Eastern Anatolia Development Region (TRB2) Climate Change Risk and Vulnerability Analysis



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DEVELOPMENT AGENCY



PATHWAYS2RESILIENCE

September 2026

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EADA – September 2026

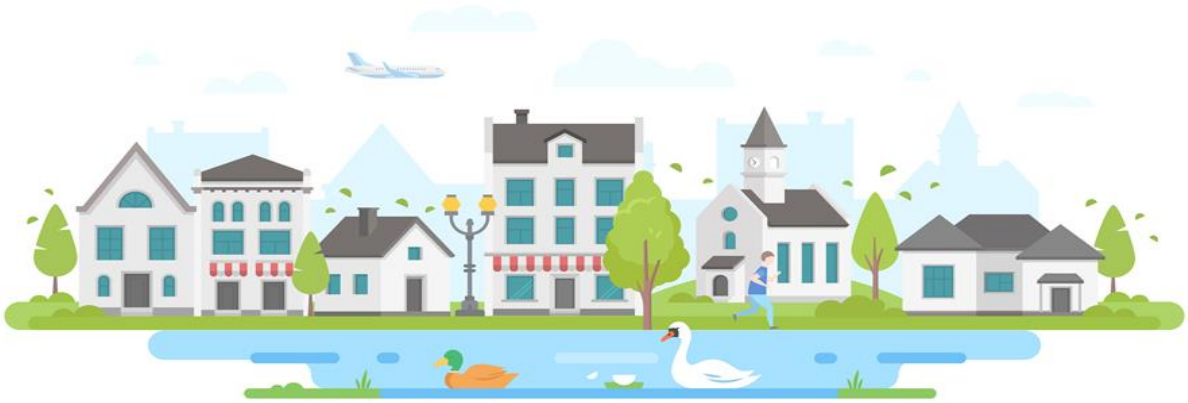


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Definitions

Evapotranspiration: The process of water changing into vapour through both evaporation and transpiration.

Evaporation: The transformation of water from its liquid state to vapour from surfaces such as soil, water bodies, and plant surfaces.

Transpiration: The release of water vapour through small openings called stomata in the leaves of plants.

Meteorological Drought: Based on precipitation, it is defined as a period during which rainfall falls below the normal values for an extended period.

Agricultural Drought: The lack of sufficient water in the soil to meet the needs of plants. It is not defined solely by low rainfall. Even if precipitation is low in a region, if there is enough water in the soil to support plant growth in the root zone, agricultural drought is not considered to occur.

Hydrological Drought: Defined as the decrease in water levels in rivers, lakes, and groundwater resources. Hydrological measurements are not typically the first indicators of drought because there is a time lag between the reduction in rainfall and snow levels and the shortage of water in rivers, streams, and reservoirs. Hydrological drought can persist long after meteorological drought has ended.

Socio-economic Drought: Relates to the supply and demand of certain economic products associated with meteorological, hydrological, and agricultural droughts. Socio-economic drought occurs when reduced rainfall leads to a situation where production cannot meet demand.

Heatwave: A prolonged period of unusually hot weather. There are various approaches to defining a heatwave. However, in general, a heatwave is defined by air temperature thresholds and the duration of the high temperatures (measured in consecutive days). The most common definition of a heatwave is a sequence of several days during which the maximum air temperature exceeds a specified threshold.

Exposure: The degree to which a person, community, or infrastructure system is exposed to future climate hazards.

Vulnerability: The propensity or predisposition of a person, community, ecosystem or infrastructure system to be adversely affected by climate hazards.

Urban Heat Island Effect: The phenomenon of increased surface energy imbalance in urban areas due to urbanization, where the urbanized surface retains more heat energy.

RCP: Representative Concentration Pathways, which are time-series scenarios detailing the changing concentrations of greenhouse gas emissions in the atmosphere.

Adaptative Capacity: The capacity of a system or individuals to modify their characteristics or behaviours in order to enhance their ability to cope with future climate hazards.

Acronyms

Abbreviation / acronym	Description
AFAD	Turkish Disaster and Emergency Management Authority
SECAP	Sustainable Energy and Climate Change Action Plan
CDP	Carbon Disclosure Project
CDS	Copernicus Data Store
CLIMAAX	Climate Adaptation and Risk Assessment Methodology
CORDEX	Coordinated Regional Climate Downscaling Experiment
CRA	Climate Risk Assessment
CRM	Climate Risk Management
ÇŞİDB	Ministry of Environment, Urbanization, and Climate Change
DRMKC	Disaster Risk Management Knowledge Centre
ET_o	Reference Evapotranspiration
FWI	Fire Whether Index
GAEZ	Global Agro-Ecological Zones
GCM	Global Climate Model
GCoM	Global Covenant of Mayors for Climate and Energy
GIS	Geographic Information System
HDD/CDD	Heating Degree Days / Cooling Degree Days
HWI	Heatwave Index
LST	Land Surface Temperature
MapSPAM	Spatial Production Allocation Model
MGM	Turkish General Directorate of Meteorology
MPI-ESM-LR	Max Planck Institute Earth System Model - Low Resolution
NUTS	Nomenclature of Territorial Units for Statistics
RCP	Representative Concentration Pathways
SPEI	Standard Precipitation Evapotranspiration Index
SSP	Shared Socioeconomic Pathways
UHI	Urban Heat Island
UTCI	Universal Thermal Comfort Index
WASP	Weighted Anomaly of Standardized Precipitation
WorldPop	Global population dataset developed by the University of Southampton

Executive Summary

The Climate Change Risk and Vulnerability Analysis of the Eastern Anatolia Development Region (TRB2) was prepared within the framework of the Pathways to Resilience (P2R) project to strengthen the capacity of the TRB2 Region—comprising Bitlis, Hakkâri, Muş and Van—to understand, assess and manage climate-related risks. The assessment provides an evidence-based basis for climate adaptation and resilience planning by combining stakeholder knowledge with qualitative risk and vulnerability assessment and quantitative, data-driven climate analysis. By bringing together stakeholder assessments and quantitative climate analyses, the report provides an important foundation for the P2R process and establishes a common evidence base for the subsequent development of the region's resilience vision, adaptation pathways and investment portfolio.

The qualitative analysis applied the Global Covenant of Mayors (GCoM) Common Reporting Framework and incorporated the results of four stakeholder surveys covering current and future climate hazards, sectoral impacts and vulnerabilities, adaptive capacity, and climate finance and investment opportunities. The participatory process was complemented by a regional stakeholder workshop held on 16 July 2026, bringing together 100 participants from 34 institutions. The workshop examined enabling conditions for climate adaptation, including data and technology, institutional capacity and competencies, behavioural change, innovation and strategic learning.

The qualitative assessment identified drought, extreme heatwaves/urban heat island effects, heavy rainfall and flooding, and heavy winter conditions as key climate risks for the region. Drought and heatwaves are expected to increase in severity and likelihood over the 2030–2050 period. Drought presents particularly significant risks to agriculture, livestock and fisheries, and energy and water supply, while extreme heat is expected to affect agriculture, public health, and energy and water systems. Heavy rainfall and flooding are also projected to increase, with agriculture, settlements and transportation among the most affected sectors. In contrast, heavy winter conditions, frost and avalanches are generally expected to remain at similar severity levels while their likelihood decreases over the longer term.

The sectoral vulnerability assessment indicates that agriculture and energy/water supply have particularly high vulnerability to drought, with significant investment requirements for adaptation. Extreme heat also creates high risks for agriculture and energy and water supply, while public health faces moderate impacts. Heavy winter conditions pose a high risk to transportation, whereas heavy rainfall and flooding create moderate impacts across agriculture, transportation and housing/settlements. These findings demonstrate the need to integrate climate risk considerations into regional infrastructure, water management, agricultural planning and public service delivery.

The quantitative assessment focused on heatwaves, agricultural drought and heavy winter conditions, using CLIMAAX workflows, regional MGM observations and climate projections, Copernicus Climate Change Service data and MED-CORDEX datasets. The additional Van analysis compares 2021–2025 with 2046–2050 using MPI Earth System Model projections under RCP8.5, adjusted against observed data through empirical quantile mapping. Urban heat exposure was assessed separately

by combining Landsat-8 land surface temperature with WorldPop population data and the locations of hospitals, schools and community facilities.

The bias-adjusted Van projections indicate increases of approximately 1.5°C in average minimum temperature and 1.7°C in average maximum temperature. Annual precipitation decreases from 345.1 to 283.2 mm (17.9%), while reference evapotranspiration (ET_0) increases from 1,206.2 to 1,269.5 mm (5.2%). Together with lower relative humidity and reduced rainfall in several spring and summer months, these results indicate greater pressure on soil moisture, agricultural water availability and heat exposure. They describe changes in average climatic conditions; heatwave frequency, duration and intensity require analysis of individual daily temperature extremes.

