older persons, children, outdoor workers, low-income households, migrants and refugees, and small-scale farmers.

Climate projections for the Eastern Mediterranean consistently indicate rising temperatures, higher evapotranspiration rates, more frequent drought conditions, elevated wildfire risk, and increasing precipitation extremes. These trends confirm the relevance of the selected hazards and provide the basis for the detailed regionalized risk analyses presented in the following sections.

Hazard workflows included in the assessment

The following CLIMAAX workflows and analyses were included in Phase 2:

Table 3-2 Main workflows and analyses applied in Phase 2

<i>Hazard Area</i>	<i>Main Workflow / Analysis</i>
<i>Heatwaves</i>	<i>EUROHEAT, XClim, LST/UHI analyses, vulnerability overlays</i>
<i>Agricultural drought</i>	<i>SPEI, evapotranspiration, irrigation deficit, crop productivity analyses</i>
<i>Wildfires</i>	<i>Fire Weather Index (FWI), temperature, and precipitation analyses</i>
<i>Heavy rainfall</i>	<i>Threshold exceedance analyses and precipitation projection workflows</i>

Compared with Phase 1, Phase 2 introduced refined hotspot analyses, higher-resolution spatial interpretation, infrastructure-related overlays, vulnerability-focused analyses, and stakeholder-informed prioritization processes.

Some specific examples for these interventions include:

- New data processing methodology for night-time Land Surface Temperature by NASA Aster satellite instead of Landsat 8 to better visualise Urban Heat Island effect.
- Prioritisation of highly heatwave exposed and vulnerable neighbourhoods in Mersin city centre
- Integration of up-to date local crop productivity data instead of more generic mapSPAM data
- Integration of local “Crop_UnitPrices.csv” instead of average GAEZ aggregated value data for more correct computation of revenue losses.
- Computation and visualisation of irrigation water requirements for main crops
- Comparison of artificial irrigation requirement for banana production in Anamur between current (2020-2024 realised) and BIAS Adjusted-future projection (2046-2050 RCP8.5)
- Definition of heavy rainfall intensity thresholds for Mersin based on past events and analysis of their future return periods

Data availability and remaining gaps

Phase 2 combined international open-source datasets with local and regional information sources.

Main datasets included:

- Copernicus Climate Data Store (CDS),
- EURO-CORDEX climate projections,
- Landsat and NASA Aster satellites imageries (both day-time and night-time),
- WorldPop population datasets,
- MGM meteorological observation records and projections
- Local agricultural productivity datasets from TUIK,
- Past disaster and event records from AFAD (pluvial floods, wildfires)
- and municipal planning and infrastructure information.

Despite these improvements, limitations remain regarding health-related indicators, infrastructure vulnerability information, long-term impact datasets, and socio-economic uncertainties. Additional datasets on public health, water consumption, ecosystem degradation, and infrastructure sensitivity would further strengthen future climate risk assessments for Mersin.

Future climate conditions in Phase 2 were assessed using BIAS-adjusted climate projections and workflow outputs aligned with the CLIMAAX methodology and EURO-CORDEX datasets. The analyses focused primarily on medium- and high-emission climate scenarios to evaluate the potential evolution of climate risks in Mersin under increasing warming.

Particular emphasis was placed on future changes in heatwave intensity and duration, drought severity, wildfire danger conditions, and precipitation extremes.

The assessment considered the following climate scenarios:

- **RCP4.5** (moderate emission scenario),
- **RCP8.5** (high emission scenario).

For bias adjustment, historical MGM observations (2020–2024) and model outputs were compared using the Quantile Mapping method and subsequently applied to mid-century projections.

These scenarios were applied particularly within heatwave, drought, and wildfire analyses.

Socio-economic assumptions

Future socio-economic developments were considered through demographic exposure patterns, urbanization trends, agricultural dependency, infrastructure concentration, and the spatial distribution of vulnerable populations. Although formal SSP-based socio-economic modelling was not implemented during Phase 2, the assessment considered continuing urban growth, increasing cooling and water demand, rising irrigation dependency, and growing pressure on infrastructure and ecosystems. WorldPop datasets and demographic indicators were used to represent exposure and vulnerability patterns within the urban system, while additional interpretation considered refugee populations, vulnerable neighbourhoods, and the ageing population structure in Mersin.

Integration of climate and socio-economic conditions

Climate projections were integrated with socio-economic vulnerability and exposure indicators through:

- spatial hotspot analyses,
- population density overlays,
- infrastructure-related interpretation layers,
- agricultural productivity analyses,
- and urban heat exposure mapping.

For example:

- Landsat-derived surface temperature analyses were combined with vulnerable population density maps to identify urban heat risk hotspots,
- irrigation deficit analyses were interpreted together with agricultural production zones,
- and wildfire danger analyses were evaluated alongside forest–settlement interface areas.

This integrated approach strengthened the operational relevance of the assessment for adaptation planning and prioritization.

Time horizons considered

Different workflows used different temporal horizons depending on methodological requirements and data availability.

The assessment generally considered:

- **current conditions** (recent observational and satellite-based datasets),
- **near future conditions** (approximately 2016–2045),
- and **mid-century projections** (approximately 2046–2075 / 2050 horizon).

For heatwave analyses specifically:

- current conditions indicate approximately **18 heatwave days/year**,
- while projections indicate up to **44 heatwave days/year by 2050** under pessimistic scenarios.

In Phase 2, the CLIMAAX workflows were adapted to the Mersin context using regional climate projections, satellite-derived datasets, local agricultural and demographic information, municipal infrastructure data, and stakeholder inputs. The assessment focused on four priority climate hazards identified during Phase 1 and validated through stakeholder engagement: **heatwaves, agricultural drought, wildfires, and heavy rainfall**.

The analyses combined the CLIMAAX hazard–exposure–vulnerability framework with local datasets to identify climate risk hotspots affecting vulnerable populations, critical infrastructure, agricultural production areas, forest ecosystems, and urban settlements. The objective was to generate decision-relevant risk information to support municipal planning, SECAP implementation, disaster risk reduction, and future climate adaptation investments.

Compared with Phase 1, the assessment was refined through higher-resolution local data, sector-specific impact analyses, and stakeholder-informed interpretation. The following sections present the regionalized hazard and risk assessment results for each priority climate hazard.

3.1 Heatwaves

The heatwave workflow was localized for Mersin by combining EURO-CORDEX climate projections for apparent temperature heatwaves using EuroHeat, CLIMAAX heatwave outputs, Landsat 8-derived day-time Land Surface Temperature (LST), Terra Aster-derived night-time LST, WorldPop population data, and local interpretation of vulnerable groups and critical infrastructure. The analysis focused on both future heatwave hazard and present-day urban exposure. According to MGM historical records of 2024; daily average summer season (May–September) temperatures and humidity were measured as: $T_{min}=25.4\text{ }^{\circ}\text{C}$; $T_{max}=31.6\text{ }^{\circ}\text{C}$; Relative Humidity=63%. High average night-time temperature (T_{min}), high day-time temperature (T_{max}) and high humidity indicate severe heatwave risk in Mersin. In addition to this, BIAS adjusted 2050 projection (MPI-RCP8.5) represent further 1.0-1.5 °C increase in night and night time temperatures ($T_{min}=26.4$; $T_{max}=33.0\text{ }^{\circ}\text{C}$; RH=57%)

Table 3-3 Temperature and humidity change between historical and BIAS-adjusted 2050 projection in Anamur

Parameters	2020-2024 (Historical)						Difference
Summer Season Months	May	Jun	Jul	Aug	Sep	Avg.	Avg.
<i>Tmin</i> , °C	19.5	25.9	28.2	28.1	25.1	25.4	1.0
<i>Tmax</i> , °C	26.7	31.9	33.8	33.8	31.7	31.6	1.5
Relative Humidity, %	64.6	67.8	62.9	62.7	57.4	63.1	-6.5

Table 3-4 Data overview workflow #1 – Heatwaves

Hazard data	Vulnerability data	Exposure data	Impact metrics/Risk output
EURO-CORDEX climate projections; CLIMAAX Heatwave Workflow; RCP4.5 and RCP8.5 scenarios	WorldPop population data; TÜİK demographic information; elderly population, children, refugees, chronic disease-sensitive groups	Landsat 8 LST; Terra Aster LST; urban built-up areas; critical public services	Heatwave days/year; 2050 apparent temperature heatwave days;
	Population density at 100 × 100 m resolution	Hospitals, schools, community centres, dense urban districts	Heatwave risk map combining LST and population density; critical infrastructure overlay, Night-time UHI map

Hazard assessment

The heatwave hazard assessment indicates a substantial increase in extreme heat exposure across Mersin during the coming decades. Based on EURO-CORDEX climate projections and the CLIMAAX Heatwave Workflow, the annual number of heatwave days is projected to increase from approximately **18 days per year at present to around 44 days per year** by 2050 under RCP8.5 conditions (Figure 1-3). The increase is evident in both the RCP4.5 and RCP8.5 scenarios, though considerably stronger under the high-emission pathway.

