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Deliverable Phase 1 – Climate Risk Assessment

AGROSHIELD - Agricultural Risk Assessment and Resilience Strategies against Drought in the Southern Marmara Basin

Project

Marmara Municipalities Union

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Document Information

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Abbreviations and acronyms

Abbreviation / acronym	Description
AFAD	Disaster and Emergency Management Presidency
AGROSHIELD	Agricultural Drought Risk Assessment and Resilience Strategies against Drought in the Southern Marmara Basin
AWD	Alternate Wetting and Drying (Irrigation Technique)
BASIN	Basin (Referring to Sub-Basin and River-Basin)
CAAP	Community Adaptation Action Plan
CLIMAAX	Climate Risk Assessment Methodology
CRA	Climate Risk Assessment
DSI	General Directorate of State Hydraulic Works
GDP	Gross Domestic Product
GIS	Geographic Information Systems
MMU	Marmara Municipalities Union
NGO	Non-Governmental Organization
OIZ	Organized Industrial Zones
R&D	Research and Development
RCP	Representative Concentration Pathway (Used in Climate Projections)
RCP 4.5	Medium Emission Scenario (Representative Concentration Pathway 4.5)
RCP 8.5	High Emission Scenario (Representative Concentration Pathway 8.5)
SMA	Soil Moisture Anomalies
SPI	Standard Precipitation Index
TAMP	Türkiye Disaster Response Plan
TARSİM	Turkish Agricultural Insurance Pool
TİGEM	Turkish State Agricultural Enterprises
TÜBİTAK	The Scientific and Technological Research Council of Turkey
TÜBİTAK MAM	The Scientific and Technological Research Council of Turkey Marmara Research Center
WEI	Water Use Index

Executive summary

The **AGROSHIELD Project** is an initiative aimed at enhancing the resilience of the agriculture sector in the Southern Marmara Basin, focusing on mitigating agricultural drought risks. The project follows the **CLIMAAX Methodology** to provide a high-resolution climate risk assessment that will inform local adaptation strategies for the boroughs of İznik, Gemlik, Karamürsel, and Gönen. This deliverable provides the findings from Phase 1, which focuses on agricultural drought risk analysis, local vulnerability mapping, and scenario-based future projections.

Main Actions and Results

- **Risk Assessment**: The assessment focused on agricultural drought as the most critical climate hazard, utilizing climate data and agricultural vulnerability metrics. It revealed that the region faces significant exposure to drought, exacerbated by insufficient irrigation infrastructure, high crop water dependencies, and increasing water demand from both agriculture and industry.
- **Severity of Drought Risks**: Key preliminary findings indicate that the Southern Marmara Basin is highly vulnerable to agricultural drought, particularly in the target boroughs. Drought impacts are projected to intensify by 2060, with some regions experiencing severe yield losses in crops such as maize, rice, tomatoes, and olives.
    - **Severity**: The severity of the risk is evident in the significant decline of crop yields and the economic consequences for farmers. Vulnerability differs across regions, with **Gönen** and **Karamürsel** identified as the most susceptible.
    - **Urgency**: Immediate action is required to address these risks, including the modernization of irrigation systems, promoting drought-resistant crop varieties, and establishing early warning systems for better risk management.
- **Vulnerability of Specific Crops**: The specific crops analyzed in this assessment were chosen to ensure the study is highly relevant to the local context of the Southern Marmara Basin. For each target borough—İznik, Gemlik, Karamürsel, and Gönen—the four most produced crops were selected. This method ensures the findings directly reflect the region's actual agricultural patterns and provides a detailed, practical basis for assessing yield and revenue loss projections.

    - **Maize**: Maize, which has a deep root system and high-water demand, is particularly vulnerable to agricultural drought, especially during critical growth periods such as tasseling and silking. Under **Scenario RCP 4.5**, maize is expected to face **medium-high** risk, with heatwaves and drought reducing pollination and kernel set. Under **Scenario RCP 8.5**, the risk increases to **high**, threatening maize yields severely in drought-prone areas like **Gönen** and **Karamürsel**. Adaptation strategies like frequent light irrigation and early maturing hybrid varieties are critical for maize resilience.
    - **Paddy Rice**: Paddy rice is extremely sensitive to drought due to its shallow root system and high-water requirements. Under **Scenario RCP 4.5**, it faces a **medium-high** risk, particularly in **Gönen** where rice farming is common. In the **RCP 8.5** scenario, prolonged dry spells could lead to **high** risk, with irrigation failures severely impacting yields. Adaptation measures include introducing Alternate Wetting and Drying (AWD) techniques and promoting short-season cultivars to minimize water usage.
    - **Tomato**: Tomatoes are moderately sensitive to drought due to their deep roots and high-water demand. **Scenario RCP 4.5** indicates a **moderate** risk for tomatoes, with proper irrigation management mitigating yield losses. However, under **Scenario RCP 8.5**, heat stress could disrupt fruit set, especially during extreme temperature events, resulting in **moderate** yield losses. Strategies like using shade nets, nighttime irrigation, and regulated deficit irrigation can help mitigate these impacts.

- **Watermelon**: Watermelon is somewhat resistant to drought, but its water demand is still significant. Under **RCP 4.5**, watermelon faces a **low-moderate** risk, with some water shortages during dry periods. Under **RCP 8.5**, the risk increases to **moderate** as extended dry spells deplete deeper soil layers, making it harder for the crop to access water. Mitigation efforts like early sowing, drip irrigation, and mulching will help maintain yield stability.
- **Olives**: Olives are relatively drought-resistant due to their deep roots and lower water demand compared to other crops. Under **RCP 4.5**, olives face a **low-moderate** risk, but under **RCP 8.5**, they are more vulnerable to heatwaves during flowering, which could reduce fruit set. The olive tree's resilience is a key advantage in the region, but it still requires adequate water management to avoid long-term yield declines.
- **Peach**: Peaches are highly sensitive to drought due to their moderate root depth and high-water demand. In **RCP 4.5**, the risk is **moderate**, but under **RCP 8.5**, the risk escalates to **high**, as water stress causes severe yield loss. The key adaptation strategies include adopting drought-resistant varieties, optimizing irrigation schedules, and using water-efficient practices.
- **Walnut**: Walnuts, with their deep roots and high-water demand, are also at significant risk. **RCP 4.5** forecasts a **moderate-high** risk for walnuts, while **RCP 8.5** raises the risk to **high**, particularly during the summer months when drought stress and heatwaves lead to quality losses. Enhancing irrigation infrastructure and optimizing water use for walnuts will be crucial for maintaining yields.
- **Cherry and Fig**: Both crops are moderately sensitive to drought. Under **RCP 4.5**, they face **moderate** risk, but in **RCP 8.5**, the risk increases to **high** because of heatwaves on flowering and fruit set. Improved irrigation techniques and selection of heat-tolerant varieties can mitigate the risk.

Conclusions

- The Southern Marmara Basin faces a growing threat from agricultural drought, which risks economic stability, food security, and rural livelihoods. Immediate and medium-term interventions are necessary to safeguard the region’s agricultural future.
- The findings of this project will contribute significantly to the **Marmara Basin Drought Management Plan** by providing localized, actionable data to inform regional and national climate adaptation strategies.
- Successful implementation of these strategies will require strong cooperation between local municipalities, farmers, and regional stakeholders, aligning efforts to secure water resources and enhance agricultural sustainability in the face of changing climate conditions.

1 Introduction

1.1 Background

The Marmara Basin is in the Mediterranean climate zone, where Türkiye is experiencing the most severe adverse effects of global climate change. Therefore, the Marmara Basin is at high risk in terms of water resources and agricultural production. According to climate projections, the region's current transitional climate is showing a significant shift toward hot and dry conditions. Expectations are for an increase in average temperatures, a decrease in total precipitation, and irregular precipitation patterns, paving the way for more frequent and intense prolonged dry periods.

The most tangible consequence of these climatic changes is the increasing pressure on the basin's hydrological balance. The MPI RCP 8.5 climate projection, considered a worst-case scenario, projects significant declines in both surface water potential (SWP) and groundwater recharge (GWP) by the end of the 21st century.(Republic of Türkiye Ministry of Agriculture and Forestry, General Directorate of Water Management], 2023)[1] This poses a serious threat to the basin's total usable water potential, which currently stands at approximately 4,893.74 hm

A significant increase in the frequency and severity of hydrological droughts is expected, particularly after 2060. This increase is expected to be most pronounced in sub-basins with concentrated agricultural production, such as the Gönen River in the southern parts of the basin. The agricultural sector in the Marmara Basin is grappling not only with the direct effects of climate change—decreased precipitation and rising temperatures—but also with the indirect effects. The region's intense industrialization and rapid urbanization are leading to a steady increase in demand for drinking and industrial water. While climate projections indicate a decrease in water supply, demographic and economic data suggest that water demand will increase. (RTMAF-GDWM, 2023)

Although the Marmara Basin hosts Türkiye's most densely populated industrial and population centers, it is also one of the country's most important agricultural production regions. Provinces such as Balıkesir (Gönen), Bursa (İznik, Gemlik), and Çanakkale play a key role in the national food supply. The basin's total agricultural area is 565,665 hectares, and the crops grown in these areas are of great importance to the national economy. (RTMAF-GDWM, 2023) This high dependence of agricultural production on water makes the region inherently vulnerable to droughts caused by climate change. Increased evaporation and decreased precipitation in summer increase irrigation water requirements, placing additional pressure on already dwindling water resources. This situation poses a strategic risk that directly threatens not only farmers' incomes but also regional food security and economic stability.

Analyzing agricultural drought risk requires a sub-basin-scale approach that goes beyond basin-wide assessments and understands local dynamics and differences. The Gönen district, focused on in this report, is located in the Gönen Stream Sub-basin; the Karamürsel and Gemlik districts are located in the Strait Sub-basin; and the İznik district is located in the İznik Lake Sub-basin. The sectoral vulnerability analysis conducted within the scope of the "Marmara Basin Drought Management Plan" prepared by the Ministry of Agriculture and Forestry reveals current and future drought risks for the agricultural sector of these sub-basins. Table 1-1 summarizes the results of this analysis.

Table 1-1: Drought Vulnerability Degrees of the Agricultural Sector of the Focal Sub-basins (Current and Future Projections)

Sub-Basin	Curent situation	2025-2049 Projection	2060-2074 Projection	2075-2099 Projection
Gönen Stream Sub-Basin	2 (Medium)	2 (Medium)	1 (Low)	3 (High)
Gulf Sub-Basin	4 (Very High)	4 (Very High)	1 (Low)	2 (Medium)
Lake Iznik Sub-Basin	1 (Low)	3 (High)	1 (Low)	2 (Medium)

Note: Vulnerability ratings range from 1 (Low) to 4 (Very High).
Source: 1

The data in Table 1-1 demonstrates significant differences in vulnerability among sub-basins. The Gulf Sub-basin stands out as the most vulnerable region, with a "Very High" vulnerability rating for both the current and near future (2025-2049). The Lake Iznik Sub-basin's jump from its current low risk level to "High" in the near future indicates an increasing threat to the region. The Gönen Stream

[1] Republic of Türkiye Ministry of Agriculture and Forestry, General Directorate of Water Management Marmara Basin Drought Management Plan/2023

Sub-basin, while maintaining its current moderate risk, will face a "High" risk level, particularly in the last quarter of the century (2075-2099).

The different vulnerability profiles of the focal regions stem from the unique dynamics of these three components at the sub-basin level:

- **Gönen (Gönen Stream Sub-Basin):** This region's vulnerability stems from a combination of high drought exposure and high susceptibility factors such as inefficient irrigation infrastructure and the high-water demand of livestock. A low socio-economic development index limits farmers' adaptive capacity to invest in modern irrigation technologies or switch to drought-resistant alternative crops.
- **Karamürsel and Gemlik (Gulf Sub-Basin):** This region's "Very High" vulnerability stems primarily from extreme water competition. The water demand generated by intense industry and population has driven the Water Use Index (WEI) to one of the highest levels in the basin. This restricts the agricultural sector's access to water resources. The region's reliance on water-intensive crops (e.g., sugar beet and alfalfa) and the largely inefficient irrigation systems (100% open canal system) further exacerbate vulnerability.1 This intense competition for water severely reduces the adaptive flexibility of the agricultural sector.
- **İznik and Gemlik (Lake Iznik Sub-Basin):** This region exhibits a "vulnerability paradox." Thanks to the production of high-value fruits (peaches, olives) and vegetables, the region's agricultural GDP is quite high. However, this economic success also underlies vulnerability.

Combating agricultural drought in the boroughs of Gönen, Karamürsel, İznik, and Gemlik is more than just a local problem; it's a strategic imperative at the regional and national levels. The urgency of this effort lies in three fundamental objectives:

1. **Ensuring Regional Food Security:** Agricultural production in the Marmara Region plays a critical role in the food supply of metropolitan cities, especially Istanbul. The disruption of agricultural production by drought has the potential to directly threaten regional food security by disrupting food supply chains and driving price increases.
2. **Sustainable Management of Water Resources:** Agriculture is the largest water user in the basin. Steps taken to increase water efficiency in this sector will not only ensure the sustainability of agriculture but also create water security for all sectors in the basin (drinking water, industry, ecosystems). Every drop of water saved in agriculture will increase the basin's overall drought resilience.
3. **Maintaining Rural Economic Stability:** The devastating impact of drought on farmers' incomes can deepen rural poverty and trigger migration to urban areas. Ensuring the continuity of agricultural production is vital for protecting the rural economy and maintaining social stability.

To achieve these strategic goals, the "Marmara Basin Drought Management Plan" proposes concrete and implementable measures. These measures include the modernization of existing irrigation infrastructure (transition from open canals to pressurized pipe systems), research and promotion of drought-resistant plant patterns with low water consumption and high market value, encouraging savings by switching to volume-based pricing of water rather than area-based pricing, and expanding practical training programs for farmers on modern irrigation techniques and water management. Implementing these measures with a holistic approach will enhance the region's capacity to adapt to climate change and secure its agricultural future.

In this regard, while Marmara Basin Drought Management Plan establishes a robust foundation by assessing drought risk at a regional scale, AGROSHIELD project aims to delve deeper into localized dynamics that were not fully explored in the broad-scale analysis and produce localized adaptation and mitigation strategies by applying Agricultural Drought workflow within the Climaax framework.

1.2 Main objectives of the project.

The main objective of AGROSHIELD Project is to enhance the resilience of the agriculture sector in the Southern Marmara Basin by implementing a high-resolution climate risk assessment for agricultural drought by implementing the Climaax Methodology. The Project seeks to further enhance the stakeholder capacity in the selected regions by producing borough-level adaptation actions for better adaptation planning and decision making. To achieve this, the project will apply the Climaax Agricultural Drought workflow.

The Project also seeks to achieve the specific objectives including;

- Running borough-specific climate/risk modeling for İznik, Gemlik, Karamürsel and Gönen to pin-point micro-level drought risk and vulnerabilities.
- Quantify socio-economic impacts for agricultural drought in the selected boroughs at micro scale.
- Engage local stakeholders and authorities to co-create Community Adaptation Action Plans
- Supply empirical, high-resolution evidence to strengthen local policies and land-use planning

The implementation of the Climaax Handbook and CRA Methodology will provide extensive benefit to both overall Southern Marmara Basin and targeted boroughs by providing high-resolution climate risk assessment that goes beyond the existing regional assessments by local authorities. This assessment will translate into local and actionable outcomes to reduce the vulnerability in the region.

Furthermore, Climaax community of practice cultivates methodological and knowledge exchange between European experts, providing capacity development in participating bodies.

1.3 Project team

The project is led by the MMU, working in close collaboration with the municipalities of İznik, Gemlik, Karamürsel, and Gönen, designated as the Union's focus areas.

Analyses are based on a broad network of data providers, including the Turkish Statistical Institute (TSI), the General Directorate of State Hydraulic Works (DSI), and District Directorates of Agriculture. The project's strategic framework is being shaped by the relevant action plans and strategy documents of the Ministry of Agriculture and Forestry and the Ministry of Environment, Urbanization, and Climate Change.

The project aims to engage broad stakeholders to develop effective and applicable solutions at the local level. Participatory workshops will be organized with farmers, local municipal officials, and agricultural cooperatives to jointly develop Community Adaptation Action Plans (CAAPs). Furthermore, the inclusion of other stakeholder groups, such as civil society organizations, the private sector, and academia, will ensure that the strategies developed align with regional priorities and maximize the use of local knowledge.

1.4 Outline of the document's structure

This deliverable follows the structure defined in the CLIMAAX Handbook and template, presenting the Phase 1 climate risk assessment results for the Southern Marmara Basin, focusing on the boroughs of İznik, Gemlik, Karamürsel and Gönen within the AGROSHIELD project.