The agricultural drought assessment, based on the CLIMAAX agricultural drought workflow, quantified potential crop yield and economic losses resulting from insufficient irrigation. For 2050, potential yield losses under irrigation deficit and rainfall-dependent conditions were estimated at approximately 21% for sugar beet, 10% for wheat and 34% for maize. Across the major crops assessed, potential agricultural revenue losses could exceed EUR 146 million if irrigation resources become insufficient. These results underline the importance of water-use efficiency, sustainable irrigation, drought-resilient agricultural practices and targeted investment in vulnerable agricultural areas.

A complementary wheat case study for Van estimates net irrigation requirements from crop evapotranspiration ($ETc = Kc \times ET_0$) and effective precipitation, with negative monthly deficits set to zero. The reported annual net requirement increases from 488 mm in 2021–2025 to 574 mm in 2046–2050, approximately 17.7%, with the largest monthly requirements in May and June. This case study illustrates how higher crop water demand and lower effective rainfall can increase supplementary irrigation needs. It is not a region-wide estimate or a forecast of actual water abstraction; withdrawals would also depend on irrigated area, irrigation efficiency and conveyance losses.

The heavy winter conditions assessment indicates that the probability of daily snowfall exceeding 6 cm and 25 cm is projected to decrease by approximately 2–4% by 2050 compared with current conditions. Nevertheless, this change may have implications for the water balance of the Van Lake Closed Basin. The probability of blizzard conditions is expected to remain broadly similar to current levels, with no significant increase or decrease projected.

Historical flood records complement the projection analyses by showing that damaging flooding can occur with daily rainfall of approximately 40–50 mm, especially when rainfall interacts with rapid snowmelt, steep catchments and drainage limitations. Flood adaptation therefore needs to consider catchment processes, exposed settlements and infrastructure capacity alongside rainfall intensity.

As the first systematic climate risk and vulnerability assessment covering all four provinces of the TRB2 Region, the report is intended to provide a comprehensive analytical foundation for the P2R process. Its scope and findings should therefore be considered in conjunction with the Project Proposal and the P2R TRB2 Regional Analytical Profile, with further development of the analysis where necessary to ensure that all potentially relevant climate risks, sectors, vulnerable groups and

spatial dimensions are adequately captured. This comprehensive evidence base will be important for translating the assessment findings into a regional resilience vision, prioritised adaptation pathways and a climate-resilient investment portfolio.

The additional projections are indicative planning evidence based on one model and scenario and five-year mean daily profiles. Empirical quantile mapping adjusts the reference distributions but assumes that their bias relationship remains applicable in the future; the implementation caps values outside the model reference range at observed extrema and does not explicitly preserve the modelled climate change signal. Further assessment using individual daily series, longer reference periods and multiple models should support decisions requiring estimates of extremes or detailed water allocation.

Overall, the assessment demonstrates that water scarcity, agricultural drought, increasing heat exposure and associated sectoral vulnerabilities should be central considerations in TRB2 climate resilience planning. The findings provide a common evidence base for developing targeted adaptation measures, strengthening institutional and technical capacity, improving climate information and early-warning systems, enhancing water and agricultural management, and directing investments towards the sectors and locations most exposed to future climate risks.



1. Climate Hazards and Impacts

Global climate change refers to the rise in Earth's average surface temperatures and the changes in climate caused by the rapid increase in greenhouse gas emissions into the atmosphere as a result of human activities such as fossil fuel combustion, land use changes, deforestation, and industrial processes. This process strengthens the natural greenhouse effect.

CO2 produced by human activities is the main driver of global warming. By 2020, its concentration in the atmosphere had increased by 48% compared to pre-industrial levels. The period from 2011 to 2020 was the hottest decade ever recorded. A 2°C rise in global average temperatures compared to pre-industrial times is expected to have serious negative impacts on the natural environment, human health, and well-being.

Combatting climate change and adapting to a warming world is a global priority. In some regions, extreme weather events and rainfall are becoming more frequent, while in others, extreme heatwaves and droughts are observed. Climate change is a significant threat, and its consequences affect various aspects of our lives, including:

- Climate hazards (drought, wildfires, sea level rise, heatwaves, floods, etc.)
- Social threats (health, vulnerable community groups, employment, education, etc.)
- Business threats (infrastructure and buildings, energy, agriculture, insurance, tourism, etc.)

The Paris Agreement aims to keep the global average temperature rise below 2°C and to strive to limit it to 1.5°C. Türkiye has signed the Paris Agreement and declared its target to reach Net Zero Emissions by 2053. In this framework, local governments are also preparing Sustainable Energy and Climate Change Action Plans to achieve the net-zero emissions target and protect urban life from climate risks.

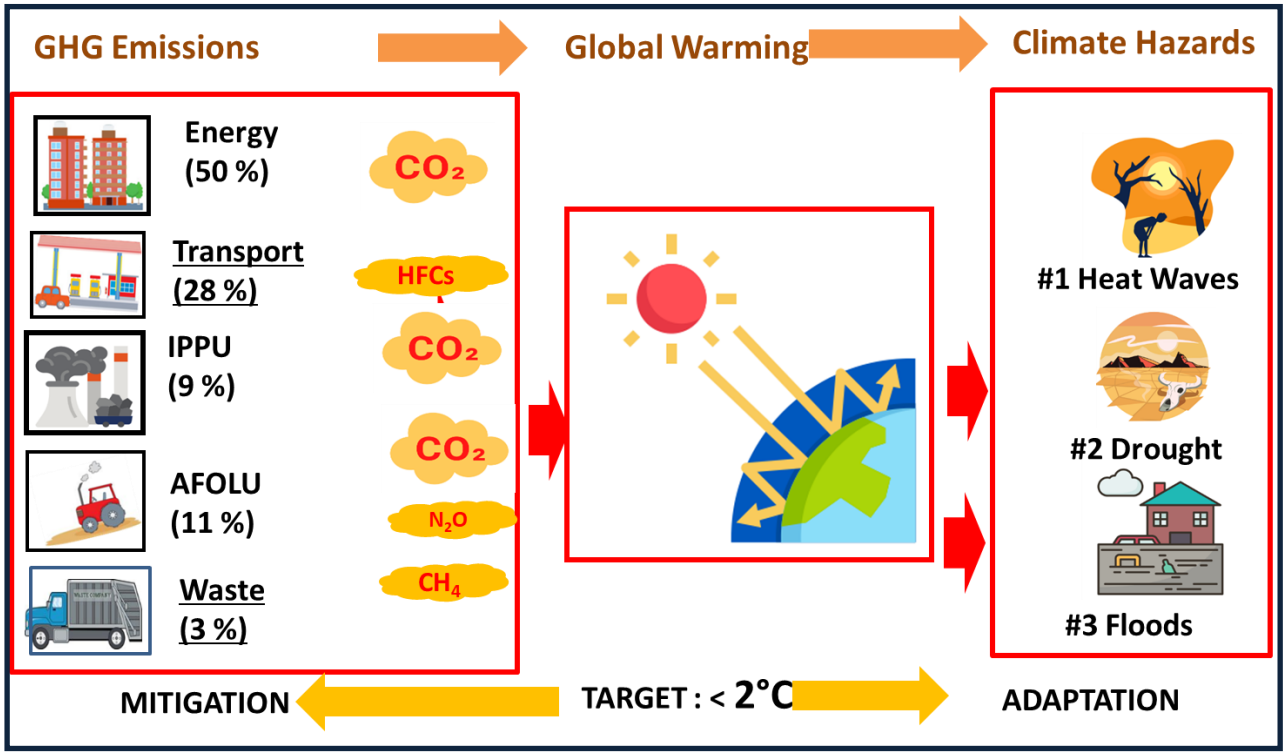


Figure 1: Global Warming and Climate Change - Causes and Consequences

The importance of climate change in cities is emphasized through the process of Sustainable Energy and Climate Action Planning. This process serves as a key tool for local governments to prepare, implement, and periodically review strategies to achieve the net-zero emissions target. It also plays a crucial role in planning adaptation activities to protect cities from the effects of extreme climate hazards. By recognizing the significance of climate change in urban areas, this planning process becomes effective in shaping strategies that address both mitigation and adaptation needs in urban environments.

The Pathways to Resilience (P2R) project aims to strengthen the climate resilience of the TRB2 Region (Van, Muş, Bitlis and Hakkâri) by improving the capacity of local and regional stakeholders to understand, assess and manage climate-related risks. The project follows a participatory and evidence-based approach, bringing together public institutions, municipalities, universities, civil society organisations, private-sector representatives and other relevant stakeholders.

A key component of P2R is the preparation of a set of technical and strategic deliverables that provide a common evidence base for climate resilience planning. These deliverables focus on identifying major climate hazards and their potential impacts, assessing exposure and vulnerability, identifying priority risks and resilience needs, and translating the findings into practical adaptation and risk-reduction pathways for the region.

On 16 July 2026, a workshop was held with 100 participants representing 34 different institutions from the TRB2 Region. The purpose of the workshop was to analyse, through stakeholder participation, the strengths, areas for improvement, external threats and opportunities of the region in terms of its available data, information and technological infrastructure; existing institutional capacity, technical infrastructure and areas of expertise; behaviours, practices and habits that support climate change adaptation; and innovative practices, pilot projects and learning mechanisms. The findings of this participatory assessment will contribute to shaping the region's climate change adaptation strategies.