The results suggest that heatwaves will become both more frequent and longer-lasting, increasing thermal stress across urban districts, agricultural areas, and coastal settlements. As one of Türkiye's largest Mediterranean metropolitan regions, Mersin is particularly exposed due to the combined effects of high summer temperatures, humidity, rapid urbanization, and growing population concentrations in coastal areas. These findings confirm heatwaves as one of the most significant climate hazards affecting the region.

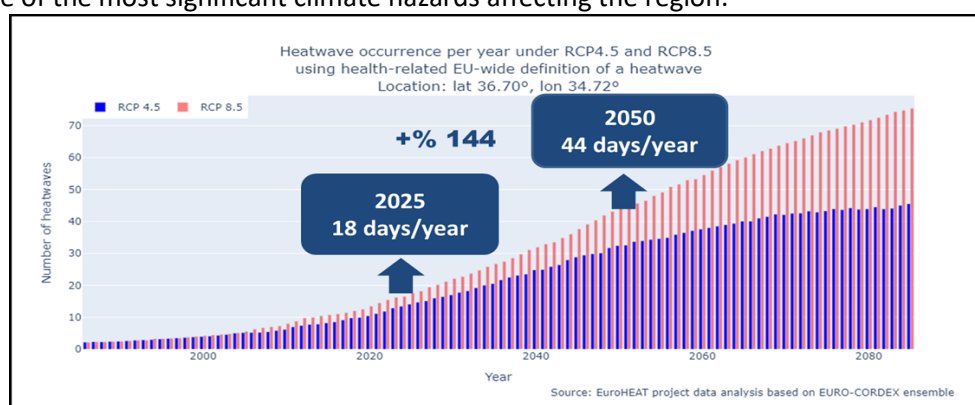


Figure 3-1 Projected increase in annual heatwave days and relative heatwave risk to vulnerable populations in Mersin under RCP4.5 and RCP8.5 scenarios.

Figure source: Copernicus Climate Data Store (CDS), EURO-CORDEX climate projections, CLIMAAX Heatwave Workflow, and analyses conducted by MMM.

Risk assessment

The heatwave risk assessment combined **surface temperature exposure** with **population vulnerability**. Land Surface Temperature (LST) is a key indicator for analysing heatwaves and the urban heat island (UHI) effect, which refers to higher surface and air temperatures in urban areas compared to their rural surroundings.

In the CLIMAAX Heatwave Risk Assessment Workflow, we use satellite-based LST images as the exposure component. The workflow currently defines the Landsat 8 image download methodology and related codes. At the Mersin Metropolitan Municipality, we have already applied Landsat 8 datasets for daytime observations during the summer season. However, since daytime land surface temperatures often exceed 50 °C and are distributed relatively homogeneously across the city centre, it was not possible to effectively visualize temperature variations or the urban heat island effect. Therefore, we searched for another data source providing nighttime LST images. Two of the most widely used satellite sources for LST data are Terra ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) and Landsat 8 (Thermal Infrared Sensor – TIRS). Landsat 8 offers consistent global coverage and good temporal consistency but has fewer thermal bands and generally only provides daytime 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 clearer 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 centres. 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

WorldPop-based population mapping identified dense and vulnerable population areas. The analysis highlights that heatwave risk is highest where **high surface temperature and high population density overlap**. This shifts the interpretation from “where is it hot?” to “**where is it hot and who is exposed?**”

The final heatwave risk map identifies priority intervention areas in the urban core. A further overlay with critical infrastructure, including hospitals, schools, and community centres, helps translate the technical risk output into municipal action priorities.

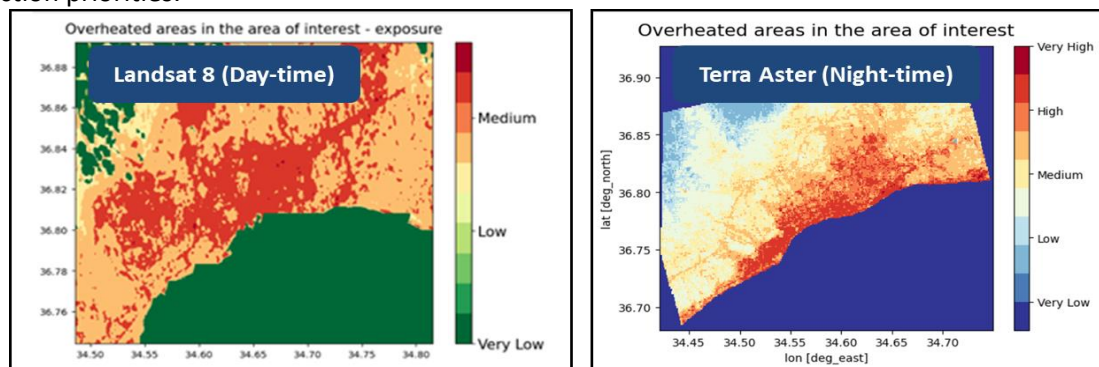


Figure 3-2 Mersin urban heat island / LST exposure map.

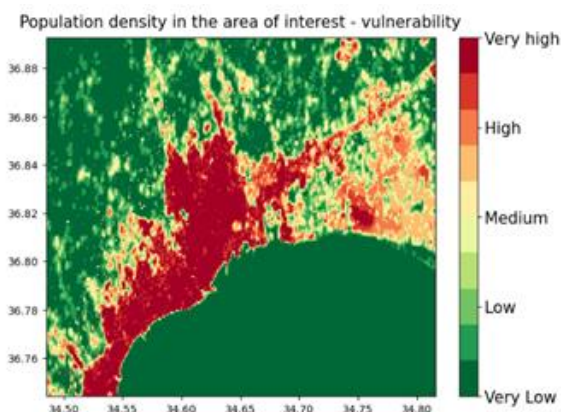


Figure 3-3 Vulnerable population density in Mersin city centre.

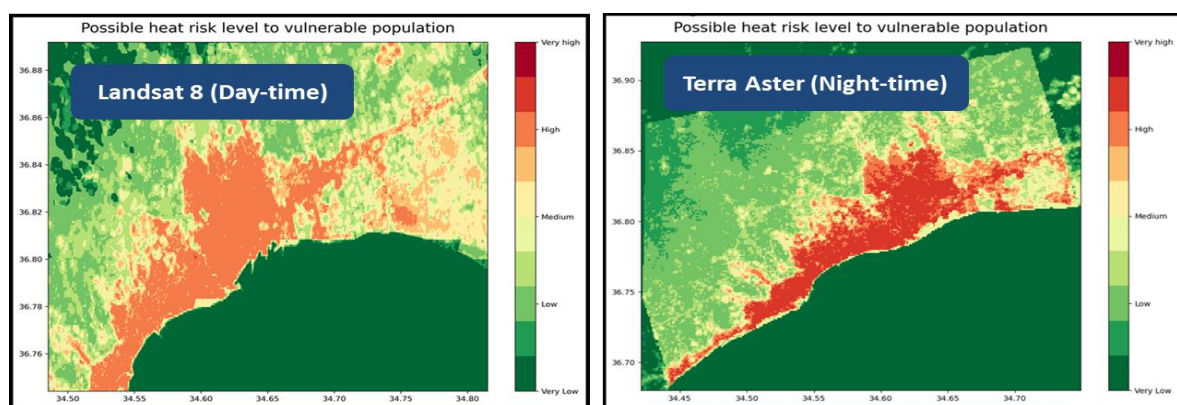


Figure 3-4 Heatwave risk map combining LST and vulnerable population density.