Introduction provides background information on the Marmara Basin, outlines the project's objectives, describes the project team, and introduces the document structure.
Climate Risk Assessment – Phase 1 details the implementation of selected workflow (Agricultural Drought). It covers scoping, risk exploration, risk analysis, preliminary key risk assessments findings including severity, urgency, and capacity, preliminary monitoring and evaluation, and work plan.
Conclusions summarize the main outcomes of Phase 1 and highlight implications for strengthening climate resilience in the Southern Marmara Basin.
Progress Evaluation and Contribution to Future Phases reviews achievements against Key Performance Indicators (KPIs) and defines next steps for Phase 2 and Phase 3.
Supporting Documentation compiles background studies, figures, tables, and datasets that ensure transparency and reproducibility of results.
References list the key sources used in the preparation of this deliverable.

2 Climate risk assessment – phase 1

2.1 Scoping

This section discusses the scoping of the climate risk assessment implemented in targeted boroughs of southern Marmara Basin, as the first step in the CRA Handbook.

2.1.1 Objectives

AGROSHIELD in its project design, focuses on strengthening the Southern Marmara Basin's agricultural resilience by delivering a high-resolution, borough-level climate risk assessment for agricultural drought and translating it into policy-ready tools and actions. Guided by the CLIMAAX CRA Framework, the project follows a three-phase path—establish a common baseline with the Agricultural Drought Workflow, refines the analysis using high-resolution local data, and co-design adaptation options.

The overall objective of the AGROSHIELD project is to utilize the Climaax CRA methodology to produce high-resolution climate risk assessment based on agricultural drought in the target boroughs with the purpose of enhancing the adaptation and decision-making capacities of stakeholders. The expected outcomes of AGROSHIELD include;

- Borough-specific climate/risk modeling for İznik, Gemlik, Karamürsel, and Gönen to pinpoint micro-level drought risks and vulnerabilities.
- Increased supply of empirical, high-resolution evidence to strengthen local adaptation capacities and plans.
- Increased understanding of socio-economic impacts of agricultural drought at the local level.
- Development of Community Adaptation Action Plans with local stakeholders and vulnerable target groups.

The CRA is designed to feed directly into governance: findings will be shared and disseminated with local authorities to feed into municipal adaptation plans, land-use policies, water-management plans to ensure that there is a formal institutional uptake rather than a stand-alone study. Borough-level local governments are explicitly positioned to integrate the evidence into their policies and planning processes.

One of the key reasons why the CRA conducted by MMU focuses on borough-level assessment is the fact that borough municipalities are often neglected in the adaptation planning processes. Adaptation planning process is usually conducted amongst authorities at the national and province levels, often disregarding borough municipalities in the process. Our CRA ensures that borough-level actors are placed in the center of the planning process through high-resolution climate risk assessment.

Furthermore, within the context of the AGROSHIELD Project, all findings will culminate into Community Adaptation Action Plans, which will be developed through participatory workshops and iterative drafting, then formally endorsed by the borough-level authorities and other stakeholders.

2.1.2 Context

2.1.2.1 Assessment and Management of Climate Hazards, Impacts and Risks in the Region

Climate hazards in the Marmara Region, particularly drought, have been addressed with a scientific and systematic approach to date. This process is being implemented through comprehensive studies such as the "Marmara Basin Drought Management Plan." Risk assessment is based on internationally accepted methodologies:

- **Drought Analyses:** The severity, duration, and geographic distribution of drought in the region were analyzed using various meteorological and hydrological indices such as the Standard Precipitation Index (SPI), the Palmer Drought Severity Index (PDSI), and the Standard Precipitation-Evaporation Index (SPEI). These analyses were used to identify past drought periods and create future risk maps.
- **Sectoral Vulnerability Analysis:** A "sectoral vulnerability analysis" was conducted to measure the potential impacts of drought on different sectors. This analysis is based on three main components:

    1. **Exposure:** This refers to the extent to which a region is exposed to climatic stress (e.g., lack of rainfall).

    2. **Sensitivity:** This measures the extent to which sectors such as agriculture and industry are structurally affected by drought (e.g., dependence on water).

    3. **Adaptive Capacity:** This assesses the ability of a region and its sectors to cope with and adapt to the effects of drought (e.g., socioeconomic development, technological infrastructure). As a result of these analyses, the vulnerability of the basin and sub-basins to drought was determined and the regions and sectors at risk were prioritized.[1]

2.1.2.2 The Project's Problem and Its Place within the Broader System

The project's primary objective is to minimize the negative impacts of drought and water scarcity triggered by climate change on the socio-economic structure and ecosystem in the Marmara Basin.[1] This problem, beyond being a local problem, is directly related to regional and national development goals:

- **Regional and National Development**: The Marmara Basin is one of the most developed and densely populated regions in Türkiye. It hosts industrial centers such as Istanbul and Kocaeli, as well as important agricultural areas such as Balıkesir and Çanakkale.[1] Water scarcity in the region has the potential to directly threaten the national economy and development goals (e.g., the Eleventh Development Plan) by disrupting both industrial production and agricultural activities. (RTMAF-GDWM, 2023)

- **Food Security:** The region plays a critical role in the national food supply. A decrease in agricultural production due to drought could lead to disruptions in food supply chains and price increases, jeopardizing national food security.
- **Strategic Management of Water Resources:** Increasing urban, industrial, and agricultural demand for dwindling water resources is creating intersectoral competition. Managing this problem requires strategic planning for a sustainable and equitable distribution of water, which forms a fundamental part of national water policies.

2.1.2.3 Governance Context of Climate Risk Assessment

The Marmara Region's climate risk management is addressed within a multi-layered governance structure. This structure includes policy, legal regulations, and institutional coordination mechanisms extending from the national to the local level:

- **National Policies and Strategies:**
  - **National Drought Management Strategy Document and Action Plan (2017-2023):** Draws the national framework for combating drought.
  - **Türkiye Agricultural Drought Combating Strategy and Action Plan:** Identifies risks and adaptation measures specific to the agricultural sector.
  - **Eleventh Development Plan and National Regional Development Strategy:** Integrates adaptation to climate change and the sustainable use of resources into national development goals.
  - **Türkiye Disaster Response Plan (TAMP)**: Defines drought as a slowly developing natural disaster and organizes response processes.

- **Legal and Institutional Structure**: Drought management is carried out through coordination boards at different levels:
  - **National Level:** Institutions such as the Water Management Coordination Board, Basin Management Central Board, Agricultural Drought Management Coordination Board, and AFAD determine national policies and ensure inter-institutional coordination.
  - **Basin Level**: The Basin Management Board coordinates the implementation and monitoring of plans at the basin level.
  - **Provincial Level**: Provincial Water Management Coordination Boards and Agricultural Drought Provincial Crisis Centers prepare and implement emergency action plans at the local level.

2.1.2.4 Related Sectors in the Region and How They Will Be Affected by Climate Change

The main sectors expected to be affected by drought in the Marmara Basin are as follows:

- **Agriculture:** The most affected area, as it is the most dependent on water. A decrease in output and quality, an increase in the cost of irrigation, problems with fodder, and the degradation of pasture areas are some of the issues that can be experienced in agriculture.
- **Drinking and Utility Water:** The demand for drinking water is high due to population density. Drought may cause water shortages and deterioration in water quality by reducing dam occupancy rates.
- **Industry:** The region is an industrial zone of Türkiye. Facilities that use large amounts of water in the production process might experience disruptions in production.
- **Ecosystem:** Drying of wetlands, damage to aquatic life, a decrease in biological diversity, and an increased risk of forest fires are the expected environmental effects.

- **Tourism:** Tourism activities that depend on natural beauty and water resources—such as lake tourism and coastal tourism—may be negatively affected. A decrease in green areas can reduce the attractiveness of the region.
- **Energy:** In particular, the energy production capacity of hydroelectric power plants (HES) may decrease due to lower water levels.

2.1.2.5 External Factors on the Problem

The drought problem in the region is not an isolated phenomenon but it is shaped by larger-scale national initiatives and policies. These "external influences" include the following:

- **National Strategy and Action Plans:** Documents such as the "National Drought Management Strategy" and the "Türkiye Agricultural Drought Combat Strategy" provide the framework and legal basis for measures to be implemented in the Marmara Basin.
- **National Development Goals:** High-level policies such as the Eleventh Development Plan define the efficient use of water resources and adaptation to climate change as imperatives, encouraging local governments and institutions to take steps in this direction.
- **Disaster Management System:** The Türkiye Disaster Response Plan (TAMP) considers drought as a type of disaster and requires provincial-level response plans to be integrated into this national system.

Possible Adaptation Interventions: The main adaptation interventions recommended in the report to mitigate the impacts of drought and achieve the targets are grouped into seven main groups[1]:

1. **Efficient Use of Water in Irrigation:**
- Encouraging the transition from traditional (flood) irrigation systems to pressurized (drip, sprinkler) irrigation systems.
- Expanding the planting of drought-resistant and less water-consuming plant species.
- Setting irrigation water prices based on the amount of water consumed (volume-based).
2. **Reducing Losses and Leakage in Drinking Water Networks:**
- Renovating old infrastructure and reducing loss and leakage rates through smart grid systems (SCADA).
3. **Water Recycling in Industry:**
- Using highly water-efficient technologies in industrial facilities and reusing treated wastewater in production processes (using graywater).
4. **Monitoring and Early Warning Systems:**
- Establishing an early warning system that monitors meteorological and hydrological data (dam fill rates, groundwater levels, soil moisture) in real time.
5. **Reducing Environmental Damage:**
- Ecological restoration of river and stream beds, protection of wetlands, and increased measures against forest fires.
- Preventing agricultural pollution through Good Agricultural Practices.
6. **Protecting Wetlands:**
- Protecting water resources that feed wetlands and reducing pressure on these areas.
7. **Raising Awareness:**
- Organizing training and awareness campaigns on water conservation and efficiency for farmers, industrialists, and the public.
- Promoting a water conservation culture through initiatives such as the "National Water Efficiency Mobilization."[1]

2.1.3 Participation and risk ownership

Stakeholder engagement is at the heart of the AGROSHIELD project design, and it guides decisions from early scoping through implementation. In the first phase, which covers the preliminary assessment, the team has engaged only with borough municipalities to establish a baseline and clarify institutional roles.

In the next phases, AGROSHIELD will widen participation through a bottom-up approach that involves local stakeholders such as farmers and producer groups, water user associations, civil society organizations, extension services, academia, and private actors in agricultural value chains, with deliberate inclusion of women and youth.

Following completion of a high-resolution Climate Risk Assessment, participatory workshops will be organized in each locality to co-produce Community Adaptation Action Plans that set localized adaptation actions that align with municipal and regional development strategies. Draft plans will be validated in open sessions, refined through iteration, and paired with capacity building actions. This pathway aims to build local ownership, improve feasibility, reduce conflict risk, and ensure that adaptation measures are equitable, evidence based, and ready for integration into policy and day to day decision making.

2.1.3.1 Relevant Stakeholder Groups

To develop an evidence-based agricultural drought risk assessment, AGROSHIELD Project interacts with a broad range of stakeholders:

- **Public Institutions (Central Government):** In addition to internal stakeholders such as the General Directorate of Water Management (SYGM), the General Directorate of State Hydraulic Works (DSI), and the General Directorate of Forestry (OGM), which are affiliated with the Ministry of Agriculture and Forestry, numerous ministries and affiliated organizations, including AFAD, the Ministry of Environment, Urbanization and Climate Change, the Ministry of Health, the Ministry of Energy and Natural Resources, and the Ministry of Culture and Tourism, are involved in the process as external stakeholders.
- **Local Governments**: Metropolitan municipalities, provincial and district municipalities, and Special Provincial Administrations are the primary stakeholders responsible for the implementation of plans at the local level.
- **Academia and Research Institutions**: Institutions such as universities and TÜBİTAK provide strategic support to the process with their scientific and technical knowledge.
- **Private Sector:** Chambers of Industry and Organized Industrial Zones (OIZs) are important stakeholders, particularly in the industrial sector's water use and drought adaptation.
- **Non-Governmental Organizations (NGOs) and Professional Organizations:** NGOs operating in the fields of environment and agriculture, as well as professional organizations such as Chambers of Agriculture, participate in planning processes as the voice of local communities and farmers.
- **Vulnerable Groups:** The vulnerable groups and regions (priority groups) most affected by drought risk will be identified through sectoral vulnerability analyses. Representatives of these groups play a key role in the planning and implementation processes.
- **Most Vulnerable Sectors and Groups**: Analyses indicate that agriculture is the sector most likely to be affected by drought. Therefore, farmers, livestock breeders, and agricultural workers who earn their living from agriculture and livestock constitute the most vulnerable groups. Representatives of these groups include Irrigation Associations, Chambers of Agriculture, local agricultural cooperatives, and producer associations.
- **Most Vulnerable Regions:** Vulnerability analyses revealed significant differences among sub-basins. Regions such as the Gulf Sub-Basin (for industrial and agricultural sectors), the Western Istanbul Sub-Basin (for drinking water), and the future Lake Iznik Sub-Basin (for agriculture and ecosystems) were identified as "very high" or "high" risk. The population living in these regions and the economic units operating in them are the priority groups. Representatives of these regions are the relevant municipalities, district governorships,

special provincial administrations, and provincial directorates of ministries (e.g., the Provincial Directorate of Agriculture and Forestry).

2.1.3.2 Governance and Risk Ownership

Drought management is carried out through a multi-layered governance structure organized at the national, basin, and provincial levels. This structure clarifies inter-institutional coordination and the distribution of responsibilities:

- **National Level:**
    - **Coordination Boards:** High-level boards such as the Water Management Coordination Board, the Basin Management Central Board, and the Agricultural Drought Management Coordination Board determine national policies and ensure inter-institutional coordination.
    - **AFAD (Disaster and Emergency Management Presidency):** Directs the main coordination and response activities at the national level in managing drought as a disaster.

- **Basin Level:**
    - **Basin Management Board:** The board, chaired by the Governor, monitors and evaluates the implementation of drought management plans at the basin level and ensures coordination among relevant institutions. Its duties also include ensuring public participation and information.
- **Provincial Level:**
    - **Provincial Coordination Boards:** Provincial Water Management Coordination Boards and Provincial Disaster and Emergency Coordination Boards (İADKK) ensure the implementation of plans at the provincial level.
    - **Agricultural Drought Provincial Crisis Centers:** Conduct crisis management and response activities at the local level, particularly in droughts affecting the agricultural sector.

Risk ownership is based on the hierarchical and sector-based structure defined by the Türkiye Disaster Response Plan (TAMP). TAMP considers drought a "slow-developing natural disaster" and organizes response processes through "service groups." Each service group has a "main solution partner" and "support solution partners." This structure clarifies risk ownership in specific areas:

- **Agriculture and Forestry Service Group**: The main solution partner is **the Ministry of Agriculture and Forestry**. It is responsible for damage assessment in agricultural areas, ensuring food security, and managing risks related to animal health.
- **Infrastructure Services Group: The Ministry of Environment, Urbanization and Climate Change** is the primary solution partner. It assumes responsibility for the emergency repair of infrastructure lines such as drinking water and sewer lines and for restoring services to normal.
- **Health Services Group**: **The Ministry of Health** is the primary solution partner. It is responsible for public health, combating epidemics, and managing health risks related to water quality.

This national structure is brought down to the local level through **Provincial Disaster Response Plans.** Provincial directorates and local governments, under the coordination of governorships and district governorships, undertake the management of risks within their areas of responsibility.

2.1.3.3 Risk Tolerance

Agriculture is the primary livelihood for the region's communities, which creates very low tolerance for production losses and prolonged uncertainty. Public institutions approach risk tolerance through a structured framework that sets clear triggers and proportional actions. Graduated Intervention Thresholds define distinct measures for mild, moderate, and severe drought, so that preparedness and response scale with impact. Under the Disaster Response Plan of Türkiye (TAMP), escalation ranges from Level 1, when local resources can cope, to Level 4, when national support is required. Within this ladder, acceptable risk is the band of impacts that can be managed with local capacity, contingency stocks, and routine sectoral measures without higher-level intervention. This alignment of community sensitivity and institutional thresholds clarifies who does what and when, supports early warning and timely communication, reduces avoidable economic disruption, and helps safeguard water and food security while preventing unnecessary escalation.

2.1.3.4 Communication and Dissemination

AGROSHIELD includes a detailed communication and dissemination strategy to ensure that climate risk analysis findings reach stakeholders at local and national level. The Marmara Municipalities Union (MMU) has maintained bilateral meetings with local public institutions and municipalities; before implementation, project components were presented to local authorities and letters of support were secured.

As Phase 1 concludes, the pace of communication will increase and structured dissemination will begin, with MMU sharing Phase 1 results through written briefs, policy notes, and digital channels such as the union website, newsletters, and social media. Outreach will be anchored by the Marmara Urban Forum (MARUF), a biennial international urban forum organized by MMU to be held on 1–3 October 2025 in Istanbul, where a dedicated session on AGROSHIELD will be organized and the CLIMAAX methodology and initial findings will be presented. Other CLIMAAX recipient municipalities in Türkiye were also invited to join and exchange practices.

In addition, Phase 3 will convene co-design workshops with local stakeholders to develop participatory Community Adaptation Action Plans that translate risk insights into location-specific priorities, investment pipelines, and governance commitments. Through this sequence, the project moves from analysis to engagement to adoption, creating a feedback loop that improves decision quality, strengthens institutional ownership, and supports replication across the region.