The workshop was organised around four thematic groups: water resources, agriculture, ecosystems and health. During the thematic group table discussions, the "Enabling Conditions" for climate change adaptation and risk management were examined individually. For each enabling condition, participants assessed the region's strengths and weaknesses, as well as potential threats and opportunities, using a brainstorming approach. The views and recommendations generated during the discussions were documented for further integration into the P2R process. The Enabling Conditions addressed during the workshop were:

- Data, information and technology
- Institutional capacity and competencies
- Behavioural change
- Innovation and strategic learning

Table 1: General Profile of TRB2 Region

Cities	Bitlis Municipality, Hakkari Municipality, Muş Municipality and Van Metropolitan Municipality
Geographical Boundary	TRB2- Eastern Anatolia Development Region
Area	41,558 km² (Total of TRB2)
Population (2025)	2,141,244 (Total of TRB2)
City's Economic Structure	Livestock, Agriculture, Fishery, Services
City's Climate Class	Dsb (Cold Winter, Dry Warm Summer)
Heating Degree Days (HDD)	(2025) HDD = 3005 (T≤15 ^{o}C) (Average of TRB2)
Cooling Degree Days (CDD)	(2025) CDD = 279 (T>22 ^{o}C) (Average of TRB2)
Annual Precipitation, mm	Bitlis=1056 mm, Hakkari=685 mm, Muş=605 mm, Van=345 mm
Heavy Rainfall, mm/24h - Bitlis	96 mm (15.12.2013); 95 mm (26.10.2018); 90 mm (4.3.2025)
Heavy Rainfall, mm/24h-Hakkari	90 mm (20.11.2023), 85 mm (23.4.2011), 82 mm (8.12.2025)
Heavy Rainfall, mm/24h- Muş	86 mm (22.02.2004), 68 mm (26.10.2015), 60 mm (15.12.2016)
Heavy Rainfall, mm/24h- Van	122 mm (27.2.2014), 48 mm (26.10.2016), 46 mm (20.3.2024)
Annual Evapotranspiration	Bitlis=990 mm, Hakkari=1057 mm, Muş=980 mm, Van=1206 mm
Maximum Temperature (2025)	Bitlis=36.1 ^{o}C ; Hakkari= 37.7 ^{o}C ; Muş=38.9 ^{o}C : Van=36.3 ^{o}C
Hot Days T>30 ^{o}C (2025)	Bitlis=55 days ; Hakkari= 67 days ; Muş=83 days; Van= 43 days
Very Hot Days T>35 ^{o}C (2025)	Bitlis=2 days ; Hakkari= 27 days ; Muş=42 days; Van= 1 day
Minimum Temperature (2025)	Bitlis=-24.4 ^{o}C ; Hakkari=-15.4 ^{o}C; Muş=-20.4 ^{o}C; Van=-16.4 ^{o}C
Heavy Winter Days<-10 ^{o}C	Bitlis=25 days ; Hakkari= 12 days ; Muş=13 days; Van= 8 day
Land Use	Cropland:20%, Grasslands:53%, Forestland: 9%, Waterland:9%, Other:9%

(1) Source: Updated Köppen-Geiger climate map of the World (https://people.eng.unimelb.edu.au/mpeel/koppen.html)

(2) Source: General Directorate of Meteorology (https://www.mgm.gov.tr)



2. Qualitative Risk and Vulnerability Analysis

2.1. Applied Methodology

The **Global Covenant of Mayors for Climate and Energy (GCoM) Common Reporting Framework** was used for climate risk assessments.

GCoM is the world's largest city and local government alliance, supporting voluntary actions for a low-emission, climate-resilient future.

EADA P2R Project Team conducted 4 surveys to assess potential climate hazards, current and future climate risks, and sectoral impacts. Surveys were shared with internal and external stakeholders via Google Forms. Results were first reviewed internally and later at the **EADA Stakeholder Workshop** held on July 2026.

Survey Objectives:

- **Survey 1:** Identify current and future climate hazards for TRB2 Region.
- **Survey 2:** Assess negative impacts of climate hazards on urban service sectors and vulnerable community groups.
- **Survey 3:** Evaluate climate hazards' effects on service sectors, current adaptive capacity, and sectoral vulnerabilities.
- **Survey 4:** Climate finance and investment opportunities and challenges

Key Climate Hazards Evaluated:

Excluding events like sea level rise, monsoon rains, and typhoons, which are irrelevant for TRB2, the following hazards were assessed:

- Heavy Rainfall – Flooding
- Hailstorms
- Storms – Tornadoes
- Fog
- Severe Winter Conditions – Cold Waves

- Heat Waves – Urban Heat Islands
- Drought
- Forest Fires
- Soil Salinization – Degradation
- Landslides
- Avalanches
- Waterborne and Airborne Diseases
- Vector-Borne Diseases
- Pest Invasions

Sectors and Services Evaluated:

- Energy and Water Supply
- Transportation and Communication
- Food – Agriculture – Forestry
- Waste Management – Wastewater
- Industry – Commerce – Tourism
- Housing – Residential Areas
- Education
- Health Systems – Public Health
- Emergency Management

Vulnerable Population Groups Evaluated:

- Elderly (>65 years)
- Patients
- Disabled Individuals
- Youth/Students
- Children
- Women
- Migrants
- Rural/Small Producers
- Outdoor Workers
- Agricultural Labourers

The results of the surveys and the risk and vulnerability analysis are presented in Tables 2, 3, and 4.

Table 2: Climate Hazards and Potential Impacts

Climate Hazards	Impact Description	Most Affected Sectors	Affected Vulnerable Groups
Heavy Rainfall and Floods	Surface flooding due to excessive rainfall, submerging transport lines, residential areas, and agricultural lands.	Food, Agriculture, Forestry; Transport; Wastewater; Housing	Poor; Disabled; Migrants; Small Producers
Storms/Tornadoes	Roof damage due to extreme wind; damage to saplings during the flowering season.	Transport; Food, Agriculture, Forestry; Housing	Disabled; Small Producers; Elderly
Cold	Disruption of transport and	Food, Agriculture,	Elderly; Small Producers;

Wave/Frost Hazard	energy/water supply due to extreme winter conditions; reduced agricultural yield due to spring frosts.	Forestry; Transport; Education; Public Health	Chronically Ill; Poor
Extreme Heat Wave/Urban Heat Island	Life-threatening conditions for the chronically ill, elderly, and poor; forest fires; reduction in agricultural and livestock production.	Food, Agriculture, Forestry; Public Health; Energy & Water Supply; Industry, Trade, Tourism	Elderly; Agricultural Workers; Outdoor Workers; Chronically Ill; Small Producers; Poor
Drought	Reduced agricultural production, soil salinization due to excessive irrigation, decreased energy production and water reserves.	Food, Agriculture, Forestry; Energy & Water Supply; Public Health; Industry, Trade, Tourism	Small Producers; Poor; Chronically Ill; Elderly
Soil Desertification /Degradation	Decline in agricultural yield; excessive fertilizer consumption.	Food, Agriculture, Forestry; Energy & Water Supply; Industry, Trade, Tourism	Small Producers; Poor
Insect Infestation	Reduced agricultural yield due to locust infestation.	Food, Agriculture, Forestry; Public Health; Housing	Small Producers; Poor
Airborne and Waterborne Diseases	Life-threatening risk for chronically ill and elderly individuals due to diseases transmitted through air or water.	Public Health; Food, Agriculture, Forestry; Emergency Management; Education	Elderly; Chronically Ill; Children under 5 years old
Vector-Borne Diseases	Life-threatening risk for chronically ill and elderly due to diseases transmitted through insects.	Public Health; Emergency Management; Food, Agriculture, Forestry	Elderly; Chronically Ill; Children under 5 years old; Students
Forest Fires	Reduction in forest areas; fire hazards and life threats for settlements near forests; decline in bee and insect populations; threats to wildlife.	Food, Agriculture, Forestry; Emergency Management; Energy & Water Supply; Housing	Small Producers; Poor; Disabled; Elderly
Hailstorm	Crop damage during flowering season due to heavy hail; vehicle damage.	Food, Agriculture, Forestry; Transport	Small Producers

Fog	Disruption of air traffic due to dense fog.	Transport	Disabled
Landslides	Transport disruptions; risk of building collapse in landslide-prone areas.	Housing	Poor
Avalanche	Life-threatening risk for locals and tourists; disruption of transportation.	Transport; Tourism; Housing	Disabled

2.2. Current Situation Analysis of Climate Hazards

The potential risks currently posed by climate hazards in the TRB2 Region were assessed through Survey 1 with the participation of 25 stakeholders. Climate risks were evaluated using a two-dimensional matrix based on the magnitude and likelihood of each hazard. As a result, drought was classified as a high risk, while extreme heatwaves and the urban heat island effect, heavy winter conditions, and heavy rainfall were classified as moderate risks. These hazards were identified as priorities for the region.