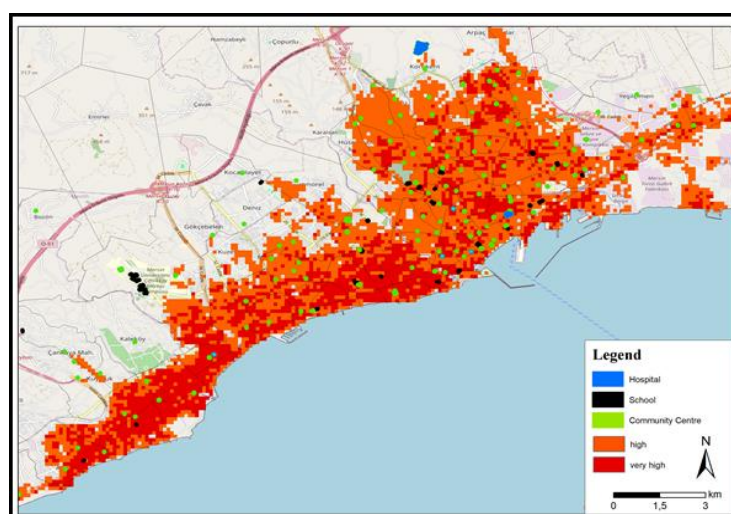


Figure 3-5 Heatwave risk and critical public services overlay.

Indirect impacts were not modelled quantitatively but were considered during the interpretation of results. These include increased energy demand for cooling, pressure on health services, reduced labour productivity during extreme heat events, and increased social support needs among vulnerable population groups.

3.2 Agricultural drought

The agricultural drought workflow was adapted for Mersin by focusing on the region's high-value crops and its dependence on irrigation. Although Mersin's relative drought risk is lower than many inland regions of Türkiye, the region has **very high evapotranspiration** and strong dependence on artificial irrigation, especially for summer crops.

Hazard Assessment

The drought hazard assessment shows that Mersin receives approximately **570 mm annual precipitation**, while evapotranspiration is much higher and projected to increase from around **1450 mm to 1510 mm by 2050**. This imbalance indicates that the region's agricultural system is highly dependent on artificial irrigation.

Table 3-5 Data overview workflow #2 – Agricultural drought

Hazard data	Vulnerability data	Exposure data	Impact metrics/Risk output
Climate data from CDS and MGM (Daily precipitation, max/min temp,	Irrigation availability from GAEZ (percentage of cropland in each grid-cell equipped with irrigation	Agricultural production areas (Lemon, banana, tomato, grape); TÜİK	Maps showing crop yield loss due to irrigation deficit, for local main crops (lemon, banana, tomato, grape) Maps showing irrigation requirements (mm) for

humidity, solar rad., wind speed), Elevation, Soil AWC, Regional Crop Coef. and growing season lengths (for banana, lemon, tomato, grape)

systems) at 11 km res. Farmers, irrigation-dependent production systems, cooperatives

2024 crop production data. Regional Crop Unit Prices. Crop production (ton) data from MapSPAM-2020, (at 5 arc-min res.)

all local main crops. BIAS adj. irrigation requirement for banana between historic (MGM 2020-24) vs proj. (MPI-RCP8.5; 2046-50) Comparison of annual precipitation, ET0, yield loss, and irrigation req.: MPI 2021-25 vs MPI 2046-50. Annual revenue and revenue losses for each main crop per grid cell based on local production data and local unit prices

The analysis also assessed soil available water capacity and showed that soil water retention is generally moderate, which further increases the importance of efficient irrigation planning.

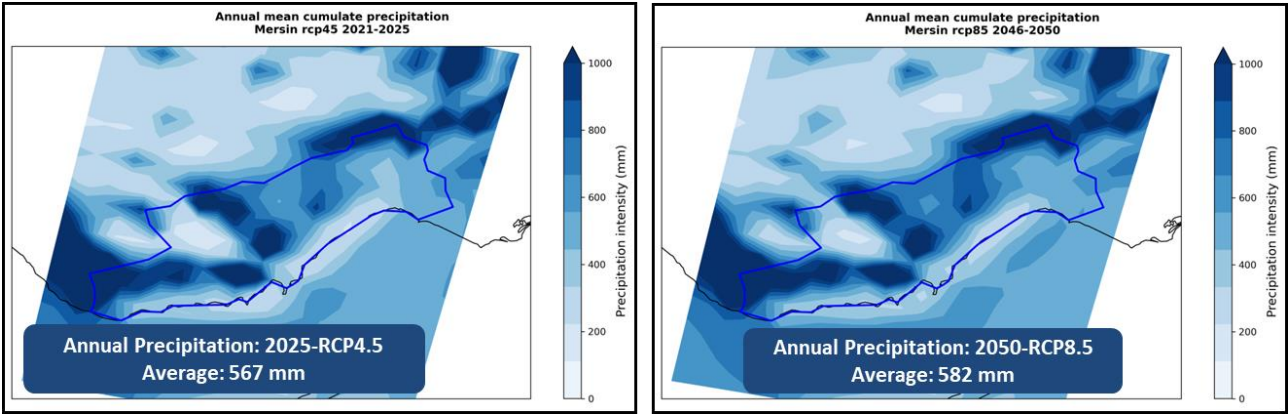


Figure 3-6 Annual precipitation maps for current and future conditions.

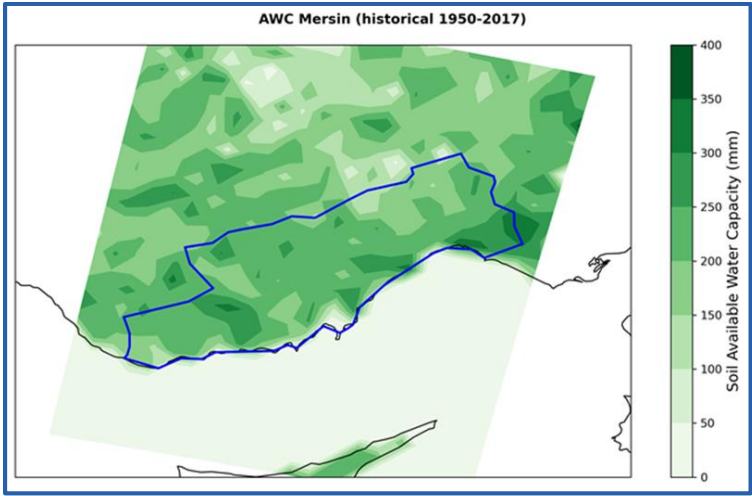


Figure 3-7 Soil available water capacity in Mersin.

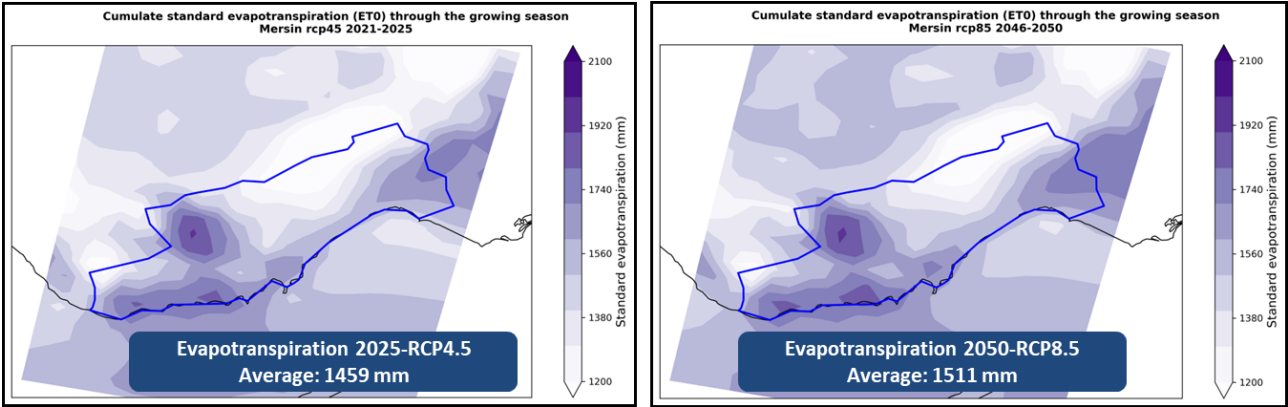


Figure 3-8 Annual evapotranspiration maps for Mersin.

The same GCM/RCM model was compared for two different temporal periods and scenarios (MPI 2021-24 RCP4.5 vs MPI 2046-50 RCP8.5). Model-to-Model comparison shows no significant change between current and future conditions at the regional level. Further detailed analysis was performed for crop (banana), location (Anamur District: lat:36.1648; lon:32.7723), effective precipitation (seasonal change rather than annual sum), and also current historical vs. BIAS-adjusted projection basis.