2.2 Risk Exploration

In alignment with the CLIMAAX Framework, this stage of the Climate Risk Assessment (CRA) process initiates the risk exploration phase by identifying the primary climate-related hazards, exposures, and vulnerabilities. This stage considers stakeholder engagement and public concerns to ensure the assessment focuses on the most significant and apparent risks affecting the region.

2.2.1 Screen risks (selection of main hazards)

Climate-related hazards significantly impacting agricultural productivity, economic stability, and community livelihoods in the Southern Marmara Basin have been screened in line with the CLIMAAX methodology. The Marmara Basin, due to its economic and natural importance, is particularly susceptible to drought, which is a widespread disaster risk in Türkiye. These hazards directly affect vital sectors such as agricultural irrigation, industry, drinking water supply, and ecosystems. For our project, agricultural drought has been identified as the primary and most critical climate hazard, through stakeholder consultations and preliminary assessments. This selection was made considering the region's high dependency on agriculture and the economic losses caused by past drought events. Other relevant risks are considered due to their direct interaction with drought conditions and their compounding effects (Heatwaves, Soil degradation and desertification, Heavy Rainfall, Wildfires).

Agricultural Drought

Irregular precipitation, rising temperatures, and consequent increased evapotranspiration are causing significant declines in soil moisture in the region. Future climate projections indicate a continued increase in the frequency and intensity of drought events, becoming more pronounced during critical agricultural growing seasons.

Definition and Impact: Agricultural drought refers to periods of significantly reduced water availability compared to the region's climatological norms, caused by variability in precipitation patterns, rising temperatures, and increased evapotranspiration rates. These conditions disrupt agricultural productivity, water supply, and overall ecosystem balance, leading to potential severe economic losses.

Regional Significance: As agriculture constitutes a vital economic foundation in the Southern Marmara Basin, the increasing frequency and severity of droughts pose substantial risks to water resource availability, food security, economic stability, and rural livelihoods. Effective management of these risks is crucial for the region's economic sustainability.

Affected Areas and Groups: The AGROSHIELD project specifically targets agricultural areas within the İznik, Gemlik, Karamürsel, and Gönen boroughs. The groups most affected by drought impacts include:

- Smallholder Farmers: They are particularly vulnerable due to limited financial resources, inadequate access to irrigation technologies, and a higher dependency on climate-sensitive crops.
- Rural Communities and Agricultural Workers: These groups face socio-economic instability stemming from reduced agricultural productivity, job losses, and deteriorating socio-economic conditions.
- Livestock Producers: They are directly impacted by water shortages and reduced feed availability, threatening animal health and economic viability.
- Agribusinesses: They suffer reduced profitability due to lowered agricultural yields and increased operational costs associated with drought mitigation.

Observed and Expected Hazards: Current observations indicate an increasing frequency and severity of drought events, decreasing groundwater levels, significant fluctuations in precipitation, and rising temperatures. Future climate projections suggest:

- Continued warming trends leading to intensified drought conditions.
- Increased frequency of extreme drought events, especially during critical crop-growing seasons.
- Reduced overall precipitation and altered rainfall patterns further exacerbating drought impacts.
- Potential for increased soil degradation and declining agricultural productivity in the medium and long term. These projected hazards underscore the urgency of implementing effective adaptation measures.

Focus of the CRA: This Climate Risk Assessment explicitly focuses on agricultural drought due to its significant implications for regional agriculture, the economy, and community resilience. The

AGROSHIELD project will implement the CLIMAAX Agricultural Drought Risk Workflow, utilizing high-resolution climate data with local exposure and vulnerability datasets, and adapting the methodology to the local context.

Available Data and Knowledge: The assessment will utilize various data sources in line with the methodologies detailed in the CLIMAAX Handbook. While the project proposal does not list specific datasets, it implies the use of:

- High-resolution climate models,
- Climate indices (e.g., Standardized Precipitation Index (SPI), Soil moisture anomalies (SMA)),
- Vegetation health data,
- Agricultural yield records and groundwater monitoring data,
- The Marmara Basin Drought Management Plan also details various meteorological, hydrological, and remote sensing indices used for drought analysis, including SPI, Palmer Drought Indices (scPDSI, scPHDI), SPEI, PNPI, RDI, Deciles Index, SRI, SGI, SRSI, NDVI, EVI, and VCI.

Further Data and Knowledge Needs: Despite available datasets, certain information gaps must be addressed to enhance the accuracy of future risk assessments:

- High-resolution climate projections specific to the Southern Marmara Basin are essential for localized vulnerability mapping and risk analysis,
- Detailed socio-economic data, particularly data on income distribution, rural employment patterns, and access to adaptive resources, are needed to enhance vulnerability assessments,
- Real-time soil moisture and groundwater monitoring data are crucial for dynamic drought risk forecasting and early warning systems,
- Increased local expertise and capacity development in advanced drought modeling, scenario analysis, and vulnerability mapping methodologies are also important.

Addressing these gaps will strengthen the region's capacity for proactive drought risk management, enabling more effective planning and targeted adaptation measures.

2.2.2 Workflow selection

Among the workflows offered by the CLIMAAX Handbook, the "Agricultural Drought" workflow has been selected as it directly relates to the identified hazard of "Agricultural Drought". This selection aligns with the project's main objective of conducting a high-resolution assessment of agricultural drought risk in the Southern Marmara Basin.

2.2.2.1 Workflow #1: Agricultural Drought

The project, AGROSHIELD, prioritizes addressing agricultural drought as its core climate hazard. Consequently, the "Agricultural Drought" workflow from the CLIMAAX Handbook has been chosen as the primary methodology for this assessment.

The workflow is specifically tailored to evaluate agricultural drought risks within the Southern Marmara Basin, focusing on regions heavily reliant on agriculture that are particularly susceptible to fluctuations in precipitation and soil moisture. The project concentrates on four target boroughs: İznik, Gemlik, Karamürsel, and Gönen. The İznik Lake sub-basin, for example, shows a higher risk for drought based on the SPI 24-month period. These areas are identified as highly exposed due to their significant agricultural land use, where reduced water availability directly impacts crop yields and rural economies.

Key exposed elements and vulnerable groups within these regions include:

- Agricultural Areas and Crop Production: A substantial portion of the Southern Marmara Basin consists of cultivable agricultural land, making it broadly exposed to drought conditions. The assessment considers crop-specific land cover and water dependency to understand varying impacts.
- Rural Population and Agricultural Workers: The distribution of rural populations and agricultural workers in the target boroughs highlights considerable socio-economic exposure, as their livelihoods are directly tied to agricultural productivity.
- Livestock Density: Regions with high livestock density are significantly affected during drought periods due to reduced availability of pasture and fodder, impacting economic stability.
- Water Resources and Infrastructure: Existing irrigation systems and critical water resources are under stress, which exacerbates drought impacts. The adequacy of irrigation infrastructure and access to water resources are crucial vulnerability factors.
- Socio-economic Status: The economic standing of the rural population, including GDP per capita by settlement and the percentage of household income derived from farming, are vital vulnerability indicators. The adaptive capacity of smallholder farmers is also a key consideration.

Limitations and Boundaries:

Spatial Resolution: AGROSHIELD focuses on implementing the Climaax CRA methodology at a borough level; however, the hazard and risk models provided in the Handbook are designed at the city level as their highest resolution. To address this discrepancy, hazard and risk models have been extended to cover the entire cities in which the target boroughs are located. Specifically, the CRA methodology is applied to the following cities and their respective boroughs:

- **City of Balıkesir** - Borough of Gönen
- **City of Kocaeli** - Borough of Karamürsel
- **City of Bursa** - Boroughs of İznik and Gemlik

Specific Crops: The crop table in the Climaax Handbook does not include some of the key crops essential for implementing the CRA methodology. In response, regional crop tables have been developed, incorporating locally relevant crop coefficients to ensure a more accurate and region-specific application of the methodology.

2.2.3 Choose Scenario

The AGROSHIELD project primarily addresses agricultural drought as the most critical and recurring challenge threatening agricultural production, economic stability, and community livelihoods in the Southern Marmara Basin. Therefore, scenario selection will focus on this key risk and related socio-economic dynamics.

For the AGROSHIELD project in the Southern Marmara Basin, relevant scenario assumptions will encompass both climate change projections and anticipated socio-economic developments, tailored to the project's focus on agricultural drought and its localized impacts.

Climate Change Assumptions:

- Agricultural Drought: The core assumption is a significant alteration in water availability due to changes in precipitation patterns, rising temperatures, and increased evapotranspiration rates. This directly impacts agricultural productivity and water supply.
- Intensified Warming Trends: Future climate projections will assume continued warming trends leading to intensified drought conditions.
- Extreme Drought Events: There will be an increased frequency and severity of extreme drought events, especially during critical crop-growing seasons.
- Other Related Risks: While focusing on agricultural drought, the scenarios will also consider associated risks like heatwaves (which exacerbate drought) and soil degradation/desertification (accelerated by prolonged drought conditions). The project aims to use high-resolution climate models to capture these impacts at a micro-level.

Socio-economic Development Assumptions:

- Population Growth and Economic Activities: Scenarios will consider changes in population growth and economic activities within the target boroughs of Iznik, Gemlik, Karamursel, and Gonen. These changes will directly influence water demand, agricultural land use, and overall pressure on natural resources.
- Food and Energy Consumption and Prices: Given the agricultural significance of the region, the scenarios will account for how climate change impacts food security, supply chains, and potential fluctuations in food and energy prices, particularly affecting the economic risks for smallholder farmers.
- Land Use and Infrastructure Development: Assumptions will include evolving land use patterns, potential urban expansion, and developments in irrigation infrastructure (e.g., existing irrigation development plans).

2.2.3.1 Scenario and Temporal Period

The assessment focuses on medium term temporal period (up to 2060).

2056-2060 period will be assessed separately under medium (RCP 4.5) and pessimistic (RCP 8.5) climate change scenarios. Consequently, this approach produces 2 different assessment scenarios.

- Scenario 1: Medium Term (up to 2060) RCP 4.5
- Scenario 1: Medium Term (up to 2060) RCP 8.5

2.3 Risk Analysis

This section describes how the selected risk workflows from the CLIMAAX Handbook were applied to the Southern Marmara Basin. The hazard, exposure, and vulnerability data used for the analysis will be detailed. Our primary goal is to analyze agricultural drought risk with high-resolution data for the "Agricultural Risk Assessment and Resilience Strategies against Drought in the Southern Marmara Basin" (AGROSHIELD) project, bridging the gap between regional-scale assessments and localized climate adaptation planning.

2.3.1 Workflow #1

In line with the AGROSHIELD project's main objectives, agricultural drought risk management has been identified as the core workflow. This workflow aims to enhance the resilience of the agricultural sector in the Southern Marmara Basin. The CLIMAAX methodology provides a comprehensive approach by combining climate-related hazards, exposure, and vulnerability data.

Table 2-1 Data overview workflow #1

Hazard data	*Vulnerability data*	*Exposure data*	*Risk output*
Climate Datasets on Climaax Handbook: climate and thermal zone, soil water capacity, precipitation rates, elevation, solar radiation, humidity, evapotranspiration rates, Specific Crop Values: crop coefficients and season values	**Agricultural vulnerability data:** Crop-specific land cover, water dependency of crop types, irrigation availability	Agriculture area coverage, crop production values	Agricultural Drought Risk Categories (1-3) Crop yield and revenue loss maps produced by Climaax Handbook

The hazard assessment was conducted for four most produced crops in each target boroughs to ensure a comprehensive coverage on yield loss projections. Going beyond the crops available for assessment in Climaax Handbook crop tables, our assessment utilizes regional parameters as shown in the crop tables below for each target borough.

Table 2-2 Gönen Regional Crop Table

Crop	Clim	Kc_in	Kc_mid	Kc_end	lgp_f1	lgp_f2	lgp_f3	lgp_f4	Season Start	Season End	RD1	RD2	DF	Type	Ky
Watermelon	4	0,36	0,99	0,73	0,244	0,1789	0,333	0,236	112	235	0,3	1	0,45	1	1,10
Tomato	4	0,48	1,14	0,77	0,195	0,1948	0,383	0,221	112	266	0,3	1	0,5	1	1,05
Paddy Rice	4	0,77	1,18	0,76	0,162	0,1976	0,449	0,198	122	289	0,2	0,6	1	1	1,20
Maize	4	0,29	1,18	0,31	0,188	0,25	0,338	0,225	122	282	0,3	1	0,55	1	1,25

Table 2-3 Karamürsel Regional Crop Table

Crop	Clim	Kc_in	Kc_mid	Kc_end	lgp_f1	lgp_f2	lgp_f3	lgp_f4	Season Start	Season End	RD1	RD2	DF	Type	Ky
Tomato	4	0,46	1,1	0,75	0,195	0,195	0,383	0,221	112	266	0,3	1	0,5	1	1,05
Olive	4	0,49	0,62	0,6	0,119	0,332	0,213	0,332	91	344	0,7	1,7	0,6	2	0,60
Cherry	4	0,49	0,86	0,63	0,144	0,263	0,426	0,167	91	300	0,6	1,5	0,5	2	0,85
Peach	4	0,57	0,88	0,66	0,138	0,229	0,45	0,183	70	288	0,6	1,5	0,55	2	1,15

Table 2-4 İznik & Gemlik Regional Crop Table

Crop	Clim	Kc_in	Kc_mid	Kc_end	lgp_f1	lgp_f2	lgp_f3	lgp_f4	Season Start	Season End	RD1	RD2	DF	Type	Ky
Olive	4	4	0,5	0,68	0,119	0,332	0,213	0,332	91	344	0,7	1,7	0,6	2	0,60
Walnut	4	0,43	1,07	0,55	0,107	0,049	0,684	0,16	91	316	0,7	2	0,5	2	1,10
Fig	4	0,48	0,6	0,61	0,272	0,259	0,317	0,152	91	315	0,7	1,5	0,65	2	0,75
Cherry	4	0,49	0,93	0,67	0,144	0,263	0,426	0,167	91	300	0,6	1,5	0,5	2	0,85

2.3.1.1 Hazard assessment

For the hazard assessment, this report utilizes climate datasets present in the Climaax Handbook for agricultural drought workflow for 2 different identified scenarios including:

- Scenario 1: Medium Term (up to 2060) RCP 4.5
- Scenario 2: Medium Term (up to 2060) RCP 8.5

Scenario 1: Medium Term (up to 2060) RCP 4.5

- **Gönen**

Hazard data including cumulative precipitation intensity, available water capacity and cumulative standard evotranspiration for Balıkesir (Gönen) under Scenario 1 is shown below.

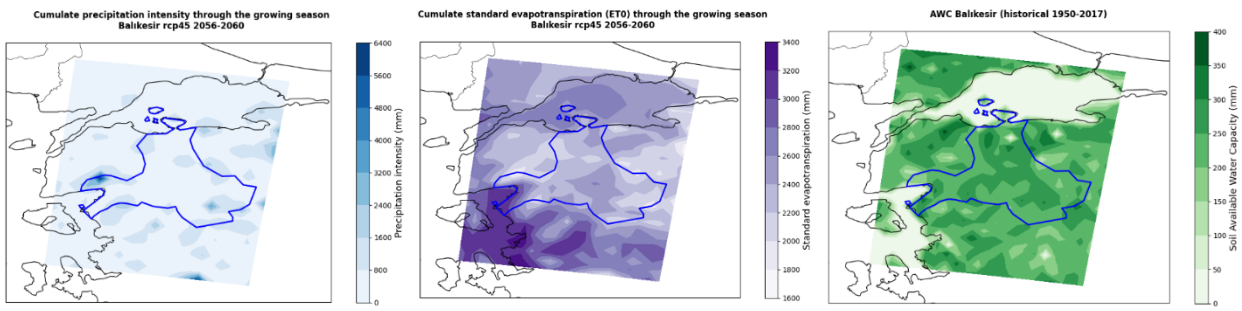

Figure 2-1 Cumulate Precipitation Intensity, Cumulate Standard Evapotranspiration through the Growing Season, and Available Water Capacity.

Potential yield losses due to precipitation deficits for Gönen, under Scenario 1, were calculated using crop parameters for maize, rice, tomato and watermelon.

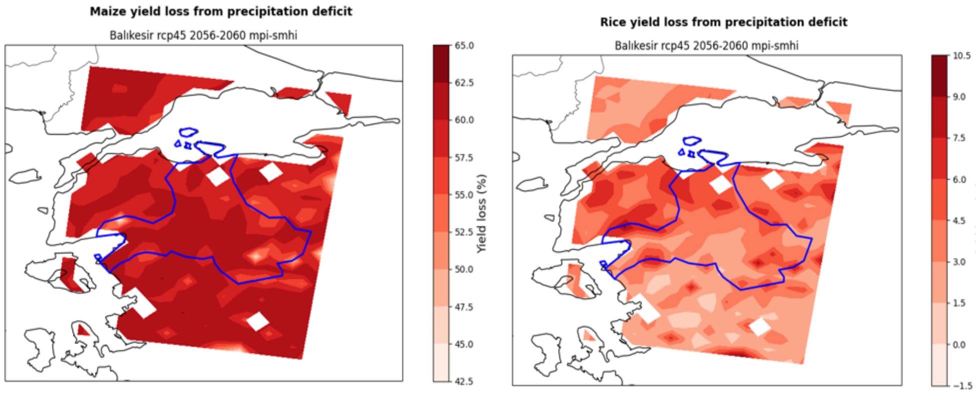

Figure 2-2 Maps of Yield Loss in Maize and Rice Crops from Precipitation Deficit.