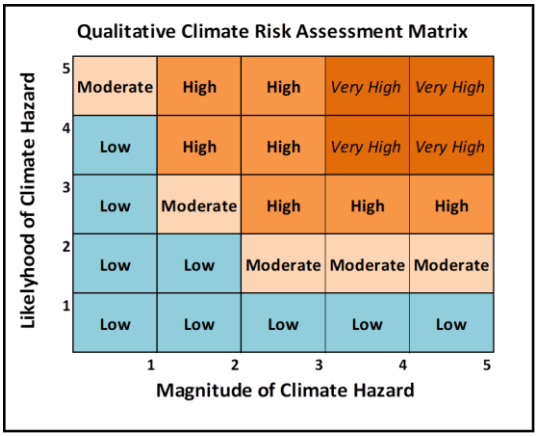


Table 3: Current Situation Analysis of Climate Hazards

Climate Hazard	Current Situation	Magnitude (m: 0-5)	Likelihood (p: 0-5)	Risk Level
Heavy Rainfall and Flooding	Currently affecting the region, expected to increase	2.3	1.6	Moderate
Storms/Tornadoes	Currently not affecting, not expected to increase	0.9	1.0	Low
Heavy Winter Conditions	Currently affecting the region, expected to decrease	2.9	1.2	Moderate
Extreme Heat Waves/Urban Heat Island	Currently affecting the region, expected to increase	1.9	2.3	Moderate

Drought	Currently affecting the region, expected to increase	2.3	2.6	High
Soil Salinization/Degradation	Currently not affecting, not expected to increase	0.9	1.0	Low
Insect Infestation	Not currently affecting, unlikely in the future	1.3	1.0	Low
Airborne/Waterborne Diseases	Not currently affecting, unlikely in the future	0.8	0.8	Low
Vector-Borne Diseases	Not currently affecting, unlikely in the future	0.7	0.6	Low
Wildfires	Not currently affecting, unlikely in the future	0.3	0.6	Low
Hailstorms	Not currently affecting, unlikely in the future	1.1	1.0	Low
Fog	Not currently affecting, unlikely in the future	0.7	0.9	Low
Frost	Currently affecting the region, expected to decrease	3.2	1.6	Moderate
Avalanches	Currently affecting the region, expected to decrease	2.6	1.3	Moderate

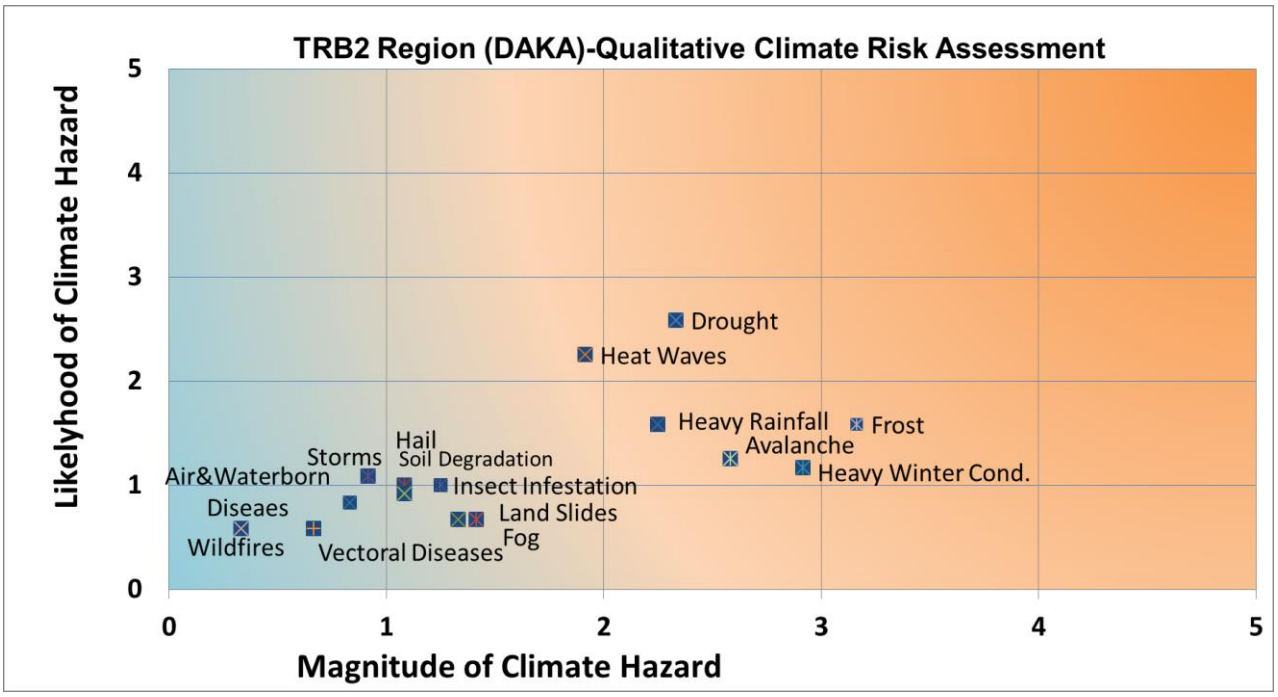


Figure 2: Current Situation Analysis of Climate Hazards in TRB2 Region

2.3. Future Analysis of Climate Hazards

The future state of climate hazards and their impacts on service sectors have been assessed through Survey 1 and Survey 2. The extent to which the primary climate hazards could affect service sectors is presented in the table below.

Table 4: Future Situation Analysis of Climate Hazards

Priority Climate Hazards	Future Severity of Hazard	Future Likelihood of Hazard	Expected Time Scale	Top 5 Most Affected Sectors
Drought	Expected to Increase	Expected to Increase	Medium Term (2030-2050)	Agriculture,
				Energy and Water Supply
				Public Health
				Industry, Trade, Tourism
				Emergency Management
Extreme Heat Waves / Heat Island	Expected to Increase	Expected to Increase	Medium Term (2030-2050)	Agriculture,
				Public Health
				Energy and Water Supply
				Industry, Trade, Tourism
				Education
Heavy Winter Conditions, Frost	Remain the same	Expected to decrease	Long Term (>2050)	Transportation
				Agriculture,

and Avalanches				Energy and Water Supply
				Public Health
				Emergency Management
Heavy Rainfall and flooding	Expected to Increase	Expected to Increase	Medium Term (2030-2050)	Agriculture
				Residential Areas
				Transportation
				Industry, Trade, Tourism
				Emergency Management

2.4. Sectoral Vulnerability Analysis

The adaptation capacities of service sectors against primary (major) climate hazards were evaluated through Survey 3, and resilient or vulnerable sectors were identified and presented in the table below. The assessment was conducted considering the Potential Future Impacts (R) of climate hazards on the service/sector and the sector's current Adaptation Capacity (K). The evaluation criteria are defined as follows:

Sectoral Risk (R)

- **0-1 : Very Low:** The sector/service is unaffected.
- **1-2 : Low:** The sector/service may be disrupted.
- **2-3 : Moderate:** The sector/service shows signs of deterioration.
- **3-4 : High:** The sector/service deteriorates.
- **4-5 : Very High:** The sector/service ceases operations. Unmanageable.

Adaptation Capacity (K)

- **0-1 : Very High:** No need for adaptation improvement.
- **1-2 : High:** Additional improvement may be required.
- **2-3 : Moderate:** Additional investment is required for adaptation.
- **3-4 : Very Low:** Significant investment is required for adaptation.
- **4-5 : None:** Extremely high investment is required for adaptation.

Table 5: Sectoral Vulnerability Analysis

Primary Climate Hazards	Top 3 Affected Sectors	Potential Impact on the Sector (1 Low – 5 High)	Sectoral Adaptation Capacity (1 High – 5 Low)
Drought	Agriculture, Livestock, Fishery	4.6 – Very High: The sector/service ceases operations. Unmanageable.	3.9 – Very Low: Significant investment is required for adaptation.
	Energy and Water Supply	4.6 – Very High: The sector/service ceases operations. Unmanageable	3.8 – Very Low: Significant investment is required for adaptation.
	Public Health	1.9 – Low: The sector/service may be disrupted.	3.0 – Moderate: Additional investment is required for adaptation.

Extreme Heat Waves / Heat Island	Agriculture, Livestock, Fishery	3.5 – High: The sector/service deteriorates.	3.4 – Moderate: Additional investment is required for adaptation.
	Energy and Water Supply	3.5 – High: The sector/service deteriorates	3.4 – Moderate: Additional investment is required for adaptation.
	Public Health	2.7 – Moderate: The sector/service shows signs of deterioration.	3.0 – Moderate: Additional investment is required for adaptation.
Heavy Winter Conditions, Frost and Avalanches	Transportation	3.7 – High: The sector/service deteriorates	3.5 – Very Low: Significant investment is required for adaptation.
	Agriculture, Livestock, Fishery	2.7 - Moderate: The sector/service shows signs of deterioration.	3.2 - Moderate: Additional investment is required for adaptation.
	Energy and Water Supply	2.3 – Low: The sector/service may be disrupted.	3.1 – Moderate: Additional investment is required for adaptation
Heavy Rainfall and flooding	Agriculture, Livestock, Fishery	2.7 – Moderate: The sector/service shows signs of deterioration.	3.3 – Moderate: Additional investment is required for adaptation.
	Transportation	2.7 – Moderate: The sector/service shows signs of deterioration.	3.3 – Moderate: Additional investment is required for adaptation.
	Housing-Settlements	2.7 – Moderate: The sector/service shows signs of deterioration.	3.2 – Moderate: Additional investment is required for adaptation.