As shown in the table below, current conditions in Anamur—one of Türkiye’s most important banana-producing regions—have been compared with projected conditions for 2050. The analysis indicates an approximate 15% decrease in annual precipitation and 8% increase in evapotranspiration by 2050. These projected changes suggest increasing climate-related challenges for banana production in the region, particularly with regards to water availability and agricultural sustainability.

Table 3-6 Comparison of historic and BIAS adjusted 2050 projection for precipitation and ET0 in Anamur

Parameters	MGM Historic 2020-24	Model-MPI 2021-25	Model-MPI 2046-50	Bias Adj. Model-MPI 2046-50	Difference
Precipitation, mm	798	565	631	681	-14.6%
ET0-Evapotranspiration, mm	1479	1717	1781	1598	-8.0%

The agricultural drought hazard was assessed using climate projections using the EU CDS and local MGM datasets for the RCP8.5 scenario covering the temporal periods of both 2021-2025 and 2041-2045 for comparison. The regional crop coefficients for main crops of the TR622 region (**lemon, banana, tomato, and grape**) were used 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 Mersin region.

Table 3-7 Regional crop coefficients used in yield loss calculations

Crop	Clim	Kc_i n	Kc_mid	Kc_end	lgp_f1	lgp_f2	lgp_f3	lgp_f4	Sea. start	Sea. end	RD1	RD2	DF	Type	Ky
GRAPE	4	0.69	0.78	0.40	0.10	0.23	0.36	0.36	67	298	0.70	1.35	0.5	0	0.90
CITRUS	4	0.98	0.52	0.59	0.16	0.24	0.34	0.24	1	365	0.85	1.75	0.5	0	0.90
BANANA	4	0.70	1.13	1.03	0.32	0.16	0.49	0.01	1	365	0.60	1.25	0.5	0	1.15
TOMATO	4	0.41	1.10	0.75	0.21	0.21	0.38	0.17	97	236	0.45	0.80	0.5	1	1.05

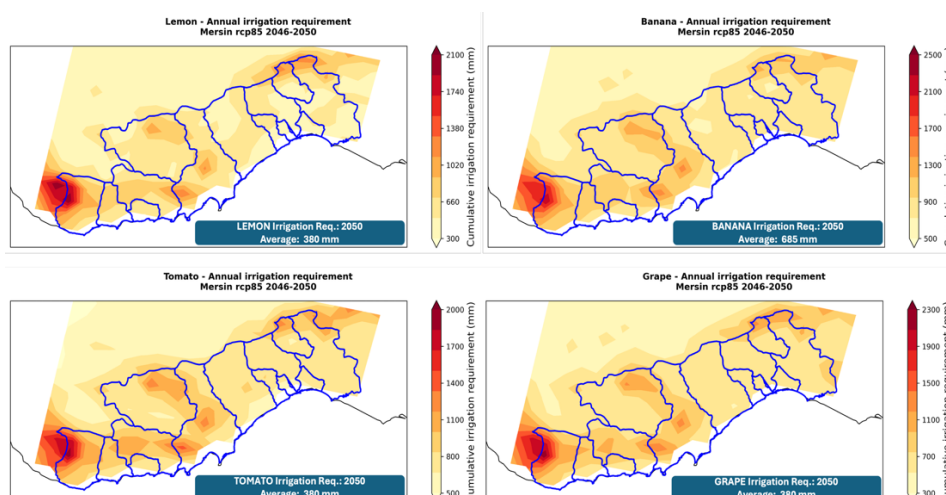


Figure 3-9 Irrigation water requirements for lemon, banana, tomato, and grape (MIP 2046-50 RCP8.5).

The change in irrigation water demand by 2050 relative to current conditions was assessed using banana production in the Anamur district as a case study. Historical climatic observations from the Turkish General Directorate of Meteorology (MGM) for the period 2020–2024 were compared with BIAS-adjusted climate projections for 2046–2050 under the RCP8.5 scenario using the MPI-ESM-LR/SMHI-RCA4 climate model combination. Crop evapotranspiration

(ETc) was calculated using banana-specific crop coefficients representative of the Anamur region, while effective precipitation was estimated from observed and projected rainfall data.

The analysis indicates that irrigation water demand for banana production in Anamur may increase from approximately 1,018 mm under current conditions to about 1,262 mm by the 2046–2050 period, corresponding to an increase of around **24%**. These results highlight the importance of efficient irrigation technologies and additional water resource investments to maintain agricultural productivity in one of Türkiye's most important banana-producing areas.

Table 3-8 Change in irrigation requirement between historical and bias adjusted 2050 Projection for Banana Production in Anamur

Parameters	2020-2024 (Historical)	2041-2050 (Projection Bias Adjusted, RCP8.5)	Difference (%)
ET ₀ , mm	1479	1598	8.0%
ET _c , mm	1443	1579	9.4%
Precipitation, mm	798	681	-14.7%
Effective precipitation, mm	638	538	-15.6%
Irrigation requirement, mm	1018	1262	24.0%

The agricultural drought hazard assessment calculated potential yield losses for four priority crops: **lemon, banana, tomato, and grape**. Under pessimistic conditions and in case of insufficient irrigation availability, potential yield losses by 2050 were estimated as: Lemon: 31%, Banana: 45%, Tomato: 46%, Grape: 39%

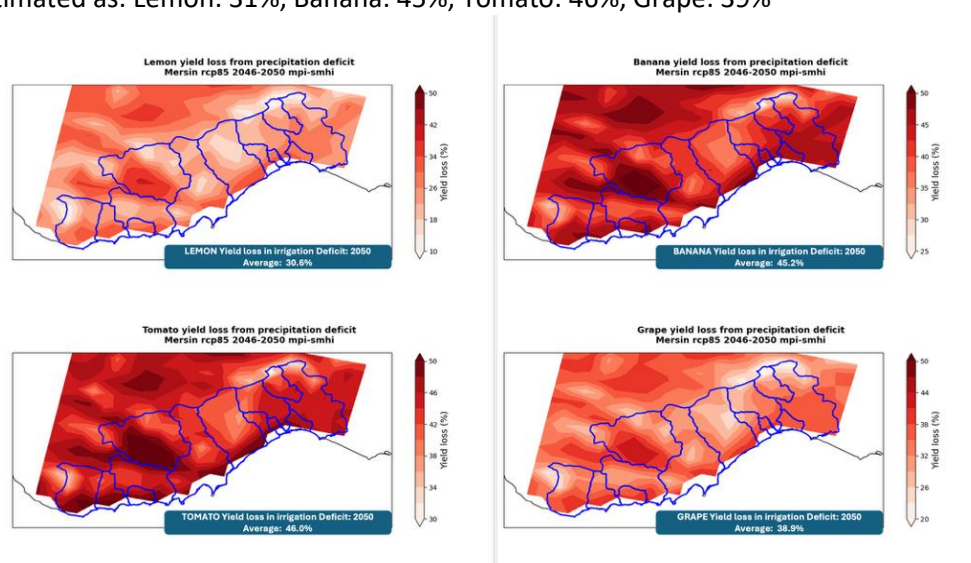


Figure 3-10 Potential yield loss in case of irrigation deficit for lemon, banana, tomato, and grape (MIP 2046-50 RCP8.5).

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 local 2024 realised productivity data from TUIK (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 accordingly.

Table 3-9 Regional unit prices of main crops used for revenue and revenue loss calculations

Crop_ID	Citrus (Lemon)	Banana	Tomato	Grape
Unit price USD per ton	1000	1000	400	500

The analysis also translated potential yield losses into economic terms. Based on 2024 TÜİK production data and producer price assumptions, the total potential income loss for these four crops could exceed **620 million USD** if irrigation resources become insufficient.

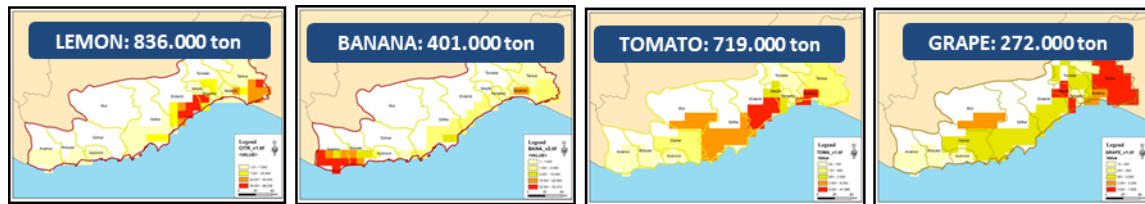


Figure 3-11 Production areas of key crops in Mersin based on TÜİK 2024 data.