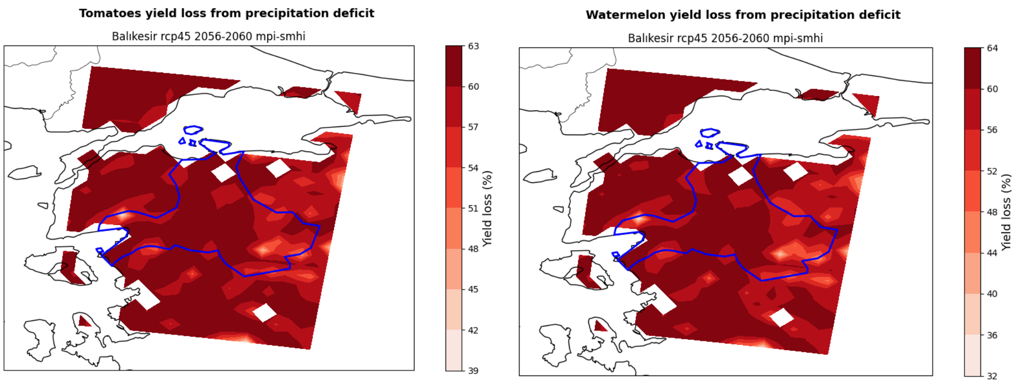

Figure 2-3 Maps of Yield Loss in Tomatoes and Watermelon from Precipitation Deficit.

- **Karamürsel**

Hazard data including cumulative precipitation intensity, available water capacity and cumulative standard evotranspiration for Kocaeli (Karamürsel) under Scenario 1 is shown below.

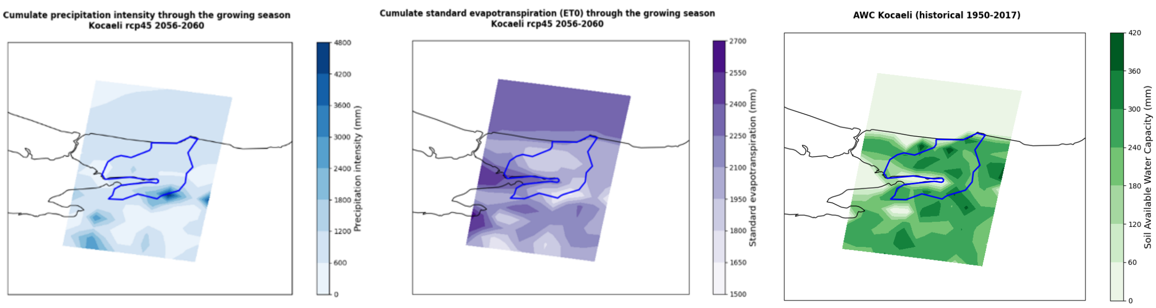

Figure 2-4 Cumulate Precipitation Intensity, Cumulate Standard Evapotranspiration through the Growing Season, and Available Water Capacity.

Potential yield losses due to precipitation deficits for Karamürsel, under Scenario 1, were calculated using crop parameters for tomato, cherry, peach and olive.

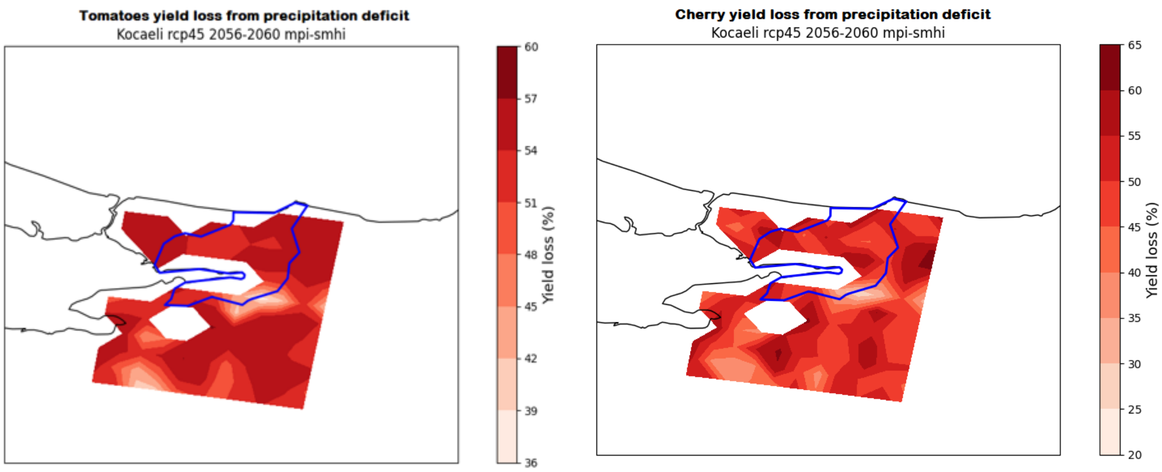

Figure 2-5 Maps of Yield Loss in Tomatoes and Cherry from Precipitation Deficit.

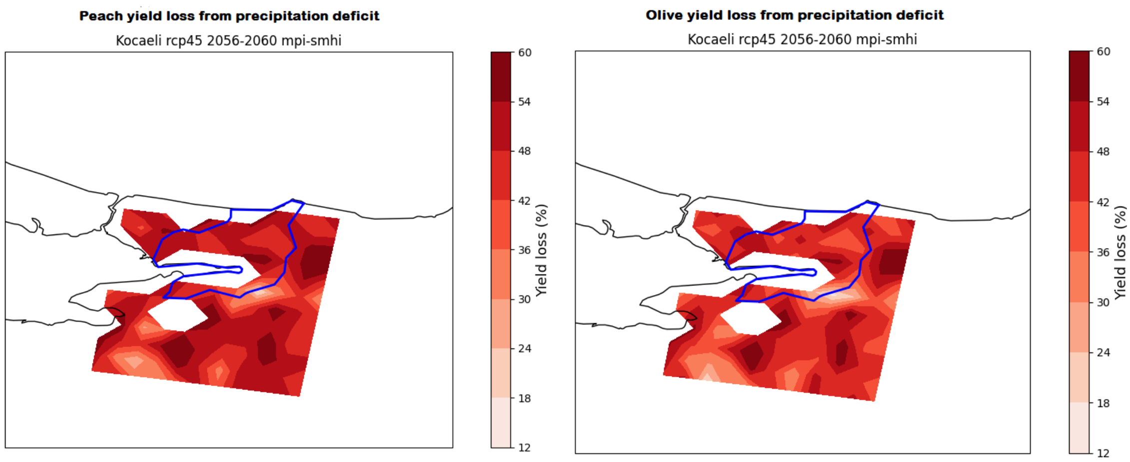

Figure 2-6 Maps of Yield Loss in Peach and Olive from Precipitation Deficit.

- **İznik & Gemlik**

Hazard data including cumulative precipitation intensity, available water capacity and cumulative standard evotranspiration for Bursa (İznik & Gemlik) under Scenario 1 is shown below.

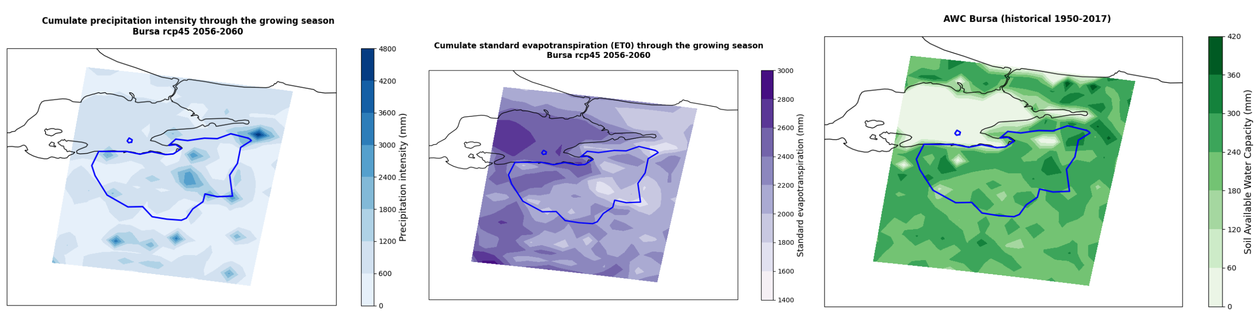

Figure 2-7 Cumulate Precipitation Intensity, Cumulate Standard Evapotranspiration through the Growing Season, and Available Water Capacity.

Potential yield losses due to precipitation deficits for Karamürsel, under Scenario 1, were calculated using crop parameters for cherry, fig, olive and walnut.

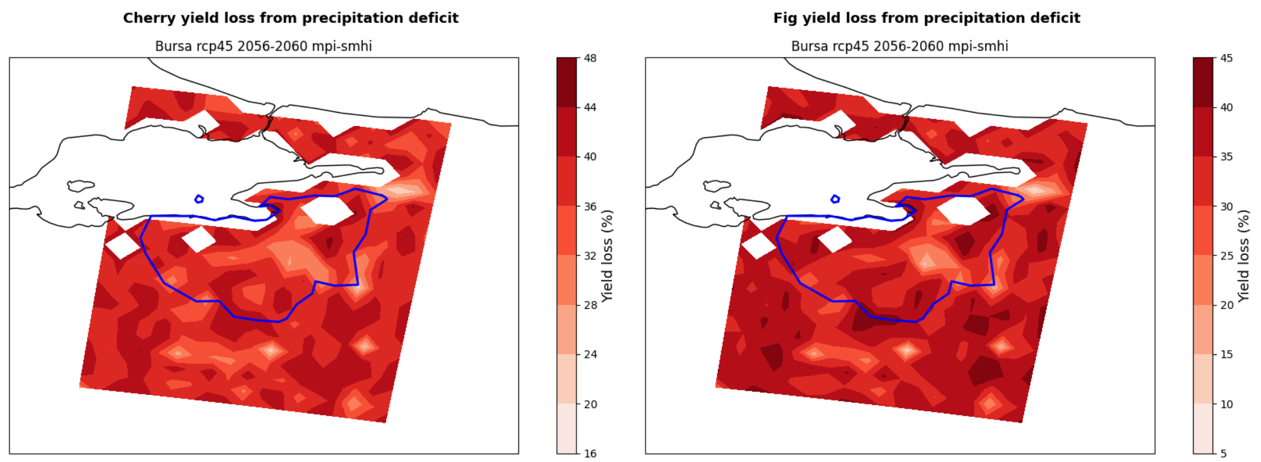

Figure 2-8 Maps of Yield Loss in Cherry and Fig from Precipitation Deficit.

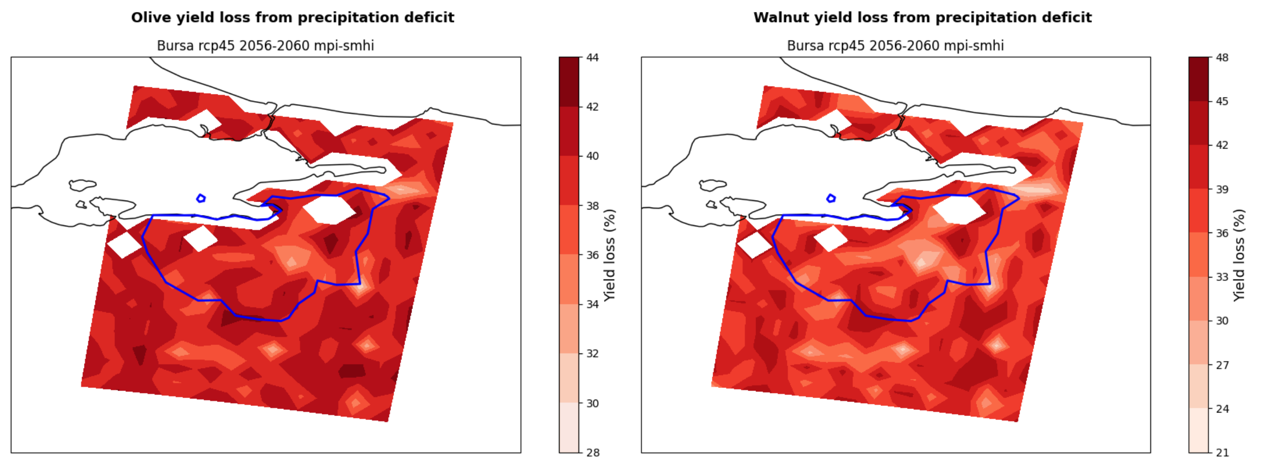

Figure 2-9 Maps of Yield Loss in Olive and Walnut from Precipitation Deficit.

Scenario 2: Medium Term (up to 2060) RCP 8.5

- **Gönen**

Hazard data including cumulative precipitation intensity, available water capacity and cumulative standard evotranspiration for Balıkesir (Gönen) under Scenario 2 is shown below.

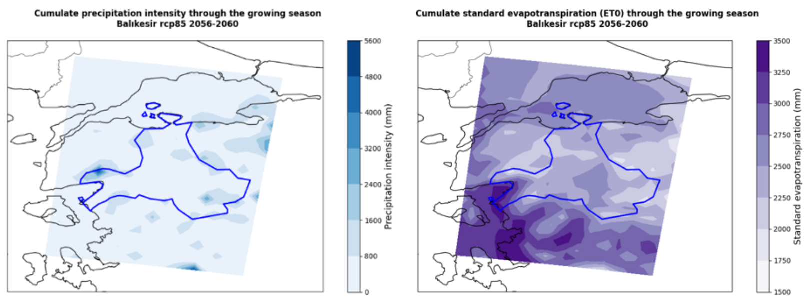

Figure 2-10 Cumulate Precipitation Intensity, Cumulate Standard Evapotranspiration through the Growing Season, and Available Water Capacity.

Potential yield losses due to precipitation deficits for Gönen, under Scenario 1, were calculated using crop parameters for maize, rice, tomato and watermelon.

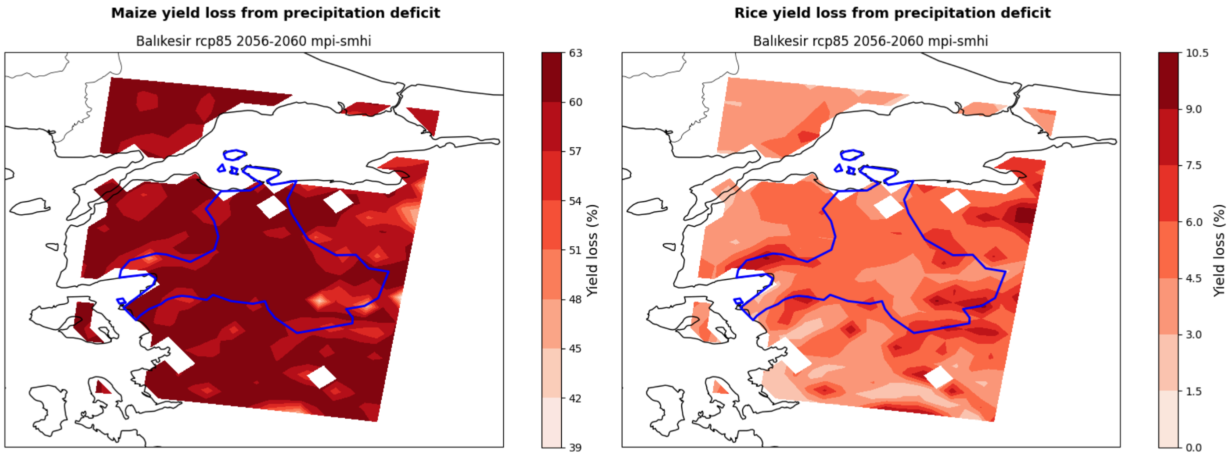

Figure 2-11 Maps of Yield Loss in Maize and Rice from Precipitation Deficit.

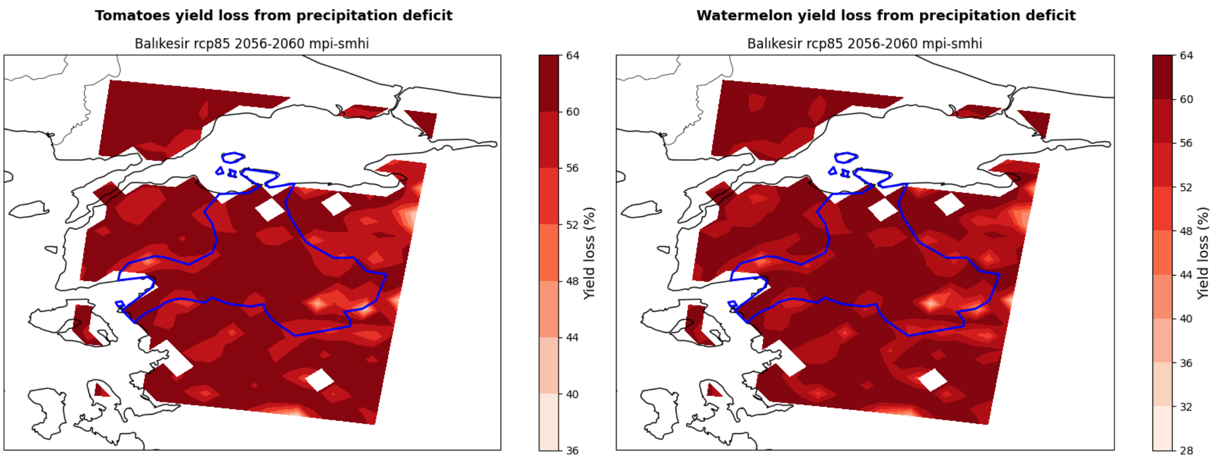

Figure 2-12 Maps of Yield Loss in Tomatoes and Watermelon from Precipitation Deficit.