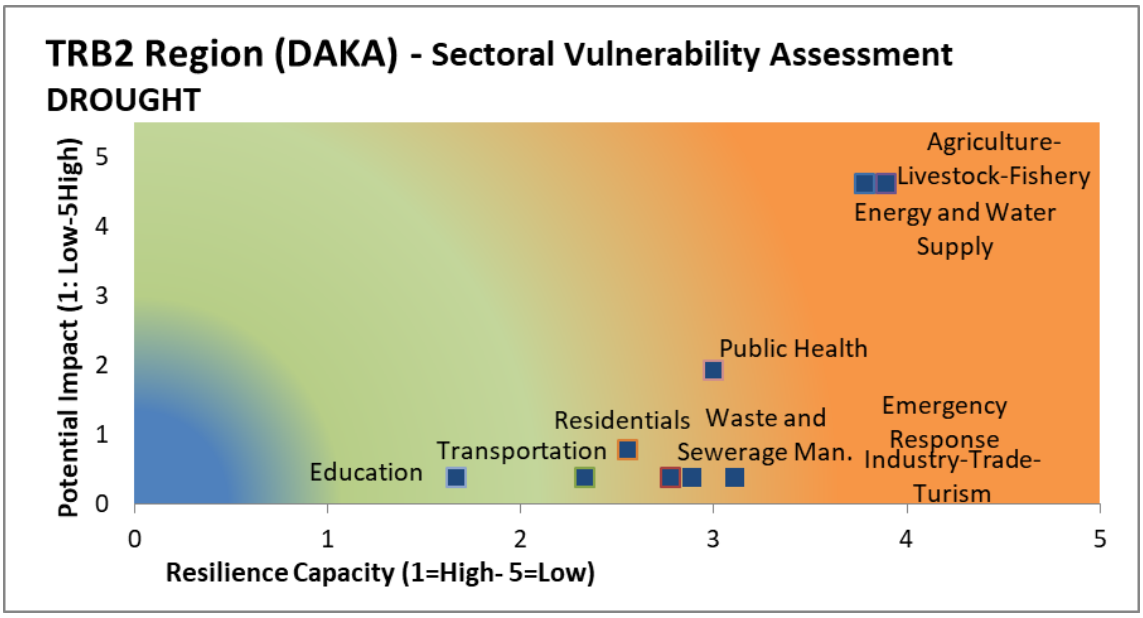


Figure 3: Sectoral Vulnerability- Drought

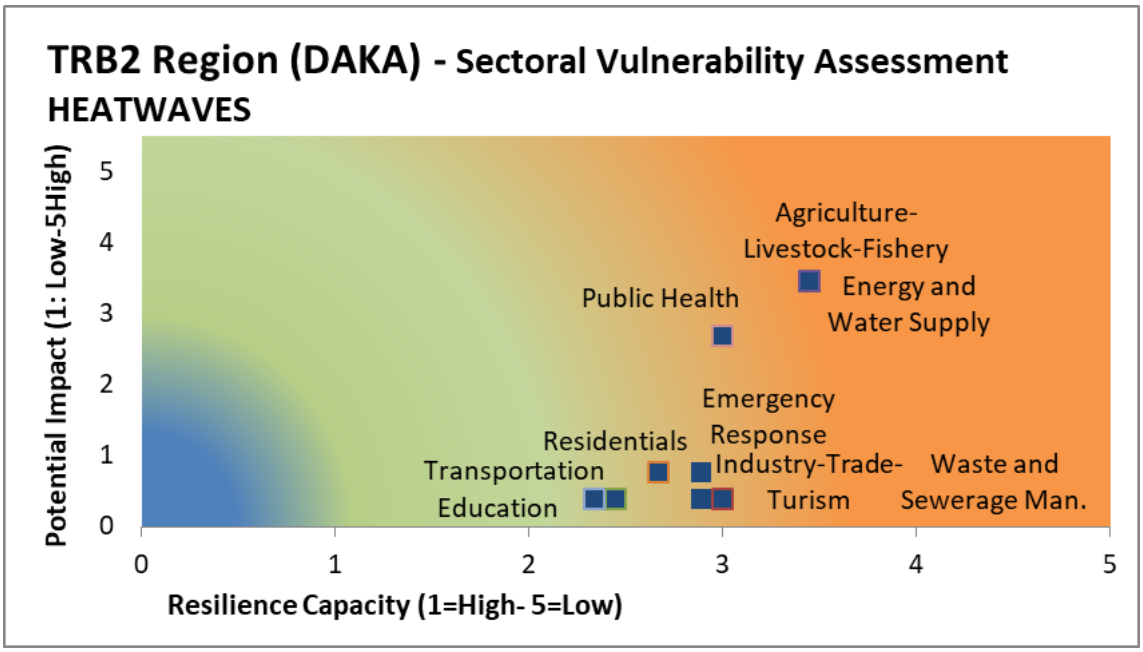


Figure 4: Sectoral Vulnerability- Heatwaves

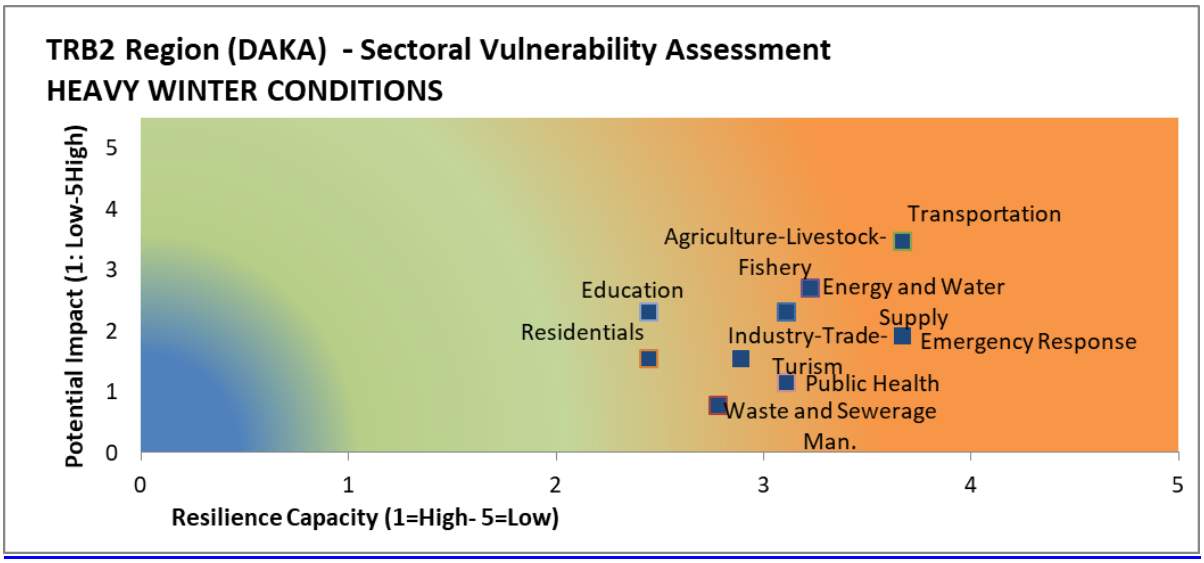


Figure 5: Sectoral Vulnerability- Heavy Winter Conditions

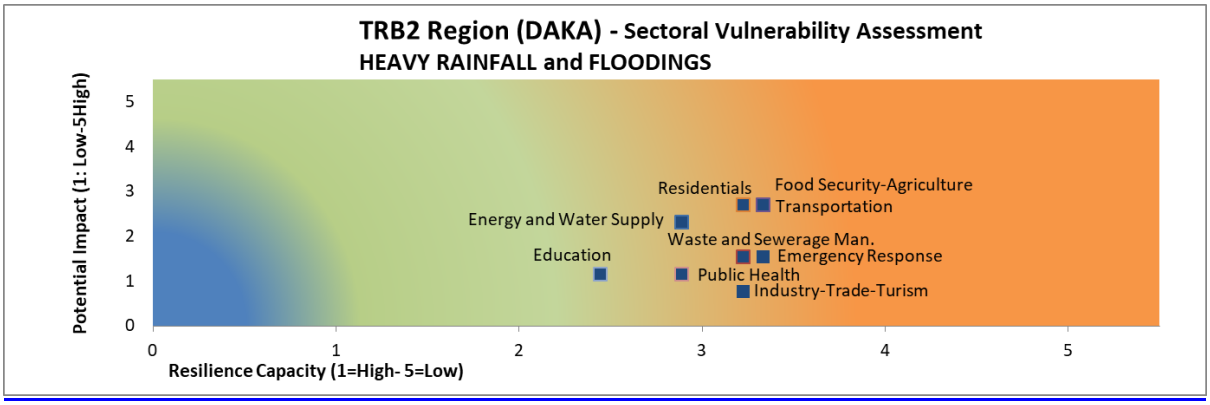


Figure 6: Sectoral Vulnerability- Heavy Rainfall and Floodings



3. Climate Projections and Quantitative Risk Assessment

3.1. Climate Model, Datasets and Projections

In order to be prepared for the consequences of climate change and minimize its negative impacts, it is necessary to predict how the observed changes and trends in the climate will evolve in the future and to determine the effects of these changes on natural and human systems. To understand the observed and past climate and forecast the future climate, models are used that provide mathematical representations of the components of the climate system, their interactions, and feedback mechanisms.