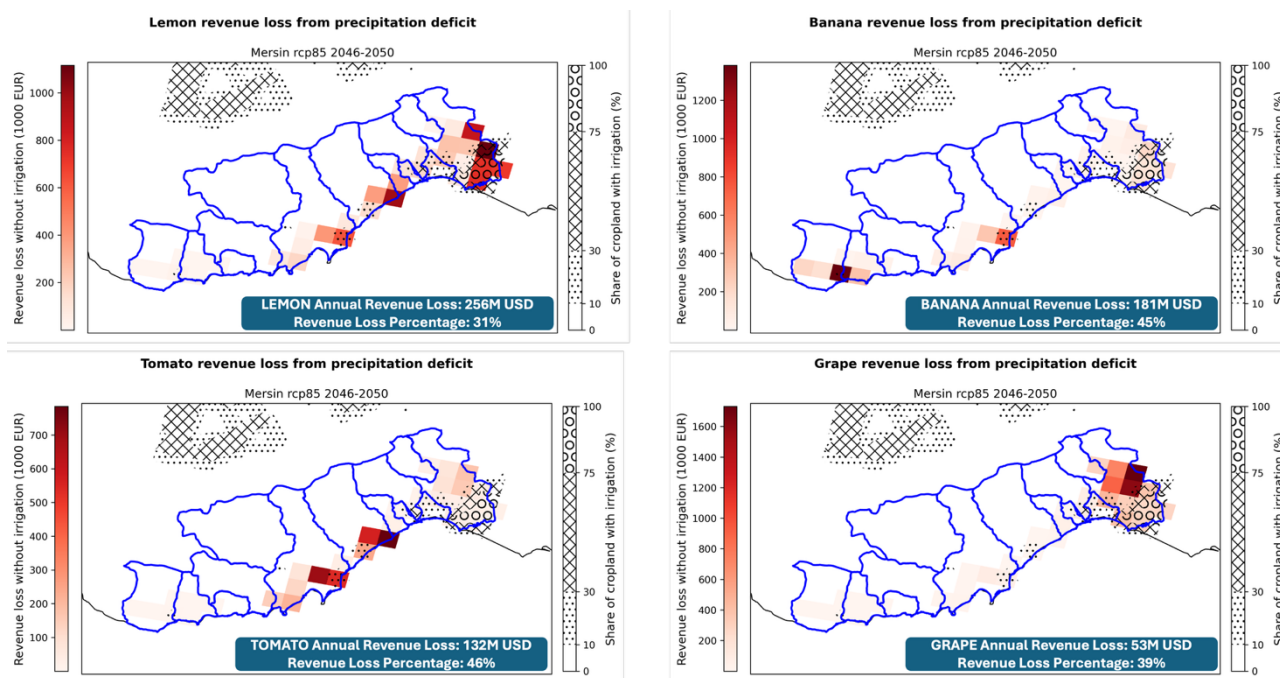


Figure 3-12 Estimated income losses under irrigation deficit conditions.

Indirect impacts include risks to farmers' incomes, food supply chains, rural livelihoods, and agricultural employment, as well as water allocation conflicts among urban, agricultural, and ecological needs.

3.3 Wildfires

The wildfire analysis used the **Fire Weather Index (FWI)** to assess meteorological fire danger. Mersin has approximately **835,000 hectares of forest area**, covering about **53% of the provincial territory**, making wildfire exposure highly relevant. Current summer FWI values regularly exceed **FWI > 40**, with some areas reaching **60–70**, especially around Gülnar and Mut.

Future climate projections indicate rising temperatures and declining precipitation across the wider Mersin-Adana region. By 2060, temperature increases of **2–3 °C** and precipitation decreases of **5–10%** are projected.

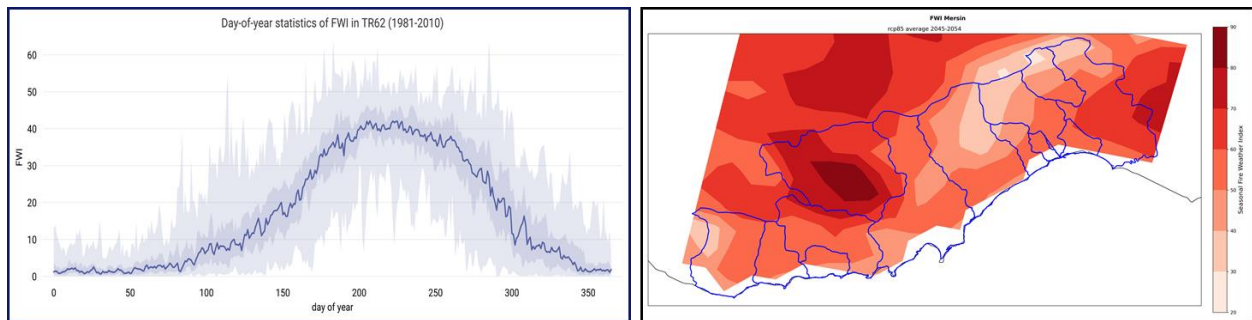


Figure 3-13 Current FWI seasonal pattern and FWI map for Mersin.

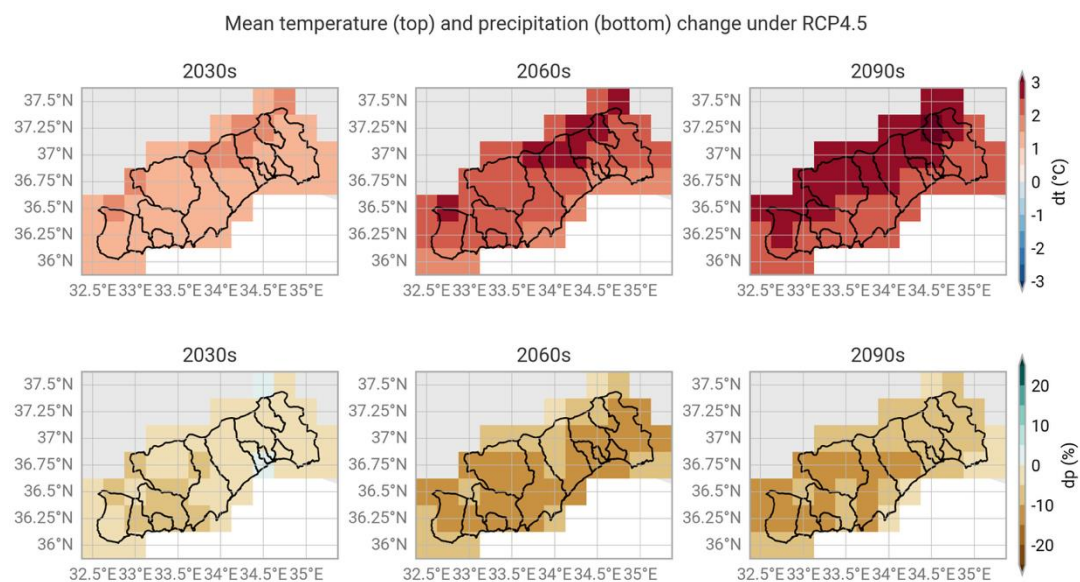


Figure 3-14 Near-mid- long-term temperature increase and precipitation decrease maps.

The number of days with **FWI > 30** may increase from approximately **125–150 days today** to nearly **200 days by 2050** in high-risk areas.

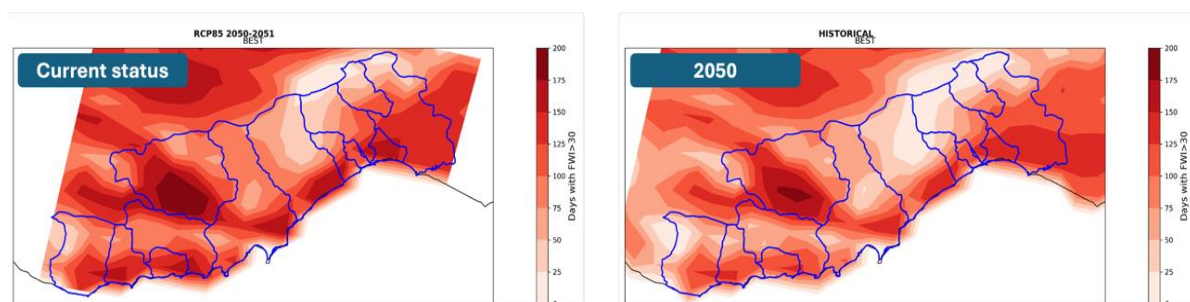


Figure 3-15 Current and 2050 number of days with FWI > 30.