- **Karamürsel**

Hazard data including cumulative precipitation intensity, available water capacity and cumulative standard evotranspiration for Kocaeli (Karamürsel) under Scenario 1 is shown below.

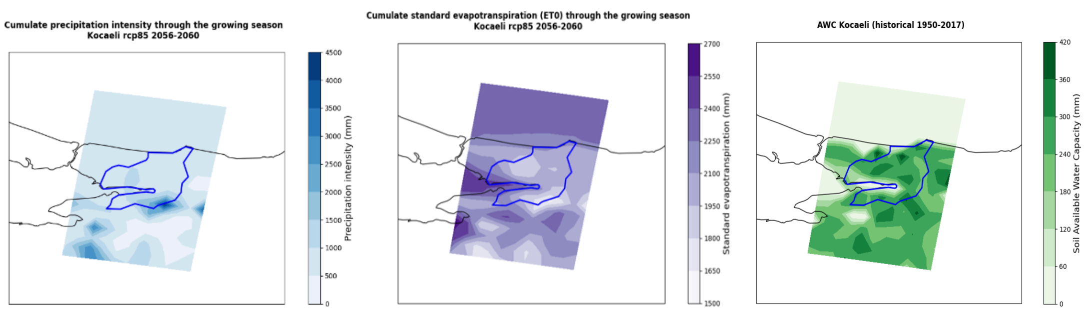

Figure 2-13 Cumulate Precipitation Intensity, Cumulate Standard Evapotranspiration through the Growing Season, and Available Water Capacity.

Potential yield losses due to precipitation deficits for Karamürsel, under Scenario 2, were calculated using crop parameters for tomato, cherry, peach and olive.

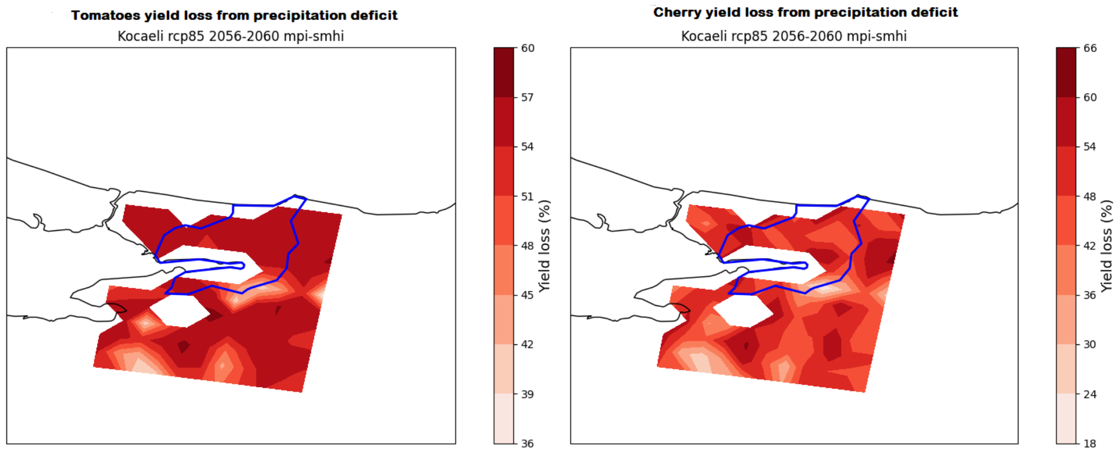

Figure 2-14 Maps of Yield Loss in Tomatoes and Cherry from Precipitation Deficit.

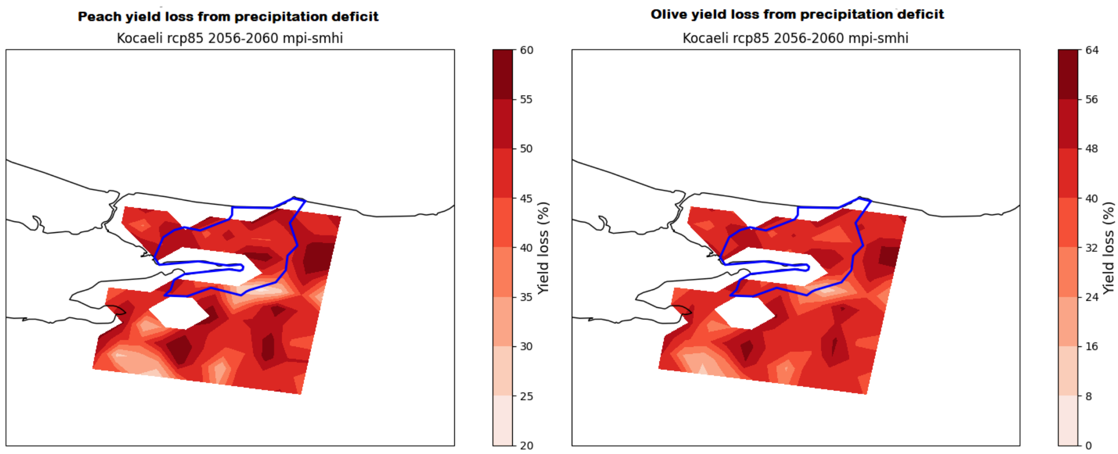

Figure 2-15 Maps of Yield Loss in Peach and Olive from Precipitation Deficit.

- **İznik & Gemlik**

Hazard data including cumulative precipitation intensity, available water capacity and cumulative standard evotranspiration for Bursa (İznik & Gemlik) under Scenario 2 is shown below.

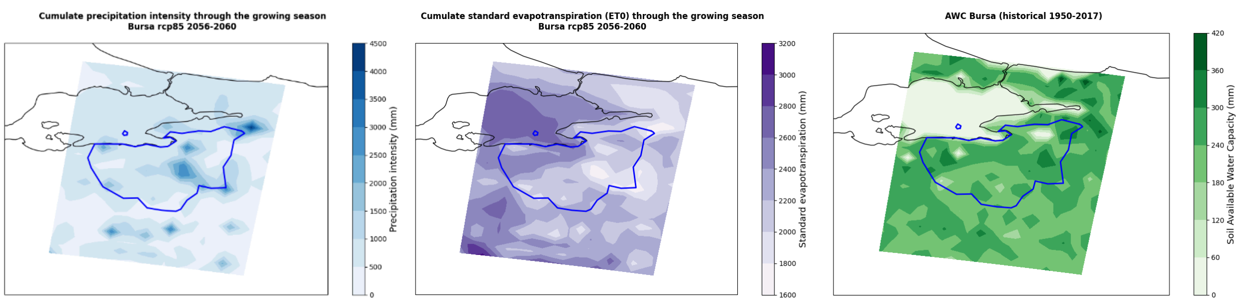

Figure 2-16 Cumulate Precipitation Intensity, Cumulate Standard Evapotranspiration through the Growing Season, and Available Water Capacity.

Potential yield losses due to precipitation deficits for Karamürsel, under Scenario 2, were calculated using crop parameters for cherry, fig, olive and walnut.

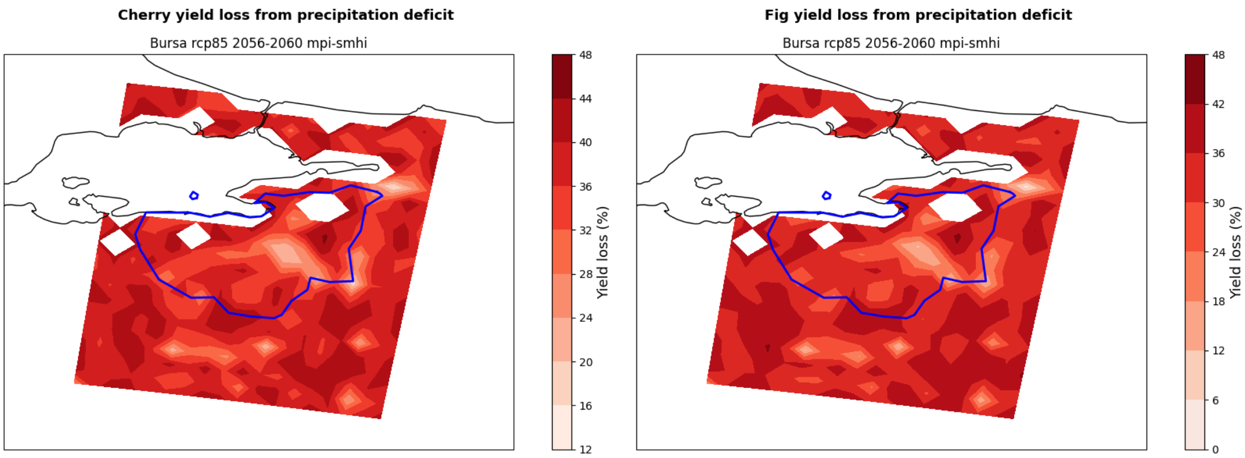

Figure 2-17 Maps of Yield Loss in Cherry and Fig from Precipitation Deficit.

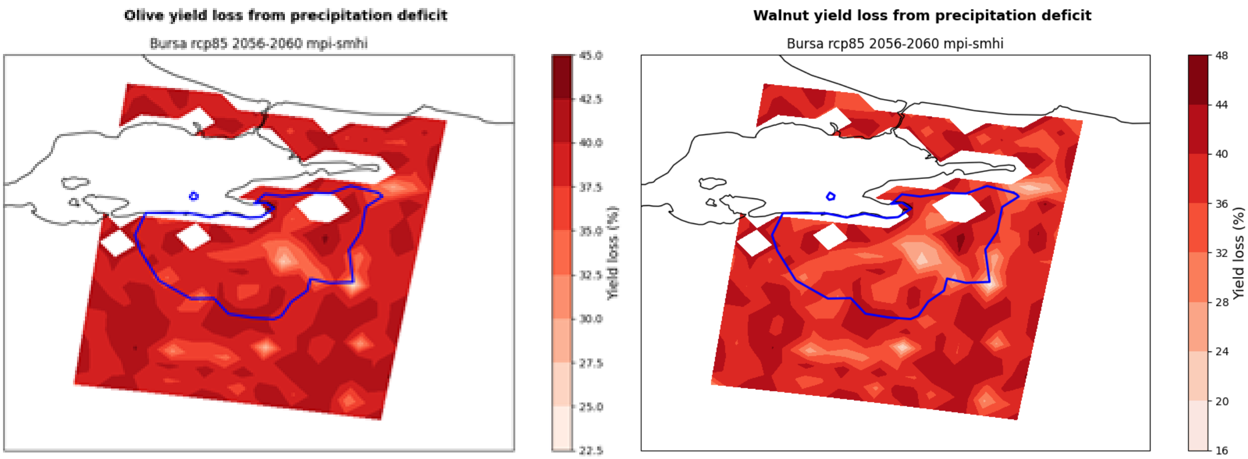

Figure 2-18 Maps of Yield Loss in Olive and Walnut from Precipitation Deficit.

2.3.1.2 Risk assessment

Finally, revenue losses were derived by merging modeled yield-loss percentages with crop-specific production and economic value data from the Harvard repository. For the risk assessment section, maps of Revenue Loss because of irrigation deficit are shown for each target borough under both selected scenarios.

Scenario 1: Medium Term (up to 2060) RCP 4.5

- **Gönen**

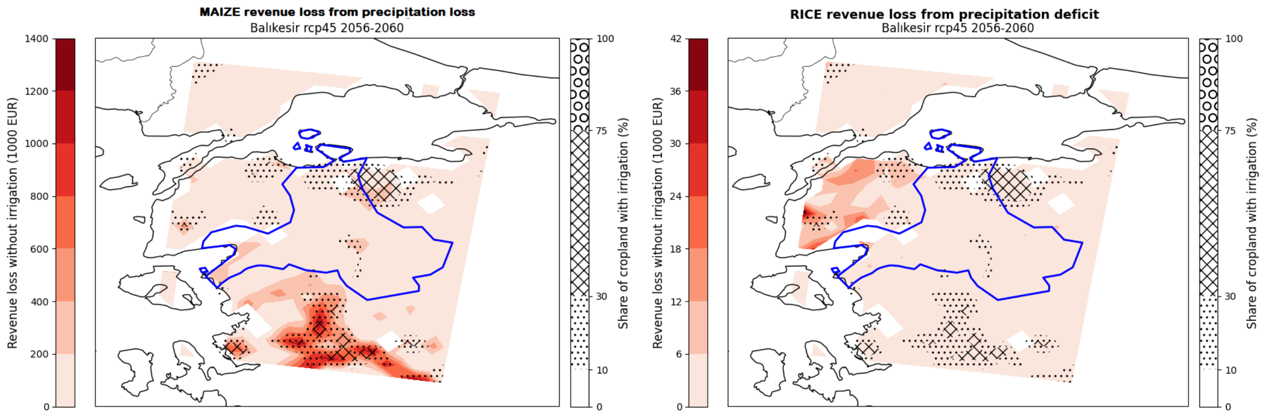

Figure 2-19 Maps of Revenue Loss in Maize and Rice from Precipitation Deficit.

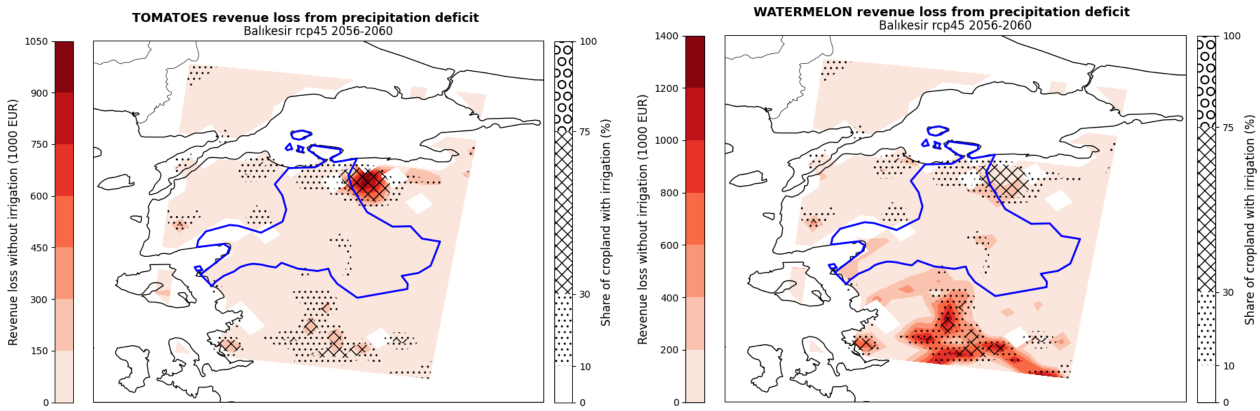

Figure 2-20 Maps of Revenue Loss in Tomatoes and Watermelon from Precipitation Deficit.

- **Karamürsel**

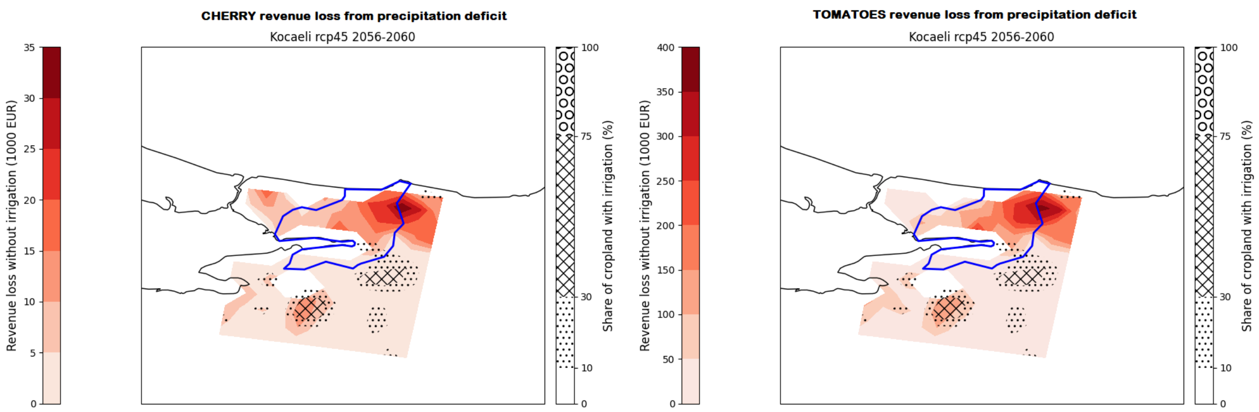

Figure 2-21 Maps of Revenue Loss in Cherry and Tomatoes from Precipitation Deficit.