In the process of preparing the TRB2 Region Climate Change Risk Analysis, data from the MGM Climate historical and projections, Copernicus Climate Change Service (C3S), MED-CORDEX projections, and regional Mediterranean climate assessments were used. Three priority hazards were selected for detailed assessment in TRB2 Region: heatwaves, agricultural drought, and heavy winter conditions. Global and regional climate models, and Representative Concentration Pathways (RCP8) scenarios were used to assess the future state of drought risk. Among these scenarios, RCP4.5 represents a moderate level of radiative forcing and global warming, while RCP8.5 represents the highest possible radiative forcing and the worst-case global warming scenario.

For the climate projection, data was obtained from the General Directorate of Meteorology as per the scope outlined below:

Dataset:

- Global Climate Model: HadGEM2-ES, MPI-ESM-MR; GFDL-ESM2
- Climate Scenarios: RCP4.5, RCP8.5
- Copernicus (CDS)
- Landsat8 Satellite images
- Worldpop population density
- Domain: Med-Cordex
- Projection temporal Period: 2046-2050

Parameters:

- Daily Minimum Temperature (°C
- Daily Maximum Temperature (°C)
- Daily Relative Humidity
- Daily Wind Speed
- Daily Solar Downward Surface Radiation
- Daily Precipitation, mm

The assessment uses MPI Earth System Model (MPI-ESM) climate model projections under RCP8.5, comparing the historical period 2021–2025 with 2046–2050.

Bias adjustment was performed using empirical quantile mapping. In the workbook, each future model value is assigned a percentile within the model's historical reference distribution. It is then replaced by the value at the same percentile in the observed reference distribution.

This approach adjusts systematic differences in the distributions of modelled and observed climate parameters. The workbook also limits values outside the model reference range to the observed minimum or maximum. Consequently, unusually high future values can be capped, potentially reducing projected extremes.

The current implementation uses five-year mean daily profiles, rather than all individual daily observations from the reference period. It is therefore useful for comparing average seasonal conditions. Conventional quantile mapping also assumes that the reference-period bias relationship remains applicable in the future and does not explicitly preserve the modelled climate change signal.

Under the RCP8.5 scenario, possible change in climate parameters between Historical 2025 and BIAS Adjusted 2050 projection in Van Region is represented in Table 6. Projections indicate warmer and drier conditions in Van for 2046–2050 compared with 2021–2025. Average minimum and maximum temperatures increase by approximately 1.5°C and 1.7°C, respectively. Higher summer temperatures, particularly in May and July, suggest greater potential for heatwave conditions and reduced night-time cooling, although heatwave frequency and duration require analysis of daily temperature extremes.

Annual precipitation decreases from 345 to 283 mm (−17.7%), while reference evapotranspiration (ET_0) increases from 1,206 to 1,269 mm (+5.2%). Together with lower relative humidity, these changes indicate increased agricultural drought pressure. Reduced rainfall during spring and summer could limit soil moisture and increase irrigation requirements, particularly during sensitive crop growth stages.

Table 6: Possible Change in Climate Parameters between Historical 2025 and BIAS Adjusted 2050 Projection in VAN

Change in Climate Parameters between Historical 2025 and BIAS Adjusted 2050 Projection in VAN														
Parameters	2021-2025 (Average Historical) VAN													
Months	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	***Ave.***	***Total***
Tmin, °C	*-5.2*	*-4.9*	*-0.4*	*5.1*	*8.4*	*13.6*	*16.9*	*17.3*	*12.8*	*7.4*	*2.3*	*-1.7*	***6.0***	*-*
Tmax, °C	*4.3*	*4.4*	*8.7*	*15.9*	*19.7*	*26.1*	*29.3*	*30.4*	*25.3*	*18.6*	*12.5*	*7.0*	***16.8***	*-*
Precipitation, mm	*44.4*	*16.1*	*47.7*	*42.5*	*55.9*	*4.2*	*2.4*	*1.8*	*10.0*	*49.6*	*34.9*	*35.3*	*-*	***345.1***
Relative Humidity, %	*67.7*	*65.4*	*64.8*	*54.4*	*54.7*	*40.6*	*40.2*	*35.6*	*40.9*	*54.0*	*65.5*	*68.1*	***54.3***	
ET0, mm	*26.0*	*37.4*	*64.8*	*105.7*	*135.3*	*178.4*	*194.5*	*187.6*	*134.6*	*78.4*	*38.7*	*25.0*	*-*	***1206.2***
Parameters	2046-2050 (Average Projection BIAS Adjusted, RCP8.5)													
Months	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	***Ave.***	***Total***
Tmin, °C	*-4.1*	*-2.2*	*1.0*	*5.8*	*11.0*	*15.2*	*18.2*	*17.8*	*14.4*	*9.5*	*4.7*	*-2.4*	***7.4***	*-*
Tmax, °C	*5.1*	*8.3*	*11.8*	*16.8*	*22.2*	*27.6*	*31.2*	*30.5*	*27.3*	*21.5*	*13.8*	*6.8*	***18.6***	*-*
Precipitation, mm	*33.3*	*33.1*	*26.1*	*37.2*	*45.4*	*12.8*	*0.1*	*0.0*	*0.7*	*13.0*	*42.4*	*39.1*	*-*	***283.2***
Relative Humidity, %	*68.3*	*63.4*	*59.9*	*53.3*	*49.1*	*39.0*	*33.4*	*35.6*	*37.3*	*45.9*	*61.4*	*65.8*	***51.0***	
ET0, mm	*29.1*	*44.9*	*75.9*	*108.4*	*144.3*	*178.8*	*202.7*	*178.7*	*141.4*	*91.6*	*44.8*	*28.8*	*-*	***1269.5***
Parameters	ANOMALI (Difference : (BIAS 2046-50)- (HIST 2021-25)													
Months	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	***Ave.***	***%***
Tmin, °C	*1.1*	*2.7*	*1.4*	*0.7*	*2.6*	*1.6*	*1.3*	*0.5*	*1.6*	*2.1*	*2.4*	*-0.7*	***1.5***	
Tmax, °C	*0.9*	*3.9*	*3.1*	*0.9*	*2.5*	*1.5*	*1.9*	*0.0*	*2.0*	*2.9*	*1.3*	*-0.1*	***1.7***	
Precipitation, mm	*-11.1*	*17.0*	*-21.7*	*-5.3*	*-10.5*	*8.6*	*-2.4*	*-1.8*	*-9.3*	*-36.6*	*7.4*	*3.8*		***-17.9%***
Relative Humidity, %	*0.5*	*-2.0*	*-5.0*	*-1.0*	*-5.6*	*-1.6*	*-6.8*	*0.0*	*-3.6*	*-8.1*	*-4.1*	*-2.3*	***-3.3***	
ET0, mm	*3.1*	*7.6*	*11.1*	*2.7*	*9.0*	*0.4*	*8.2*	*-8.9*	*6.9*	*13.2*	*6.2*	*3.8*		***5.2%***

3.2. Data-Based Heat Waves Risk Assessment

Heatwaves are prolonged periods of excessively high temperatures, often accompanied by dry conditions, that can significantly impact human health, agriculture, and ecosystems. They are typically defined based on local climate norms, with temperatures exceeding a certain threshold for an extended duration, such as several days or weeks. These extreme heat events can result in a range of adverse effects, including heat-related illnesses, increased mortality rates, wildfires, and severe droughts. Urban areas, where concrete and asphalt absorb and retain heat, are particularly vulnerable due to the urban heat island effect.

One of the main negative impacts of heatwaves is the overheating of the urban areas, which lowers the comfort of living and can pose a threat to human health, especially in vulnerable populations, but also droughts and water scarcity

In the risk we focused on estimating risk based on population exposure and vulnerability, combined with high-resolution observation data for the temperature.

The heatwave risk assessment has been performed by combining Land Surface Temperature exposure with population vulnerability. Landsat 8 Satellite-based LST analysis represents overheated urban areas in the TRB2 Region city centres, especially where dense built-up surfaces, asphalt, concrete, and limited vegetation increase the urban heat island effect.