Wildfire risk

Wildfire risk assessment combined both fire hazard and vulnerability components:

Hazard components:

- Fire Weather Index (FWI): Measures weather conditions that favour fire ignition and spread, including temperature, humidity, wind speed, and precipitation.
- Vegetation Density and Flammability: Areas with abundant and highly combustible vegetation provide more fuel for wildfires.

Vulnerability components:

- Wildland–Urban Interface (WUI): Zones where forests and human settlements meet are particularly vulnerable due to increased exposure of people and property to wildfire impacts.
- Population Density: Higher population concentrations increase potential human impacts and evacuation challenges.

- Protected Areas and Critical Ecosystems: Wildfires can cause significant ecological damage and biodiversity loss. [4]
 - Restoration Costs: Post-fire recovery of forests, infrastructure, and ecosystems can require substantial financial resources
- Mersin Wildfire Risk Map combining these components is shown in Figure 3-16. The results show that wildfire risk is particularly high in **Gülnar, Mut, and other forest–settlement interface areas**.

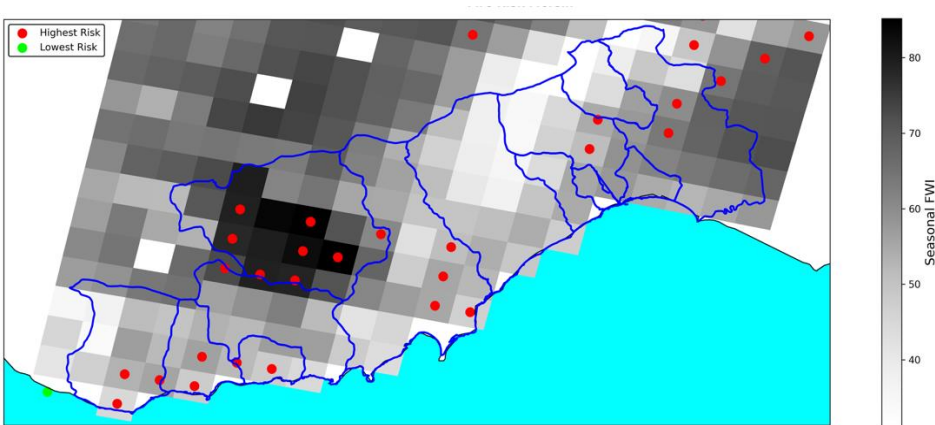


Figure 3-16 Total wildfire risk map for Mersin.

Indirect impacts include risks to settlements, ecosystems, protected areas, electricity lines, tourism assets, rural livelihoods, and emergency response capacity.

3.4 Heavy Rainfall

EURO-CORDEX precipitation projections, local (MGM) historical maximum daily precipitation data and flood-event information were used in heavy rainfall hazard and risk analysis. The rainfall risk assessment linked projected precipitation changes with local impact thresholds. Historical events in 2016, 2019, and 2020 caused casualties, building damage, transport disruption, and emergency response challenges. These events were used to define locally meaningful risk thresholds for Mersin. Based on recent damaging events, local rainfall thresholds were defined as follows:

Table 3-10 Heavy rainfall thresholds and return periods used in flood risk assessment

Return period	Maximum daily rainfall	Risk threshold
5 years	80 mm/24h	Moderate
10 years	100 mm/24h	High
25 years	130 mm/24h	Very High
50 years	180 mm/24h	Catastrophic

The analysis showed that rainfall events currently around **100 mm/24h** may increase by **20–30%** during 2041–2070, reaching **120–130 mm/24h** in some areas. This means that events currently associated with very high risk may occur more frequently in future climate conditions.

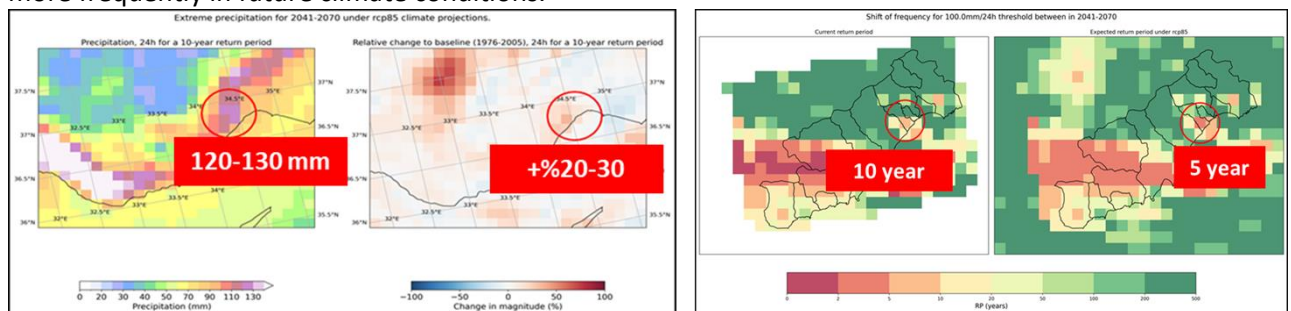


Figure 3-17 Projected change in 24-hour heavy rainfall intensity and return period.

The analysis indicates that the **100 mm/24h high-risk threshold**, currently associated with approximately a 10-year return period in Mersin city centre, may occur around every 5 years in the future. In some districts, such as Erdemli, Silifke, Gülnar, and Mut, this threshold is already reached more frequently. Indirect impacts include disruption to transport, damage to buildings and basements, pressure on drainage infrastructure, risk to emergency services, and cascading effects on port/logistics operations.

Dataset limitations

The main limitations of the Phase 2 datasets are:

- EURO-CORDEX spatial resolution is useful for regional analysis but limited for micro-scale urban planning.
- LST is not the same as air temperature and depends on satellite pass time and cloud conditions.
- Health data, morbidity indicators, and emergency service records were not yet integrated quantitatively.
- Socio-economic futures were not modelled through full SSP scenarios.
- Agricultural loss estimates depend on assumptions regarding future irrigation availability and producer prices.
- Flood risk was assessed through rainfall thresholds and historical impacts; detailed hydrodynamic modelling was outside the scope of Phase 2.

Despite these limitations, the Phase 2 regionalized analyses provide a substantially improved evidence base for Mersin by connecting climate hazards with **local exposure, vulnerability, economic impacts, and municipal adaptation priorities**.



4 Conclusions

Phase 2 resulted in the development of a localized and multi-risk Climate Risk Assessment (CRA) framework for MMM by integrating climate projections, satellite analyses, local datasets, stakeholder feedback, and sector-specific interpretation processes. Compared to Phase 1,

Phase 2 has expanded and deepened in terms of regional data, and new assessment methods. In this context, the main innovations of Phase 2 and the significant outcomes are as follow:

- Based on EURO-CORDEX climate projections and the EuroHEAT Workflow, the annual number of heatwave days is projected to increase from approximately 18 days per year at present to around 44 days per year by 2050 under RCP8.5 conditions
- New data processing methodology for night-time Land Surface Temperature by the Terra Aster satellite instead of Landsat 8 was developed. Terra Aster LST maps provided better visualization of the Urban Heat Island effect. By means of more clear heatwave risk map, highly heatwave-exposed and vulnerable neighbourhoods were identified.
- We have integrated “region-specific crop coefficient”, local “Crop_UnitPrices.csv” (instead of the average GAEZ aggregated value) and up-to-date local crop productivity data (instead of more generic mapSPAM data)
- Under pessimistic conditions and in case of insufficient irrigation availability, potential yield losses by 2050 were estimated as: Lemon: 31%, Banana: 45%, Tomato: 46%, Grape: 39%. Based on 2024 TÜİK production data and producer price assumptions, the total potential income loss for these four crops could exceed 620 million USD if irrigation resources become insufficient.
- Computation and visualisation of irrigation water requirements for main crops were also carried out. Artificial irrigation requirement for banana production in Anamur between current (2020-2024 realised) and BIAS Adjusted-future projection (2046-2050 RCP8.5) were computed. The analysis indicates that irrigation water demand for banana production in Anamur may increase from approximately 1,018 mm under current conditions to about 1,262 mm by the 2046–2050 period, corresponding to an increase of around 24%. These results highlight the importance of efficient irrigation technologies and additional water resource investments to maintain agricultural productivity in one of Türkiye's most important banana-producing areas.
- Heavy rainfall workflow showed that rainfall events as high risk threshold of 100 mm/24h may increase by 20–30% by 2041–2070, reaching 120–130 mm/24h in some areas. This means that events currently associated with very high risk may occur more frequently in future climate conditions. At the same time, return period of 100 mm of high risk threshold will decrease from 10 years to 5 years.
- Mersin has approximately 835,000 hectares of forest area, covering about 53% of the provincial territory, making wildfire exposure highly relevant. Current summer FWI values regularly exceed FWI > 40 (extremely dangerous), even some areas reaching 60–70. Current situation is so dangerous. Moreover, the number of days with FWI > 30 will increase from 125–150 days to nearly 200 days by 2050 in high-risk areas especially around Gülnar and Mut districts.