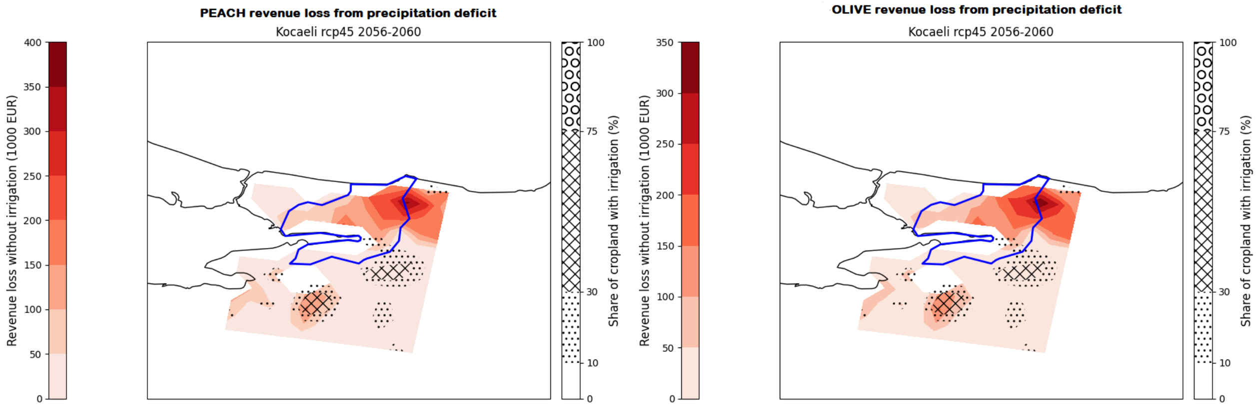

Figure 2-22 Maps of Revenue Loss in Peach and Olive from Precipitation Deficit.

- **Gemlik & İznik**

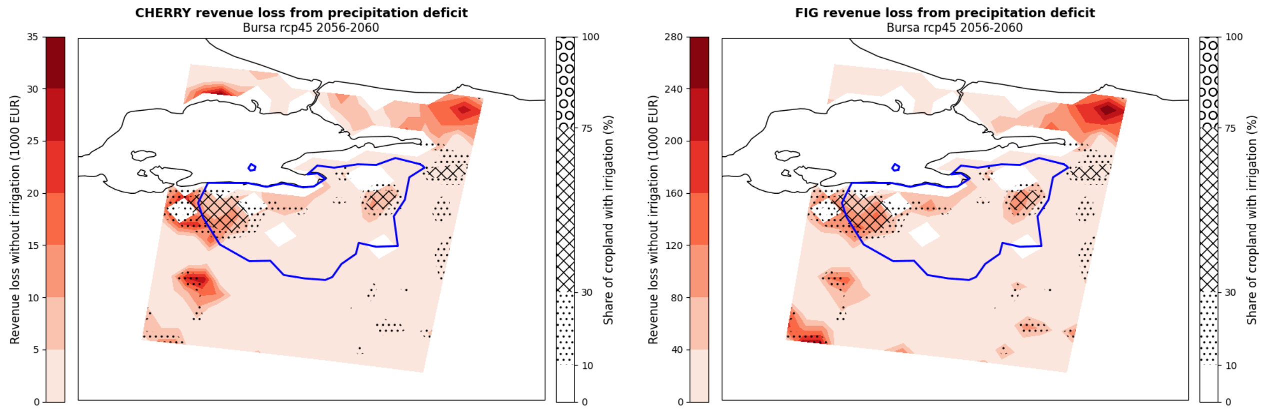

Figure 2-23 Maps of Revenue Loss in Cherry and Fig from Precipitation Deficit.

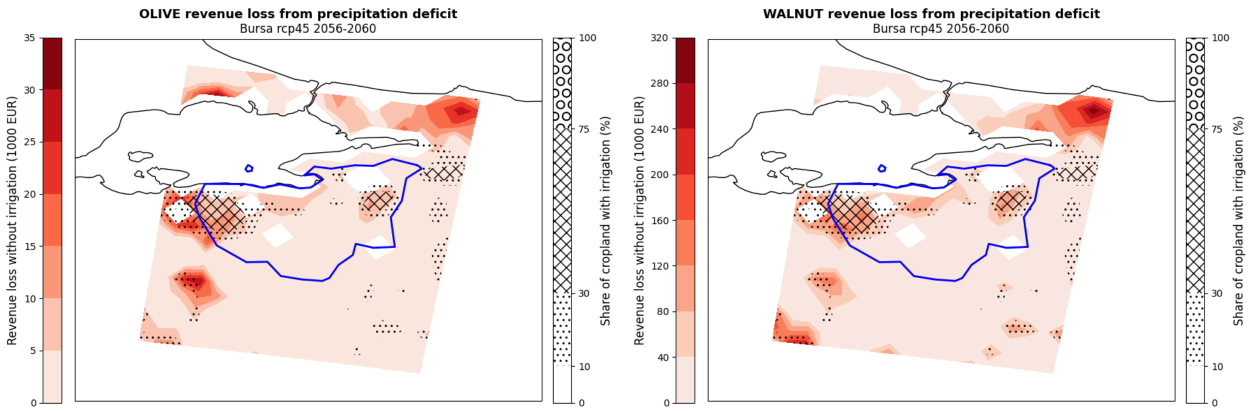

Figure 2-24 Maps of Revenue Loss in Olive and Walnut from Precipitation Deficit.

Scenario 2: Medium Term (up to 2060) RCP 8.5

- **Gönen**

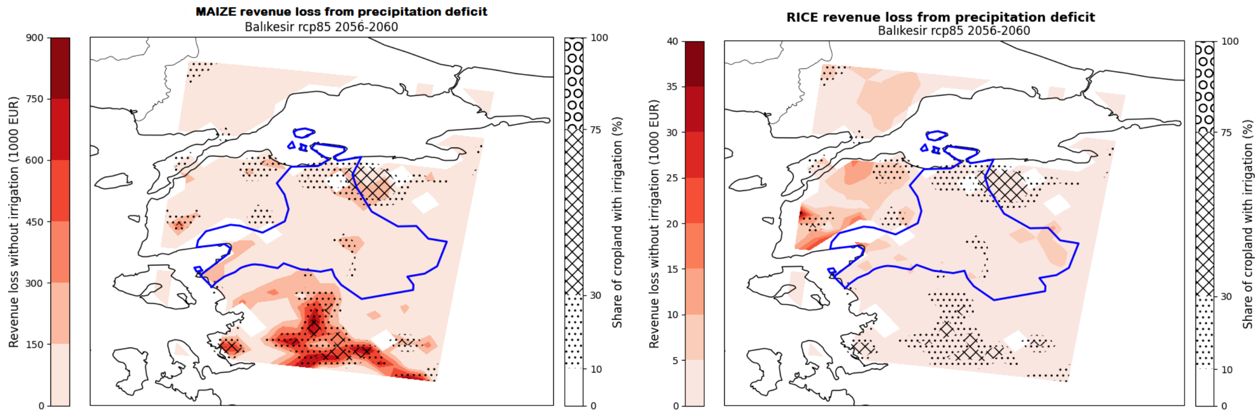

Figure 2-25 Maps of Revenue Loss in Maize and Rice from Precipitation Deficit.

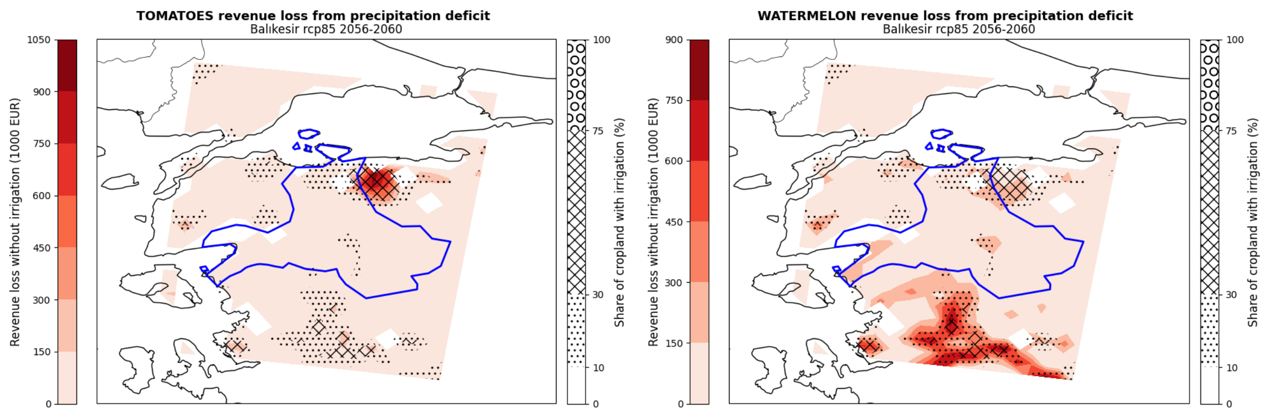

Figure 2-26 Maps of Revenue Loss in Tomatoes and Watermelon from Precipitation Deficit.

- **Karamürsel**

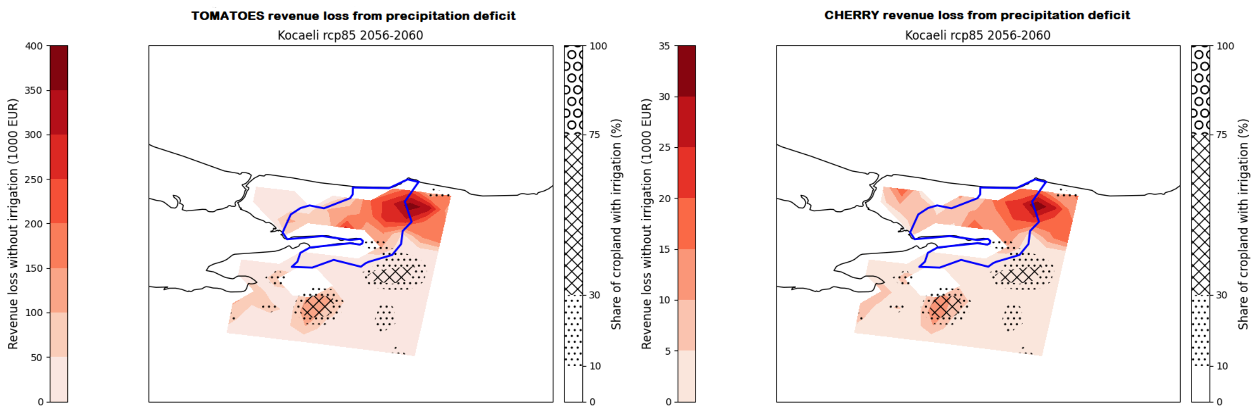

Figure 2-27 Maps of Revenue Loss in Tomatoes and Cherry from Precipitation Deficit.

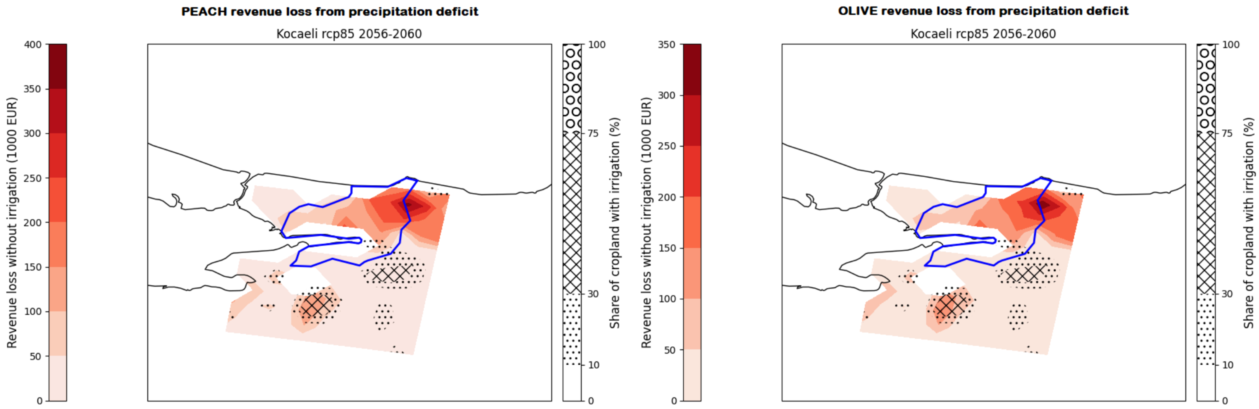

Figure 2-28 Maps of Revenue Loss in Peach and Olive from Precipitation Deficit.

- **İznik & Gemlik**

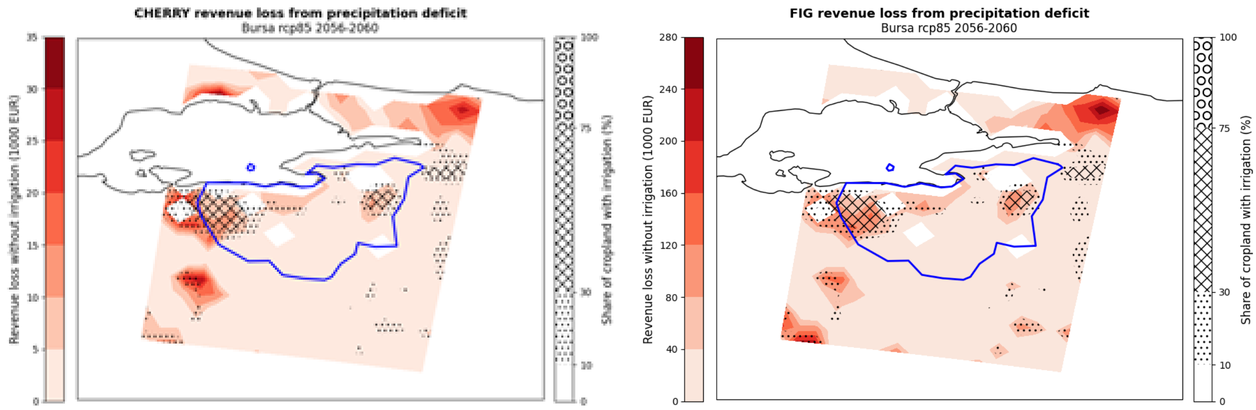

Figure 2-29 Maps of Revenue Loss in Cherry and Fig from Precipitation Deficit.

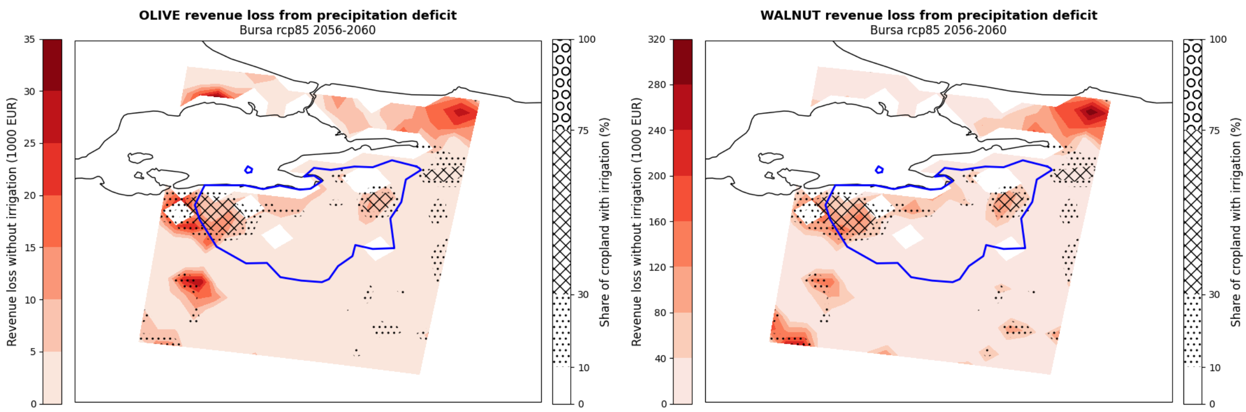

Figure 2-30 Maps of Revenue Loss in Olive and Walnut from Precipitation Deficit.

2.4 Preliminary Key Risk Assessment Findings

2.4.1 Severity

This section provides a comprehensive assessment of the severity of agricultural drought risks in the Southern Marmara Basin, regarding historical and current trends, potential impacts, frequency, and irreversible or cascading consequences.

Risk Definition and Context: The primary risk addressed by the AGROSHIELD project is agricultural drought, which refers to periods of significantly reduced water availability relative to the region's climatological norms. This reduction is primarily driven by variability in precipitation patterns, rising temperatures, and increased evapotranspiration rates. Mann-Kendall trend analysis for the Marmara Basin shows a significant increasing trend in annual average temperatures and potential evapotranspiration across most stations, while precipitation shows a general decreasing trend, further exacerbating drought conditions. Given that the economy of the Southern Marmara Basin heavily relies on agriculture, the region is highly susceptible to such droughts. Factors like inadequate water management infrastructure, limited adaptive capacities, and existing socio-economic vulnerabilities further amplify the region's exposure and susceptibility to drought impacts.