WorldPop-based population mapping identifies dense and vulnerable population areas. The analysis highlights that heatwave risk is highest where high surface temperature and high population density overlap.

To assess risk, we use a 10x10 risk matrix, which consists of exposure (level of exposure to heat based on land surface temperature data) and vulnerability (vulnerable population groups based on world population data). The heat exposure data were divided into 10 groups based on the land surface temperature thresholds (1-2. Very low <20-25°C, 3-4. Low 25-35°C, 5-6. Medium 35-45°C, 7-8. High 45-55°C, 9-10. Very High 55-60<°C), these thresholds can be changed and values will depend on the selected area. The vulnerability data were divided into 10 equally-spaced intervals based on the selected area.

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

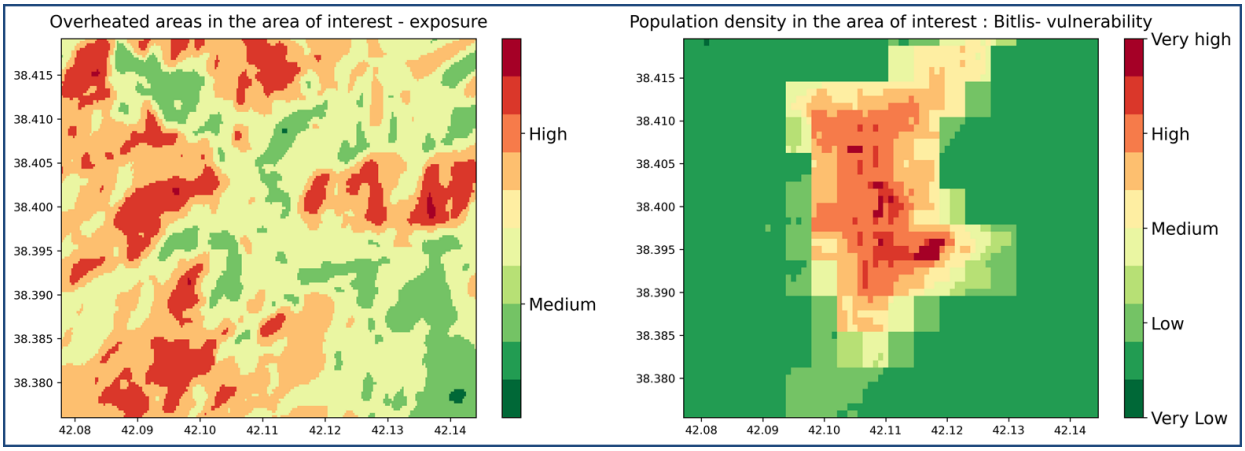


Figure 7: Land Surface Temerature and Vulnerable Population Density Maps in Bitlis

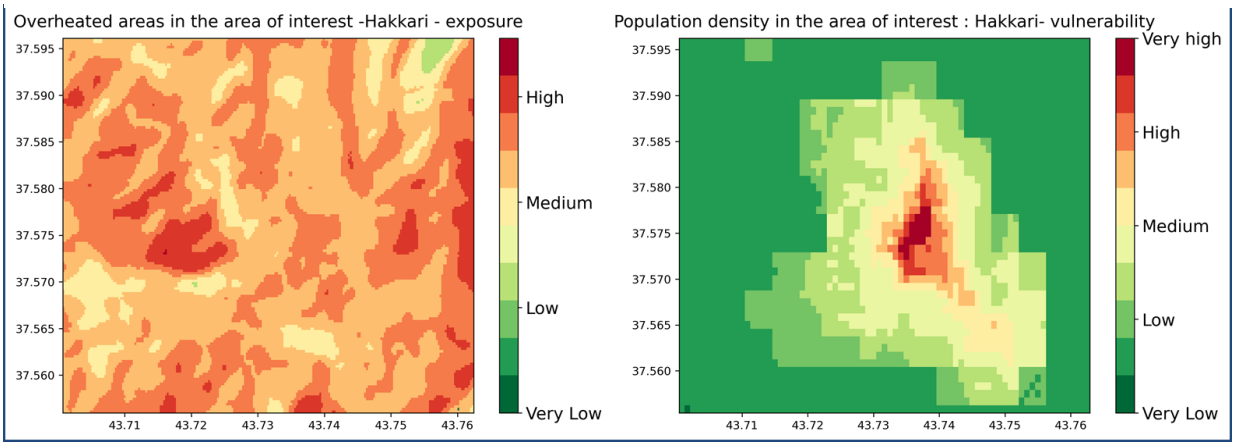


Figure 8: Land Surface Temerature and Vulnerable Population Density Maps in Hakkari