The analyses confirmed that climate risks in Mersin are spatially differentiated and closely linked to urban density, agricultural dependency, water stress, forest ecosystems, and vulnerable population groups. The results showed that:

- urban heat risks are concentrated in densely built-up coastal districts,
- agricultural drought risks are particularly significant in irrigation-dependent production areas,

- wildfire risks are increasing in forest–settlement interface zones,
- and heavy rainfall events continue to create localized flood risks in urban areas.

One of the most important outcomes of Phase 2 was the integration of multiple workflows into a common risk interpretation framework. The use of satellite-derived urban heat island analyses, climate projections, agricultural vulnerability indicators, wildfire risk mapping, and stakeholder-informed prioritization processes enabled a more comprehensive understanding of climate risks across different sectors and systems.

Stakeholder participation significantly strengthened the assessment's local relevance. The workshop held on 14 April 2026, Menti surveys, thematic discussions, and follow-up expert group meetings helped validate the findings through local knowledge and institutional experience. The discussions showed that heatwaves, drought, and water scarcity are perceived as the highest-priority climate risks for Mersin, while institutional coordination, financing, and implementation capacity remain important challenges.

Important progress was also achieved regarding institutional learning and capacity building. SECAP and greenhouse gas inventory training sessions organized for municipal staff during Phase 2 helped improve technical awareness of climate governance, emissions accounting, and adaptation planning processes within the municipality.

The main challenges encountered during Phase 2 included:

- integrating multiple datasets and workflows within a limited timeframe,
- harmonizing different spatial and sectoral datasets,
- limited availability of some local datasets,
- and translating technically complex outputs into practical and stakeholder-oriented information.

Although significant progress was achieved, some areas could not be fully addressed within the scope of Phase 2.

These include:

- heatwave-related illness and hospitalization records
- detailed hydrodynamic flood modelling,
- higher-resolution socio-economic and health vulnerability analyses,
- advanced infrastructure vulnerability modelling,
- and institutionalized inter-agency data-sharing mechanisms.

These aspects may be further developed in Phase 3 and future resilience-oriented projects.

Overall, Phase 2 established a strong evidence-based foundation for Climate Risk Management (CRM) in Mersin. The outputs generated during the process improved institutional understanding of climate risks, strengthened stakeholder engagement, and created a practical basis for future adaptation measures, resilience investments, and climate governance processes within MMM.

References

- Baccini, M., Biggeri, A., Accetta, G., Kosatsky, T., Katsouyanni, K., Analitis, A., Anderson, H. R., Bisanti, L., D'Ippoliti, D., Danova, J., Forsberg, B., Medina, S., Paldy, A., Rabchenko, D., Schindler, C., and Michelozzi, P.: Heat effects on mortality in 15 European cities, <https://doi.org/10.1093/ije/dyn086>, 2008
- Buskop, F., Sperna Weiland, F., and van den Hurk, B.: Amplifying Exploration of Regional Climate Risks: Clustering Future Projections on Regionally Relevant Impact Drivers Not Emission Scenarios, <https://doi.org/10.1088/2752-5295/ad9f8f>, 2024
- Dosio, A., Panitz, H., Schubert-Frisius, M., and Lüthi, D.: Dynamical downscaling of CMIP5 global circulation models over CORDEX-Africa with COSMO-CLM: evaluation over the present climate and analysis of the added value, <https://doi.org/10.1007/s00382-014-2262-x>, 2015
- Intergovernmental Panel on Climate Change (IPCC): Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, <https://www.ipcc.ch/report/ar6/syr/>, 2023
- Mesta, B., Kentel, E., Sasaki, H., and Nakaegawa, T.: Changes in surface air temperature for Mediterranean climate in Turkey, <https://doi.org/10.209/atm.53404>, 2025
- Mersin Metropolitan Municipality: Sustainable Energy and Climate Action Plan (SECAP), Mersin, Türkiye, 2024
- Oh, J., Kim, E., Kwag, Y., An, H., Kim, H., Shah, S., Lee, J., and Ha, E.: Heat wave exposure and increased heat-related hospitalizations in young children in South Korea: A time-series study, <https://doi.org/10.1016/j.envres.2023.117561>, 2023
- WorldPop: Open spatial demographic datasets and population projections, <https://www.worldpop.org/>, accessed 2026
- Xu, Z., Sheffield, P., Su, H., Wang, X., Bi, Y., and Tong, S.: The impact of heat waves on children's health: a systematic review, <https://doi.org/10.1007/s00484-013-0655-x>, 2014
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- https://www.medecc.org/wp-content/uploads/2021/11/MedECC_MAR1_SPM_TR.pdf
- <https://www.worldpop.org/>
- <https://zenodo.org/>
- AA. (2014). Anadolu Agency. "Doğu Akdeniz'in incisi" Mersin havadan görüntülendi. Retrieved from: <https://www.aa.com.tr/tr/pg/foto-galeri/quot-dogu-akdenizin-incisiquot-mersin-havadan-goruntulendi/0#!>.
- AFAD. (2014). Kritik Altyapıların Korunması Yol Haritası Belgesi 2014-2023. Disaster and Emergency Management Presidency.
- AFAD. (2021). Mersin İl Afet Risk Azaltma Planı. <https://mersin.afad.gov.tr/kurumlar/mersin.afad/Diger/IRAP/IRAP-MERSIN.pdf>: Provincial Directorate of Disaster and Emergency Management Presidency.
- BEPA. (2022). Türkiye Biyokütle Enerjisi Potansiyeli Atlası. Ministry of Energy and Natural Resources. Retrieved from: <https://bepa.enerji.gov.tr/>
- Bertoldi P. (2018). Guidebook 'How to develop a Sustainable Energy and Climate Action Plan (SECAP)'. Luxembourg, 2018, ISBN 978-92-79-96929-4, JRC112986.: Publications Office of the European Union.
- BF. (2023, September). Blue Flag Beaches-Mersin. Blue Flag Türkiye. Retrieved from: <http://www.mavibayrak.org.tr/en>

BUGEM. (2022). Türkiye Tarım Havzaları Üretim ve Destekleme Modeli Kapsamında Desteklenen Ürünler. Ministry of Agriculture and Forestry, General Directorate of Plant Production. Retrieved from: <https://www.tarimorman.gov.tr/BUGEM>

CA. (2021). Climate Adapt. Retrieved from: <https://climate-adapt.eea.europa.eu/>

Climate ADAPT. (2022). The Adaptation Support Tool. Climate ADAPT Sharing Adaptation Information Across Europe. Retrieved from: <https://climate-adapt.eea.europa.eu/knowledge/tools/adaptation-support-tool>

CORINE. (2018). Coordination of Information on the Environment - Çevresel Bilginin Koordinasyonu. Retrieved from: <https://land.copernicus.eu/pan-european/corine-land-cover>

CW. (2019). Historical GHG Emissions. Climate Watch. Retrieved from: https://www.climatewatchdata.org/ghg-emissions?end_year=2018&start_year=1990

Demirsoy, G., Sözen, A. (2021). Binalarda enerji verimliliğinin toplam faktör etkinliği. Journal of Polytechnic. Retrieved from: <https://dergipark.org.tr/en/download/article-file/1602434>.