Historic and Current Trends: Analysis of historical climate data for the Southern Marmara Basin, specifically during the 1995–2015 reference period, indicates a consistent increase in both the frequency and intensity of agricultural drought events. Agricultural drought indicators such as the Standardized Precipitation Index (SPI) and Soil Moisture Anomalies (SMA) demonstrate a discernible pattern of escalating soil water deficits and water scarcity over recent decades. These trends are directly correlated with significant reductions in crop yields during critical agricultural growing seasons. Current observations confirm decreasing groundwater levels, notable fluctuations in precipitation, and rising temperatures.

Spatial Variability and Exposure: Preliminary assessments and analyses at the target borough level reveal marked spatial variability in drought risk across the Southern Marmara Basin. The project's focus areas, İznik, Gemlik, Karamürsel, and Gönen boroughs, exhibit high exposure to agricultural drought due to intensive agricultural activities and dense rural populations. Agricultural lands in these specific boroughs are particularly at risk, compounded by the inadequacy of existing irrigation infrastructure and the high-water dependency of certain crop types.

Crop Specific Assessment: Climate change is expected to increase drought frequency, evapotranspiration, and heat stress across the Marmara region. Crop response depends on root depth (RD), crop coefficients (Kc), and yield response factors (Ky). The possible effect route of the key parameters are given below;

Integrated Root Depth × Kc × Ky Insights

- Shallow root + high Kc + Ky>1 (i.e. Paddy Rice) → most vulnerable.
- Deep root + high Kc + highest Ky (i.e. Maize) → tolerates water if available but suffers steep yield losses if stress occurs.
- Deep root + high Kc + low Ky (i.e. Tomato) → most manageable crop.
- Moderate–deep root + moderate Kc + moderate Ky (i.e. Watermelon) → low–moderate risk, with short season advantage.

Based on the collected data, the planting pattern in Gönen and Karamürsel is predominantly composed of annual species, whereas in İznik and Gemlik perennial species are more prevalent.

This assessment evaluates four key crops in four districts under two climate scenarios (RCP4.5 and RCP8.5, mid-term horizon up to 2060).

The crop species are chosen to reflect planting pattern of the district in order to further detail the resolution of the study area.

Annual Plants:

- **Watermelon — RD≈0.30–1.00 m | Kc_mid≈0.99 | Ky≈1.10**

Interpretation: Moderately deep rooting, medium water demand; moderately sensitive to water deficits.
RCP4.5: Maintains access to subsoil water (30–100 cm). Risk: low–moderate.
RCP8.5: Extended dry spells may deplete deeper layers (50–80 cm). Risk: moderate.
Adaptation: Mulching, drip irrigation with shorter intervals, early sowing, shelterbelts to reduce VPD.

- **Tomato — RD≈0.30–1.00 m | Kc_mid≈1.14 | Ky≈1.05**

Interpretation: Deep rooting, high water demand, least sensitive crop (lowest Ky).
RCP4.5: Manageable with proper irrigation; Risk: moderate.
RCP8.5: Heat waves reduce fruit set, but water stress causes limited yield losses. Risk: moderate.
Adaptation: Shade nets (20–30%), nighttime irrigation, potassium-rich fertilization, regulated deficit irrigation feasible.

- **Paddy Rice — RD≈0.20–0.60 m | Kc_mid≈1.18 | Ky≈1.20**

Interpretation: Very shallow rooting, very high water demand, sensitive to drought.
RCP4.5: Sustainable with stable irrigation; failure in water delivery quickly reduces yield. Risk: medium–high.
RCP8.5: Higher evaporation, unstable water supply, rapid stress if flooding <5–7 cm. Risk: high (especially in Gönen where rice is common).
Adaptation: AWD (Alternate Wetting & Drying), deeper bunds, short-season cultivars, precise land leveling.

- **Maize — RD≈0.30–1.00 m | Kc_mid≈1.18 | Ky≈1.25**

Interpretation: Deep rooting but most sensitive to stress (highest Ky); very high peak water demand.
RCP4.5: Water shortages during tasseling/silking critical. Risk: medium–high.
RCP8.5: Heatwaves combined with drought strongly reduce pollination and kernel set. Risk: high.
Adaptation: Frequent/light irrigations (maintain 40–100 cm soil water at ~60–80% FC), early-maturing hybrids, avoid late sowing.

Perennial Plants:

- **Olive**

Kc_mid: 0.62–0.67 → lower water demand compared to annuals.
Ky: 0.6–0.7 → tolerant to water deficit.
RD: Deep roots (>1.5 m).
RCP2-4.5: Low risk, withstands drought with deep roots; yield variability possible.
RCP5-8.5: Moderate risk, flowering and fruit set disrupted especially during heat waves. The most resilient perennial.

- **Cherry**

Kc_mid: ≈0.84 → medium water demand.
Ky: 0.85 → yield loss significant under drought.
RD: 1.0–1.5 m (moderate–deep).
RCP2-4.5: Moderate risk → manageable with irrigation.
RCP5-8.5: Moderate–high risk → spring frost + hot summers negatively affect flowering. Especially sensitive to phenological shifts (early flowering + late frost).

- **Peach**

Kc_mid: ≈0.88 → high water demand.
Ky: 1.15 → sensitive to water deficit.
RD: 1.0–1.5 m.
RCP2-4.5: Moderate risk → requires irrigation.
RCP5-8.5: High risk → Ky>1 means water stress causes severe yield loss. The most vulnerable perennial in Karamürsel.

- **Walnut**

Kc_mid: 1.07 → very high water demand.
Ky: 1.10 → yield strongly reduced under water deficit.
RD: Up to 1.5 m, but better developed in fertile soils.
RCP2-4.5: Moderate–high risk → dependent on irrigation infrastructure.
RCP5-8.5: High risk → summer drought + heat waves cause empty nuts and quality loss. The most vulnerable perennial in İznik/Gemlik.

- **Fig**

Kc_mid: 0.72 → low–moderate water demand.
Ky: 0.75 → tolerant to drought.
RD: 1.0–1.5 m (can root deeply).
RCP2-4.5: Low–moderate risk → tolerant, yields generally maintained.
RCP5-8.5: Moderate risk → extreme heat may cause fruit cracking and quality loss. The second most resilient perennial after olive.

Detailed Assessment of Historical and Current Trends (Potential Impacts): The agricultural drought risk in the Southern Marmara Basin poses serious, wide-ranging impacts that extend across multiple key sectors.

- **Economic Impacts:**
  - Lower crop yields directly reduce agricultural income, causing economic instability at both household and regional scales.
  - Higher production costs from supplementary irrigation, water sourcing, and crop insurance place additional financial strain, especially on smallholder farmers.
  - Extended drought periods may lead to measurable declines in regional GDP, highlighting the seriousness of unaddressed risks.
  - Agribusinesses face reduced profitability due to both lower yields and increased operational expenses associated with drought mitigation.
- **Environmental Impacts:**

    - Severe drought accelerates soil degradation and desertification, resulting in greater erosion, loss of organic matter, and long-term declines in soil quality, ultimately reducing agricultural productivity.
    - Falling groundwater and surface water levels jeopardize ecosystem sustainability and biodiversity, undermining key ecosystem services essential for farming.
- **Social Impacts:**
    - Rural communities, particularly vulnerable groups such as smallholder farmers, farm laborers, and livestock producers, are disproportionately affected.
    - Declining productivity threatens employment stability, deepens poverty, heightens economic vulnerability, and can trigger demographic changes such as rural depopulation.
    - Food security is put at risk due to reduced crop availability and potential price increases.
- **Historical and Projected Severity Levels (Quantitative Assessment):** The severity of agricultural drought risk has been quantitatively assessed using data from the 1995–2015 historical reference period (Scenario 0) and future climate projections up to 2060 (medium-term) and 2100 (long-term) under SSP1-2.6, SSP2-4.5, and SSP5-8.5 scenarios.
- **Hazard Assessment:** SPI and SMA data indicate a growing frequency and intensity of drought events across the region. Future projections anticipate a continued increase in the frequency and severity of extreme drought events, particularly during crucial crop-growing seasons.
- **Exposure Assessment:**
    - Agricultural areas: A significant portion of the Southern Marmara Basin is comprised of cultivable agricultural land, indicating widespread exposure.
    - Population exposure: The distribution of rural and agricultural worker populations in İznik, Gemlik, Karamürsel, and Gönen highlights considerable socio-economic exposure.
    - Livestock density: Regions with high livestock density are significantly impacted in drought years due to reduced availability of pasture and fodder.
    - Water resources: Existing irrigation systems and water sources are under significant stress, exacerbating drought impacts.
- **Vulnerability Assessment:**
    - Regional socio-economic data: Factors such as the percentage of rural population, GDP per capita by settlement, and the percentage of household income derived from farming illustrate the economic vulnerability.
    - Agricultural vulnerability data: The high water dependency of certain crop types, the adequacy of irrigation infrastructure, and the adaptation capacity of smallholder farmers determine the agricultural sector's vulnerability.
    - Proximity to services: Differences in access to agricultural extension, credit, and insurance services (like TARSİM) affect farmers' adaptive capacity.

Based on the integrated assessment of hazard, exposure, and vulnerability, agricultural drought risk is categorized into three distinct levels (1 – lowest risk; 3 – highest risk).

Key Messages and Fundamental Takeaways:
The assessment clearly demonstrates that agricultural drought poses a severe and escalating risk for the Southern Marmara Basin. Historically, it has led to significant impacts on crop yields and

rural economies. The climate risk in the region is characterized by both high frequency and high impact, resulting in substantial financial damage and socio-economic instability across key sectors like agriculture and water resources.
Furthermore, this climate risk has the potential to unleash irreversible environmental consequences, such as land degradation, biodiversity loss, and ecosystem destruction, alongside cascading effects like food insecurity and rural migration-. These impacts underscore the critical need for proactive strategies to prevent land degradation and erosion, aligning with the Ministry of Agriculture and Forestry's broader efforts in this domain. Continuous investment in high-resolution climate, hydrological, and socio-economic data collection and monitoring is crucial to enhance the precision of future risk assessments and support proactive policy interventions.
Areas categorized at the highest risk levels, particularly agricultural lands within İznik, Gemlik, Karamürsel, and Gönen, demand immediate and targeted adaptation interventions. Critical strategic measures include improving irrigation infrastructure, promoting drought-resistant crops, and implementing sustainable soil management practices. Continuous investment in high-resolution climate, hydrological, and socio-economic data collection and monitoring is crucial to enhance the precision of future risk assessments and support proactive policy interventions.

2.4.2 Urgency

This section assesses the urgency of addressing agricultural drought risks in the Southern Marmara Basin, considering when major impacts are anticipated, the expected worsening of the hazard, its nature as a slow-onset or sudden event, and its potential for persistence.
The impacts of agricultural drought in the Southern Marmara Basin are already significantly manifesting, making them an immediate and critical concern. Analysis of historical climate data for the region, particularly during the 1995–2015 reference period, clearly indicates a consistent increase in both the frequency and intensity of drought events, with notable severe episodes already causing significant reductions in agricultural production and economic stability. These historical trends align with observations across Türkiye, where a significant increase in meteorological disaster occurrences has been noted since 2018.
Given current climate projections, major economic, environmental, and social impacts are anticipated to intensify progressively within the short term (next 5 years) and worsen significantly by the medium term (up to 2060). Unmitigated drought conditions are projected to have severe consequences, including reduced crop yields, increased production costs for smallholder farmers, and declining groundwater levels.
The following timelines define the urgency for necessary adaptation actions:

- Immediate (0–5 years):
    - Rapid implementation of improved water management infrastructure and drought-resilient agricultural practices, particularly in the highly exposed target boroughs of İznik, Gemlik, Karamürsel, and Gönen.
    - Establishment and enhancement of early-warning systems for agricultural drought, integrating real-time soil moisture and groundwater monitoring networks to facilitate proactive risk management.
    - Urgent adoption of short-term socio-economic support measures, such as drought insurance schemes and emergency relief programs, aimed at safeguarding vulnerable groups, including smallholder farmers and rural communities.
    - Prioritize research and development (R&D) into integrated drought solutions and drought-resilient species, as identified in national strategies.
- Medium-term (up to 2060):

    - Substantial expansion and modernization of irrigation networks and water management systems to mitigate anticipated severe drought conditions. Türkiye's Water Efficiency Strategy and Action Plan (2023-2033) aims to increase irrigation efficiency to 60% by 2030 and 65% by 2060.
    - Systematic adoption and scaling-up of sustainable soil and water conservation practices, including widespread introduction of drought-resistant crop varieties and advanced agricultural techniques.
    - Continued R&D infrastructure strengthening to measure climate change impacts on agriculture.
    - Development and implementation of a "National Water Reuse Master Plan" and wider adoption of treated wastewater reuse technologies.
- Long-term (2060–2100):
    - Fundamental transformation of agricultural systems to withstand extreme drought conditions projected under higher-emission scenarios (SSP5-8.5).
    - Comprehensive, region-wide policies addressing land degradation risks, land-use planning, and integrated water resource management to sustain agriculture and rural livelihoods in drastically altered climatic conditions.

Agricultural drought in the Southern Marmara Basin is projected to intensify significantly in the near future. Climate projections for the region—consistent with global and national assessments—indicate a sustained rise in both the frequency and severity of extreme drought events, especially during critical crop-growing periods. This trend is closely linked to ongoing warming, which drives more severe drought conditions, reduces overall precipitation, and disrupts rainfall patterns, thereby worsening water shortages and increasing evapotranspiration rates. These changes are expected to heighten soil degradation and diminish agricultural productivity over the medium and long term.

National strategic frameworks, including the Climate Change Mitigation Strategy and Action Plan (2024–2030), recognize Türkiye—situated in the climate-vulnerable Mediterranean Basin—as one of the region's most severely affected by climate change, with drought and other extreme weather events becoming increasingly prevalent. The increasing frequency of these events and their severe socio-economic impacts on key sectors highlight the urgent need for action.
As a slow-onset hazard, agricultural drought develops gradually over months or even years. Unlike sudden disasters such as floods or heavy rainfall, its full impact often emerges only after prolonged exposure, making early detection and proactive management essential.
This characteristic significantly influences the urgency scoring:

- **Delayed Action Amplifies Severity:** The gradual progression of drought can lead to an underestimation of its urgency and a delay in taking necessary actions. This delay, however, can significantly amplify the ultimate severity of impacts, making them harder to reverse or mitigate once fully manifested.
- **Proactive Approach is Paramount:** Despite its slow onset, agricultural drought demands immediate and sustained proactive action. Investments made now in adaptive infrastructure, early-warning systems, and sustainable agricultural practices can significantly reduce future risks and associated economic and social damages. Conversely, delaying intervention substantially diminishes adaptive capacity, increases vulnerability, and magnifies long-term consequences. Therefore, the slow-onset nature of agricultural drought mandates high urgency for early and continuous intervention to prevent widespread, irreversible environmental and socio-economic harm.

Agricultural drought has a significant potential to persist and intensify in the Southern Marmara Basin. Climate projections consistently indicate a continued increase in the frequency and intensity of drought events across the region throughout the medium-term (up to 2060) and long-term (up to 2100) planning horizons, under all considered Shared Socio-Economic Pathways (SSPs). This persistence is driven by ongoing warming trends and altered precipitation patterns that contribute to escalating soil water deficits and water scarcity. National strategies and plans, such as the Water Efficiency Strategy (2023-2033) and the Agricultural Strategic Plan (2024-2028), are explicitly designed with long-term horizons, acknowledging the persistent nature of drought and the need for sustained adaptation efforts beyond immediate concerns. The focus on developing drought-resilient species and long-term water storage solutions within these plans further confirms the expected persistence of this climate hazard.

2.4.3 Capacity

This section assesses the existing and planned capacities to address agricultural drought climate risk in the Southern Marmara Basin. It details the status, adequacy, and specific interventions of current risk management measures across financial, social, human, physical, and natural dimensions.

Existing Climate Risk Management Measures
The Southern Marmara Basin, as part of Türkiye, benefits from various climate risk management measures, though their effectiveness and accessibility vary across different dimensions:

- **Financial Capacity:**
  - Government subsidies and financial incentives are available for improving irrigation systems and adopting water-efficient technologies.
  - Agricultural insurance schemes exist to partially cover drought-related losses, aiming to protect farmers' livelihoods.
  - EU and international funding instruments are utilized for adaptation initiatives, with the AGROSHIELD project receiving support through the CLIMAAX project, which is funded under the Horizon Europe programme.
  - National strategies emphasize developing advantageous financing mechanisms to support waste prevention, reuse, recycling, and water efficiency projects. There are also efforts to provide farmers with access to affordable financing and to develop sustainable investment instruments to support green transformation and energy efficiency projects in industry.
  - National solidarity mechanisms are also present, drawing on examples from other regions where EU funds are used for post-disaster recovery.