EIGM. (2022). General Directorate of Energy Affairs. National Energy Balance Tables. Retrieved from: <https://enerji.gov.tr/eigm-raporlari>

EMRA_a. (2022). Yıllık Sektör Raporları. Energy Market Regulatory Authority. Retrieved from: <https://www.epdk.gov.tr/Detay/Icerik/3-0-24/elektrikiyillik-sektor-raporu>

EMRA_b. (2022). Elektrik Piyasası Üretim Lisansları. Energy Market Regulatory Authority. Retrieved from: <http://lisans.epdk.gov.tr/epvys-web/faces/pages/lisans/elektrikUretim/elektrikUretimOzetSorgula.xhtml>

ESWD. (2023, 08 21). European Severe Weather Database. Retrieved from: https://eswd.eu/cgi-bin/eswd.cgi?&lang=tr_25

GCoM. (2022). Global Covenant of Mayors for Climate & Energy. Retrieved from: <https://www.globalcovenantofmayors.org/>

GEPA. (2022). Türkiye Güneş Enerjisi Potansiyel Atlası. Ministry of Energy and Natural Resources, General Directorate of Renewable Energy. Retrieved from: <https://gepa.enerji.gov.tr/MyCalculator/>

GGMCF. (2021). Carbon Footprints of World Cities. (Global Gridded Model of Carbon Footprints). Retrieved from: <https://citycarbonfootprints.info/>

GM. (2022). Governors of Mersin. Retrieved from: <http://www.mersin.gov.tr/>

GPC. (2014). Global Protocol for Community-Scale Greenhouse Gas Emission Inventories, Accounting and Reporting Standard for Cities. WRI, C40, ICLEI.

ICLEI. (2021). Local Governments for Sustainability. Retrieved from: <https://iclei.org/en/Home.html>

IPCC. (2020). The concept of risk in the IPCC Sixth Assessment Report: a summary of cross Working Group discussions. Intergovernmental Panel on Climate Change.

IPCC. (2021). Climate Change 2021 The Physical Science Basis Summary for Policymakers-Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Switzerland: Intergovernmental Panel on Climate Change.

MGM. (2022). Turkish State Meteorological Service. Retrieved from: <https://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?k=A>

MGM. (2022). Resmi İstatistikler. T.C. Meteoroloji Genel Müdürlüğü. Retrieved from: <https://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?k=A>

MGM_b. (2021). Meteoroloji Genel Müdürlüğü. Retrieved from: <https://www.mgm.gov.tr/FILES/genel/raporlar/kuraklilprojeksiyon.pdf>

MİKTB. (2023). UNESCO Dünya Mirası Geçici Listesi'ne Giren Mersin'de ki Kültür Varlıkları. Retrieved from: <https://mersin.ktb.gov.tr/#>: Mersin Provincial Directorate of Culture and Tourism.

MİTOM. (2023). Ministry of Food, Agriculture and Livestock, Directorate of Provincial Agriculture and Livestock. Retrieved from: <https://mersin.tarimorman.gov.tr/>

MMM. (2023). Mersin Metropolitan Municipality. Retrieved from: <https://www.mersin.bel.tr/>

MoAF. (2019). Doğu Akdeniz Havzası Taşkın Yönetim Planı. Ministry of Agriculture and Forestry.

MoCT. (2023). Turizm İstatistikleri. Ministry of Culture and Tourism. Retrieved from: <https://yigm.ktb.gov.tr/TR-9851/turizm-istatistikleri.html>

MoEU. (2015). Türkiye Cumhuriyeti Niye Edilen Ulusal Olarak Belirlenmiş Katkı. Ankara: Former Ministry of Environment and Urbanization.

MoEUCC. (2020). Türkiye'de İklim Değişikliğine Uyum Eyleminin Güçlendirilmesi Projesi - İklim Projeksiyonlarının Analizleri ve Değerlendirilmesi Raporu. Ankara: T.C. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı / Ministry of Environment, Urbanization and Climate Change.

MoEUCC. (2021). İklim Değişikliği. Ministry of Environment, Urbanisation and Climate Change. Retrieved from: <https://iklim.csb.gov.tr/>

MoEUCC, TUBİTAK MAM. (2022). Denizlerde Bütünleşik Kirlilik Programı 2020-2022: 2022 Akdeniz Sonuç Raporu. Kocaeli: TÜBİTAK-MAM Matbaası.

MoEUCC_b. (2020). Yerel İklim Değişikliğine Uyum Rehberi. Türkiye'de İklim Değişikliğine Uyum Eyleminin Güçlendirilmesi Projesi, Birleşmiş Milletler Kalkınma Programı.

MoIT. (2021). Mersin İl Sanayi Durum Raporu. Ministry of Industry and Technology.

MoSİT. (2015). İklim Değişikliği ve Sanayi. Former Ministry of Science, Industry and Technology.

MoTI_a. (2023). Ulaşımda ve Erişimde 2002-2023-Mersin. Ministry of Transport and Infrastructure.

MoTI_b. (2023). Denizcilik İstatistikleri. Ministry of Transport and Infrastructure. Retrieved from: <https://denizcilikistatistikleri.uab.gov.tr/gemi-istatistikleri>

MPGM. (2017). Mersin – Adana Planlama Bölgesi 1/100.000 Ölçekli Çevre Düzeni Planı Revizyonu. Former Ministry of Environment and Urbanization General Directorate of Spatial Planning.

MTHEP. (2020). Mersin İli Temiz Hava Eylem Planı. Mersin: Mersin Provincial Directorate of Environment, Urbanisation and Climate Change. Retrieved from: https://webdosya.csb.gov.tr/db/mersin/menu/thep-mersin-2020_20200214100908.pdf

MTSO. (2022). 2021 Mersin Ekonomik Raporu. Mersin Chamber of Commerce and Industry. Retrieved from: <https://www.mtso.org.tr/tr/a/2021-mersin-ekonomik-raporu>

NASA. (2023). Global Climate Change- Vital Signs of the Planet. Retrieved from: <https://climate.nasa.gov/vital-signs/global-temperature/>

- Papatya, G., & Mehmet Nedim, U. (2019). Stratejik Karar Verme Sürecini Etkileyen Faktörler: Uluslararası Taşımacılık Sektörü İşletmelerinde Bir Araştırma. *Kafkas Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi-KAÜİİBFD*, 338-358.
- PDEUCC. (2022). Mersin İli Çevre Durum Raporları. Mersin: Mersin Governorship Provincial Directorate of Environment, Urbanization and Climate Change.
- REPA. (2022). Türkiye Rüzgar Enerjisi Potansiyeli. General Directorate of Energy Affairs. Retrieved from: <https://repa.enerji.gov.tr/REPA/>
- Steadman RG. (1984). A universal scale of apparent temperature. *Journal of Climate Applied Meteorology*, s. 23:1674–1687.
- SYGM. (2016). İklim Değişikliğinin Su Kaynaklarına Etkisi Projesi, Proje Nihai Raporu. Ankara: Former Ministry of Forestry and Water Affairs, General Directorate of Water Management.
- TCDD. (2021). 2017-2021 İstatistik Yıllığı. General Directorate of Turkish State Railways.
- TurkPatent. (2023, May). Türkiye'nin Coğrafi İşaretleri. Turkish Patent and Trademark Office. Retrieved from: <https://ci.turkpatent.gov.tr/anasayfa>
- TurkStat. (2021). Turkish Statistical Institute. Central Distribution System. Retrieved from: <https://biruni.tuik.gov.tr/medas/>
- TurkStat. (2023). Turkish Statistical Institute. Central Distribution System. Retrieved from: <https://biruni.tuik.gov.tr/medas/>
- UN. (2021). Cities and Pollution. (United Nations). Retrieved from: <https://www.un.org/en/climatechange/climate-solutions/cities-pollution>
- Unal, Y., Tan, E., Montes, S.S. (2013). Summer heat waves over western Turkey between 1965 and 2006. *Theory of Applied Climatology*, s. 112:339–350.
- UNCTAD. (2019). Why the transport sector needs to adapt to climate change. United Nations Conference on Trade and Development. Retrieved from: <https://unctad.org/news/why-transport-sector-needs-adapt-climate-change>
- UNFCCC. (1992). United Nations Framework Convention on Climate Change. Rio de Janeiro.
- UNFCCC. (2015). Paris Agreement. United Nations Framework Convention on Climate Change.
- WB. (2019). World Development Indicators-Population, total-Population, total. The World Bank. Retrieved from: <https://data.worldbank.org/indicator/SP.POP.TOTL?end=2019&start=1960>.