- **Social and Human Capacity:**
  - Scientific and operational organizations such as the Turkish State Meteorological Service (TSMS) and TÜBİTAK MAM acontribute expertise to climate-related research, risk monitoring, and assessment.
  - Training programs, awareness campaigns, and multi-stakeholder workshops are organized to enhance local adaptation capacity and strengthen community-based preparedness initiatives. The AGROSHIELD project specifically plans to involve local stakeholders, including farmers, municipal authorities, and agricultural cooperatives, through participatory workshops to co-develop Community Adaptation Action Plans (CAAP).

  - National strategic plans emphasize increasing the number of trained technical personnel and professionals in areas such as carbon management, climate-friendly agriculture, and wetland preservation to enhance scientific, institutional, and human capacity.
  - Awareness-raising activities for Good Agricultural Practices (GAP) and organic farming are being promoted.

- **Physical Capacity:**
  - Existing, though often limited, water management infrastructure, including irrigation networks, is in place. Efforts are ongoing to expand and modernize these systems.
  - Basic early warning systems and monitoring networks exist for specific meteorological and hydrological conditions. Measures to prevent erosion and land degradation in agricultural and pasture lands will be developed.
  - The Water Efficiency Strategy (2023-2033) aims to significantly increase irrigation efficiency to 60% by 2030 and 65% by 2060. This includes converting open irrigation systems to closed systems, renovating old closed systems, expanding automation, and establishing comprehensive measurement and monitoring systems.
  - Focus is placed on strengthening technological infrastructure for the LULUCF (Land Use, Land Use Change, and Forestry) sector, including the development of early warning systems for drought, floods, forest fires, and landslides.
  - Promoting smart agricultural applications leveraging digitalization, artificial intelligence, and data is a key measure.
- **Natural Capacity:**
  - Measures for resource management and ecosystem health are integrated into existing climate risk management. This includes the protection and enhancement of carbon sinks (forests and agricultural lands) for effective climate response.
  - Emphasis is placed on disseminating environmentally friendly agricultural practices, ensuring rational fertilizer use, and reducing methane emissions from animal husbandry.
  - Efforts are underway to increase the effectiveness of land and soil management by promoting practices that reduce land degradation and erosion.
  - Research and development (R&D) for integrated drought solutions is supported, including the development of drought-resistant species and considering biodiversity in afforestation and planting efforts.

Sufficiency of Existing Capacity
While existing climate risk management measures are in place, the region's capacity to fully address the scale and increasing severity of agricultural drought is not yet sufficient. Similar assessments for other regions indicate that existing measures can be fragmented and inadequate.

- The AGROSHIELD project itself is designed to "bridge the gap between regional-scale assessments and localized climate adaptation planning", indicating current limitations.
- Identified information gaps exist regarding high-resolution climate projections specific to the Southern Marmara Basin and the detailed socio-economic data required for comprehensive vulnerability mapping and risk analysis.
- The need for "increased local expertise and capacity development in advanced drought modelling, scenario analysis, and vulnerability mapping methodologies" further underscores areas for improvement.

- Despite investments, significant vulnerabilities persist in physical infrastructure, as evidenced by impacts in other regions from climate events. These impacts are already manifesting, highlighting the urgency for strengthening existing adaptation measures.

Therefore, while a foundation exists, there is a clear and urgent need for substantial reinforcement and improved coordination across all capacities to effectively manage the escalating drought risk.

Specific Interventions Implemented or Planned

The Southern Marmara Basin has several key interventions planned or already underway to significantly mitigate agricultural drought risk and enhance resilience:

- AGROSHIELD Project Initiatives:
    - Conducting High-Resolution Climate Risk Assessments: This involves borough-specific climate modeling in İznik, Gemlik, Karamürsel, and Gönen to identify micro-level drought risks and socio-economic impacts.
    - Co-developing Community Adaptation Action Plans (CAAP): Engaging local stakeholders (farmers, municipal officials, agricultural cooperatives) through participatory workshops to ensure adaptation strategies align with local knowledge and resource capacities.
    - Strengthening Local Climate Resilience Policies: Providing municipalities and policymakers with empirical, high-resolution climate risk data to integrate climate adaptation into local governance and land-use planning.
    - Enhancing Socio-Economic Resilience in Agriculture: Identifying and promoting sustainable agricultural practices, such as improved irrigation efficiency and selection of drought-resistant crops, to reduce economic risks for small-scale farmers and local communities.

2.5 Preliminary Monitoring and Evaluation

The initial phase of the CLIMAAX project, focusing on agricultural drought in the Southern Marmara Basin, has provided valuable insights and learning experiences. This preliminary monitoring and evaluation identify key takeaways, challenges encountered, and areas for future development, building upon the CLIMAAX framework and the project's objectives."

What was learned and difficulties encountered: The project successfully initiated a comprehensive climate risk assessment, identifying agricultural drought as the critical hazard for the Southern Marmara Basin. Applying the CLIMAAX framework, we effectively structured the analysis by integrating hazard, exposure, and vulnerability data. This systematic approach proved crucial for understanding the complex interplay of factors contributing to drought risk. However, significant challenges were encountered in obtaining the necessary granularity of data for micro-level assessment. Specifically, there is a continued need for higher-resolution climate projections tailored precisely to the Southern Marmara Basin, as well as more detailed socio-economic data on income distribution and rural employment patterns to refine vulnerability mapping. The availability of real-time soil moisture and groundwater monitoring data also presented a challenge, which is essential for developing dynamic drought forecasting and early warning systems. Furthermore, building local expertise and capacity in advanced drought modelling, scenario analysis, and vulnerability mapping methodologies was identified as an area requiring further development. These data and capacity gaps highlight the complexities inherent in translating regional-scale methodologies to highly localized contexts.

Stakeholder Feedback and Next Steps: Initial steps for stakeholder involvement have emphasized the importance of engaging a diverse range of actors, including governmental bodies, non-governmental organizations, citizens, the private sector, and academia, to ensure inclusive participation. Preliminary consultations revealed strong interest from local governments, agricultural cooperatives, and farmers in obtaining actionable insights and tools for drought management-. The feedback received underscored the critical need for practical guidelines and decision-support tools, such as the planned Southern Marmara Basin Climate Risk Atlas, to aid localized adaptation planning. For the next iteration of the analysis, continued and expanded engagement with these stakeholders, especially through participatory workshops for co-developing Community Adaptation Action Plans (CAAPs), remains a priority to ensure the strategies align with local knowledge and resource capacities."

New Data Availability and Further Needs: While existing national datasets from institutions like TSMS and TÜBİTAK MAM, along with international sources like ERA5 and CHIRPS, have formed the basis of this phase, the need for more granular data persists. Moving forward, efforts will focus on integrating newly available high-resolution local climate data and socio-economic indicators as they become accessible. The ongoing development of Türkiye's first full-scale global climate model by TÜBİTAK represents a significant future resource that could provide highly valuable data for regional climate projections and impact studies, contributing to enhanced national research capabilities.

2.6 Work plan

Phase 2: Refinement of the CRA using high-resolution local data

- **Data Collection:** Gather high-resolution local environmental data
- **Micro-Level Vulnerability Index:** Analyze the data to identify micro-hotspots and refine the risk models.
- **Socio-economic Impact Assessment:** Quantify the potential socio-economic impacts of drought at the local level, focusing on smallholder income losses and community vulnerabilities.

Phase 3: Co-Creation of Community Adaptation Action Plans (CAAPs)
Main Activities:

- Work with local stakeholders (farmers, cooperatives, municipalities) to co-develop adaptation strategies that are practical and relevant to the region's specific needs.
- **Policy Integration:** Work with local authorities to embed findings into adaptation plans, land-use policies, and water management decisions.
- **Stakeholder Engagement:** Ensure that adaptation plans are communicated effectively and integrated into local government processes for long-term implementation.

3 Conclusions Phase 1- Climate risk assessment

The first phase of the **AGROSHIELD Project**, focused on the **Climate Risk Assessment (CRA)** for agricultural drought in the Southern Marmara Basin, has provided valuable insights into the vulnerability of the region's agricultural sector to climate change. This phase, utilizing the **CLIMAAX Methodology**, involved detailed assessments of agricultural drought risks at the borough level for İznik, Gemlik, Karamürsel, and Gönen. The phase has highlighted key risks, challenges, and potential adaptation strategies necessary for strengthening the resilience of local agricultural systems.

Main Conclusions

1. **High Vulnerability of Agriculture to Drought**:

- The Southern Marmara Basin is highly vulnerable to agricultural drought, with significant risks to key crops such as **maize**, **rice**, **tomatoes**, **watermelon**, and **olives**. Climate projections indicate increasing frequency and intensity of drought events, especially during critical growing periods. The region faces a future where water scarcity, rising temperatures, and changing precipitation patterns will exacerbate crop losses and economic instability.

2. **Regional Disparities in Vulnerability**:
   - Vulnerability assessments revealed considerable spatial variability across the target boroughs. **Gönen** and **Karamürsel** were identified as the most vulnerable regions, particularly due to their reliance on water-intensive crops and insufficient irrigation infrastructure. In contrast, **İznik** and **Gemlik**, although less exposed, still face significant risks due to the potential for heatwaves and drought impacts on perennial crops like **olives** and **peaches**.
3. **Climate Risks Compounded by Socio-Economic Factors**:
   - The region's agricultural vulnerability is compounded by socio-economic challenges, such as limited adaptive capacity, outdated irrigation systems, and high dependency on water-intensive crops. Smallholder farmers in particular are at a disadvantage due to their limited access to modern irrigation technologies and financial resources to shift to drought-resistant crops.
4. **Preliminary Key Findings**:
   - **Severity**: Agricultural drought poses a severe and escalating risk to the region, with crop yields expected to decrease significantly under **RCP 8.5** projections, particularly for **maize** and **rice** in **Gönen**.
   - **Urgency**: Immediate adaptation actions are required, particularly in **Gönen** and **Karamürsel**, to mitigate drought impacts. Early intervention through infrastructure modernization, improved irrigation systems, and drought-resistant crop adoption is critical.
   - **Capacity**: The region's adaptive capacity remains a significant challenge. There is an urgent need to strengthen local capacities for drought management, particularly through the modernization of irrigation systems, training for farmers, and the development of alternative crop strategies.
5. **Challenges Addressed and Not Addressed**:
   - **Addressed**: The CRA provided a comprehensive assessment of agricultural drought risks, integrating climate data, socio-economic factors, and crop-specific vulnerability. The engagement of local municipalities and stakeholders in the process laid a solid foundation for future adaptation planning.
   - **Not Addressed**: The project has not yet fully explored the potential for integrating broader regional water management strategies. Further studies on **water reuse**, **irrigation efficiency**, and **policy frameworks** to address water competition between sectors (agriculture, industry, and households) are required in future phases.
6. **Key Next Steps**:
   - The next phase will focus on co-designing **Community Adaptation Action Plans (CAAPs)** with local stakeholders. These plans will translate the findings from this assessment into actionable strategies for reducing vulnerability and enhancing resilience at the community level.
   - Further research will be required to fill data gaps, particularly regarding **high-resolution climate projections** for the region and **socio-economic data** on farmers' adaptive capacity. The integration of **real-time monitoring systems** for soil moisture and groundwater will also be a priority for the next phase.

Key Takeaways

- The **Southern Marmara Basin** is facing increasing agricultural drought risks due to climate change, with regions like **Gönen** and **Karamürsel** being particularly vulnerable.
- **Adaptation actions** focusing on modernizing irrigation systems, introducing drought-resistant crops, and strengthening local governance and planning are urgently needed to mitigate these risks.

In conclusion, the **Phase 1 Climate Risk Assessment** has successfully identified the critical climate risks facing agriculture in the Southern Marmara Basin. However, addressing these challenges will require continued engagement, targeted adaptation measures, and the involvement of all relevant stakeholders to ensure a resilient agricultural future.

4 Progress evaluation and contribution to future phases

Table 4-1 Overview key performance indicators

Key performance indicators	*Progress*
Climaax Agricultural Drought Workflow Implemented	Agricultural Drought Workflow implemented successfully
Regional High Resolution Risk Assessment Conducted	High resolution risk assessment will be implemented under Phase 2
Organization of Community Workshops for Adaptation Planning	Workshops will be organized under Phase 3
Community Adaptation Action Plans Developed	CAAPs will be developed under Phase 3
Stakeholders Actively Engaged	Municipal authorities engaged on local level; other stakeholder groups will be engaged in future phases

Table 4-2 Overview milestones

Milestones	*Progress*
M1: Climaax Agricultural Drought Workflow Implemented	Completed
M2: Climaax Workshop in Barcelona Attended	Completed
M3: High Resolution Climate Risk Assessments Implemented	To be completed under Phase 2
M4: Community Adaptation Action Plans Drafted	To be completed under Phase 3
M5: Climaax Workshop in Brussels Attended	To be completed under Phase 2
M6: Final Consultations and Policy Recommendations and Finalization of CAAPs	To be completed under Phase 3

5 Supporting documentation

Key outputs produced under Phase 1 are summarized below under different categories:

Main Report: AGROSHIELD Phase 1 Climate Risk Assessment Report (PDF/Word)

Visual Outputs

- **Gönen Scenario 1**
  - Balıkesir_AWC_45.png
  - Balıkesir_ET0_45.png
  - Balıkesir_Precipitation_45.png
  - Balıkesir_Maize_yield_loss_45.png
  - Balıkesir_Rice_yield_loss_45.png
  - Balıkesir_Tomatoes_yield_loss_45.png
  - Balıkesir_Watermelon_yield_loss_45.png
  - Balıkesir_MAIZ_revenue_loss_EUR_45.png
  - Balıkesir_RICE_revenue_loss_EUR_45.png
  - Balıkesir_TOMATOES_revenue_loss_EUR_45.png
  - Balıkesir_WATERMELON_revenue_loss_EUR_45.png
- **Gönen Scenario 2**
  - Balıkesir_AWC_85.png
  - Balıkesir_ET0_85.png
  - Balıkesir_Precipitation_85.png
  - Balıkesir_Maize_yield_loss_85.png
  - Balıkesir_Rice_yield_loss_85.png
  - Balıkesir_Tomatoes_yield_loss_85.png
  - Balıkesir_Watermelon_yield_loss_85.png
  - Balıkesir_MAIZ_revenue_loss_EUR_85.png
  - Balıkesir_RICE_revenue_loss_EUR_85.png
  - Balıkesir_TOMATOES_revenue_loss_EUR_85.png
  - Balıkesir_WATERMELON_revenue_loss_EUR_85.png
- **Karamürsel Scenario 1**
  - Kocaeli_AWC_45.png
  - Kocaeli_ET0_45.png
  - Kocaeli_Precipitation_45.png
  - Kocaeli_Tomato_yield_loss_45.png
  - Kocaeli_Cherry_yield_loss_45.png
  - Kocaeli_Peach_yield_loss_45.png
  - Kocaeli_Olive_yield_loss_45.png
  - Kocaeli_Tomato_revenue_loss_EUR_45.png
  - Kocaeli_cherry_revenue_loss_EUR_45.png
  - Kocaeli_peach_revenue_loss_EUR_45.png
  - Kocaeli_olive_revenue_loss_EUR_45.png
- **Karamürsel Scenario 2**
  - Kocaeli_AWC_85.png
  - Kocaeli_ET0_85.png
  - Kocaeli_Precipitation_85.png
  - Kocaeli_Tomato_yield_loss_85.png
  - Kocaeli_Cherry_yield_loss_85.png
  - Kocaeli_Peach_yield_loss_85.png
  - Kocaeli_Olive_yield_loss_85.png
  - Kocaeli_Tomato_revenue_loss_EUR_85.png
  - Kocaeli_cherry_revenue_loss_EUR_85.png

  - Kocaeli_peach_revenue_loss_EUR_85.png
  - Kocaeli_olive_revenue_loss_EUR_85.png
- **Gönen Scenario 1**
  - Bursa_AWC_45.png
  - Bursa_ET0_45.png
  - Bursa_Precipitation_45.png
  - Bursa_Cherry_yield_loss_45.png
  - Bursa_Fig_yield_loss_45.png
  - Bursa_Olive_yield_loss_45.png
  - Bursa_Walnut_yield_loss_45.png
  - Bursa_CHERRY_revenue_loss_EUR_45.png
  - Bursa_FIG_revenue_loss_EUR_45.png
  - Bursa_OLIVE_revenue_loss_EUR_45.png
  - Bursa_WALNUT_revenue_loss_EUR_45.png
- **Gönen Scenario 2**
  - Bursa_AWC_85.png
  - Bursa_ET0_85.png
  - Bursa_Precipitation_85.png
  - Bursa_Cherry_yield_loss_85.png
  - Bursa_Fig_yield_loss_85.png
  - Bursa_Olive_yield_loss_85.png
  - Bursa_Walnut_yield_loss_85.png
  - Bursa_CHERRY_revenue_loss_EUR_85.png
  - Bursa_FIG_revenue_loss_EUR_85.png
  - Bursa_OLIVE_revenue_loss_EUR_85.png
  - Bursa_WALNUT_revenue_loss_EUR_85.png

6 References

1- Republic of Türkiye Ministry of Agriculture and Forestry, General Directorate of Water Management Marmara Basin Drought Management Plan/2023