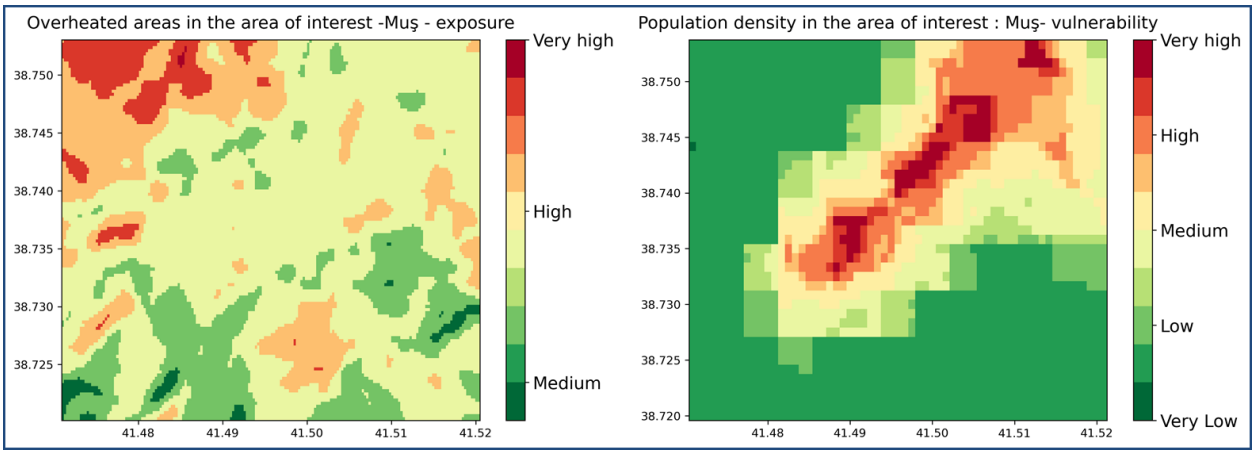


Figure 9: Land Surface Temerature and Vulnerable Population Density Maps in Muş

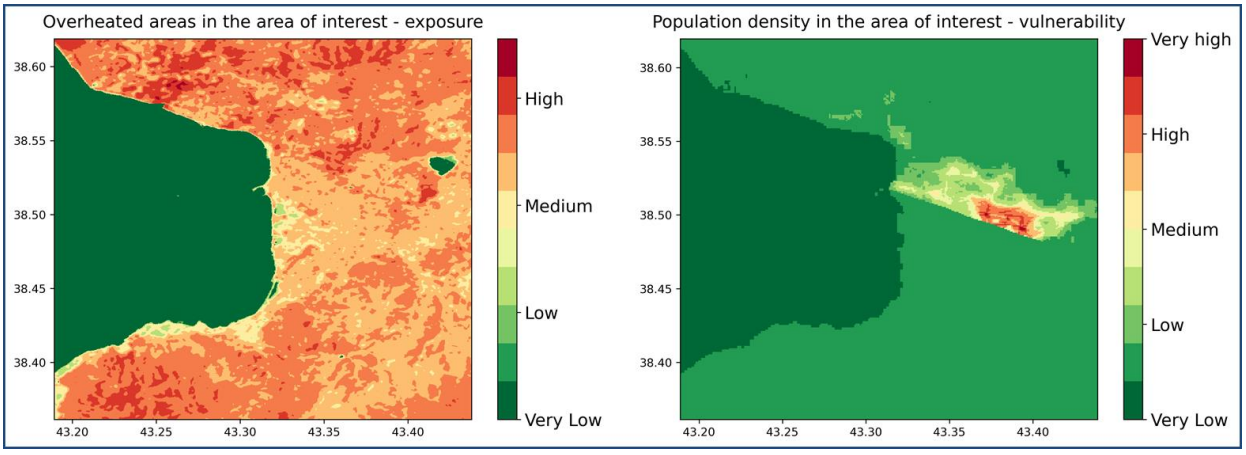


Figure 10: Land Surface Temerature and Vulnerable Population Density Maps in Van

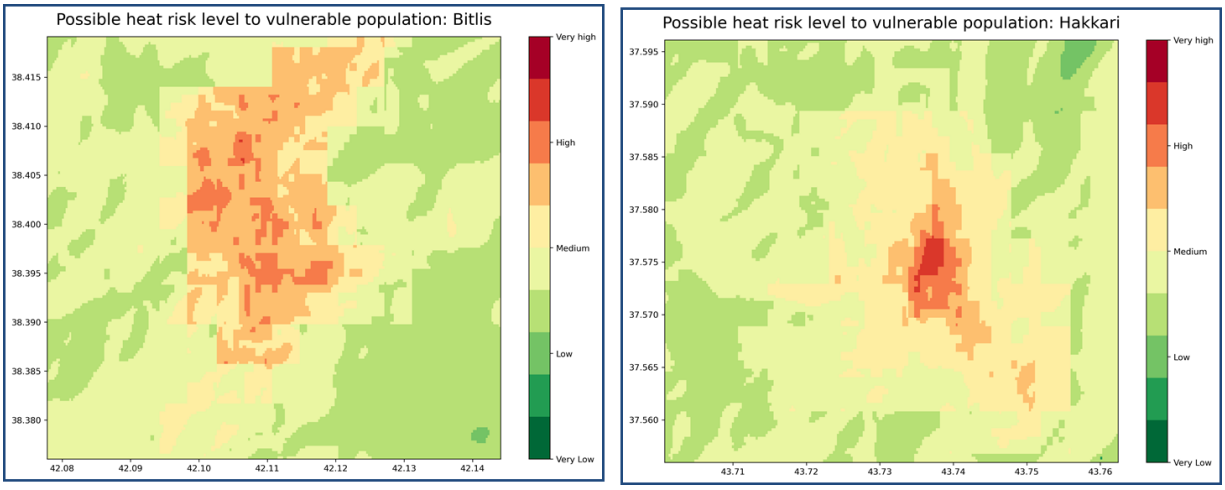


Figure 11: Heatwave Risk Map in Bitlis and Hakkari City Centres

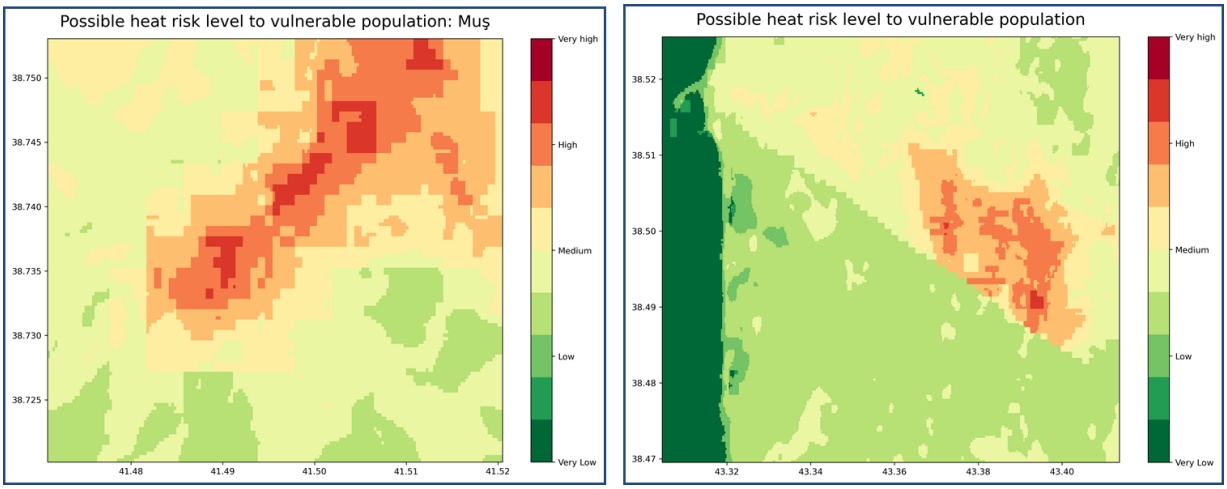


Figure 12: Heatwave Risk Map in Muş and Van City Centres

3.3. Data-Based Agricultural Drought Risk Assessment

Climate change is posing an increasing threat to food production systems, furtherly complicating the challenge of satisfying the food demand of a rising global population while respecting the limits imposed by planetary resource boundaries.

Risk quantification is a fundamental first step in the design of an effective adaptation strategy. Thus, the aim of Climaax-Agricultural Drought workflow is to provide a simple tool to quantify potential agricultural revenue losses caused by precipitation deficit. The hazard component of the assessment is represented by the potential yield losses deriving from water scarcity, defined as the deficit in crop evapotranspiration potential, in the absence of irrigation. The total crop production and the aggregated crops revenue are used to quantify the exposure of the agricultural sector in economic terms.

Quantifying risk is a fundamental first step in designing an effective adaptation strategy. Therefore, for the purpose of data-driven climate risk and vulnerability analysis, the CLIMAAX workflow program developed as part of the Horizon Europe project has been applied at the TRB2 Region. (See: https://handbook.climaax.eu/notebooks/workflows/DROUGHTS/02_agriculture_drought/AGRICULTURE_DROUGHT_Hazard.html)

This workflow aims to quantify the potential agricultural income losses caused by rainfall deficits. The hazard component of the assessment is represented by potential yield losses due to water scarcity, which is defined as a shortfall in plant evaporation and transpiration potential without irrigation. The economic exposure of the agricultural sector is measured using total crop production and total crop income. Finally, the distribution of current irrigation systems is used to map vulnerabilities. Through this tool, communities will have a spatial quantitative analysis of potential income losses caused by reduced agricultural production and will be able to identify the most vulnerable areas to rainfall deficits. More specifically, the quantified income loss here represents the 'opportunity cost' of not applying irrigation.

The workflows use Jupiter Notebook-Python code and prepared data pools (repositories). See CLIMAAX GitHub.

Used Data Sets: The evaluation is based on climate projections and global agricultural datasets that allow for predicting potential losses at approximately 10 km resolution. The data sets are downloaded from the EU Copernicus Data Store

(https://handbook.climaax.eu/notebooks/workflows/DROUGHTS/02_agriculture_drought/AGRICULTURE_DROUGHT_Hazard.html)

- Daily precipitation,
- Maximum and minimum temperature,
- 2-meter relative humidity,
- Surface solar radiation, and
- 10-meter wind speed,
- Soil available water capacity,
- Elevation,

Outputs: The output of the workflow is a map showing crops, emission scenarios, and potential income losses due to irrigation deficits for the future period in the examined region. This map helps to understand which areas are expected to experience the largest losses and which crops will be most affected by the lack of irrigation. It thus encourages cost-effective use of resources by directing adaptation efforts, such as improving existing irrigation networks, towards the most affected and vulnerable areas. Additionally, the map provides a snapshot view of potential future growth seasons, which can be used to guide agricultural land expansion in areas and crops that are less affected by water stress.

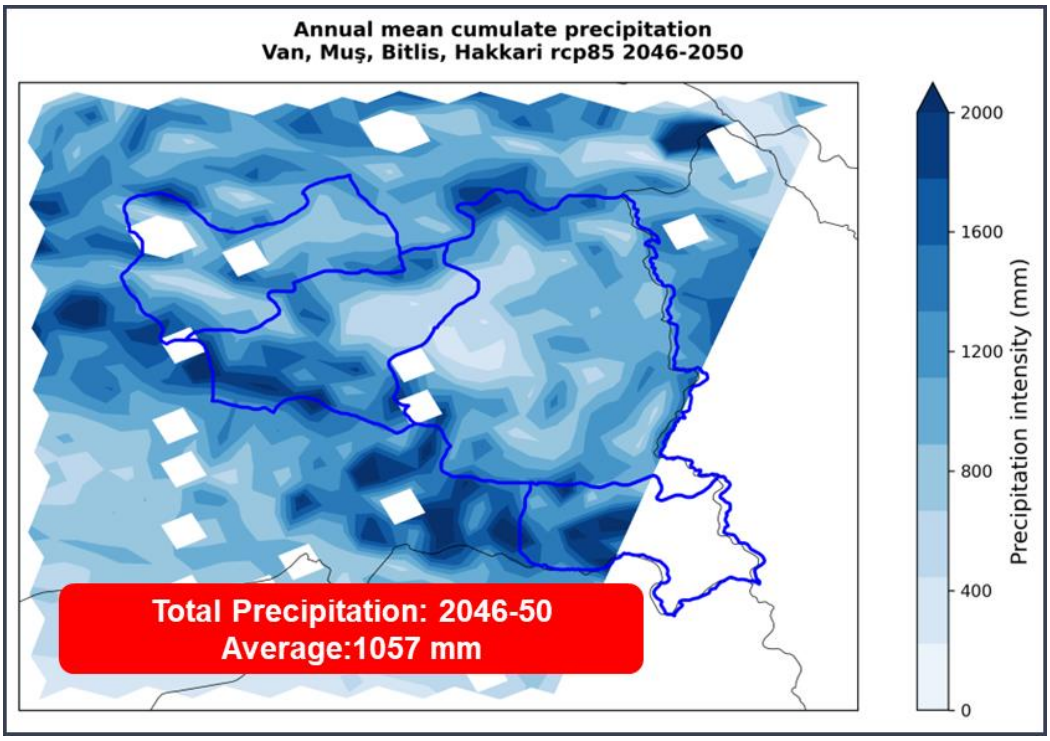


Figure 13: Annual Precipitation in TRB2 Region

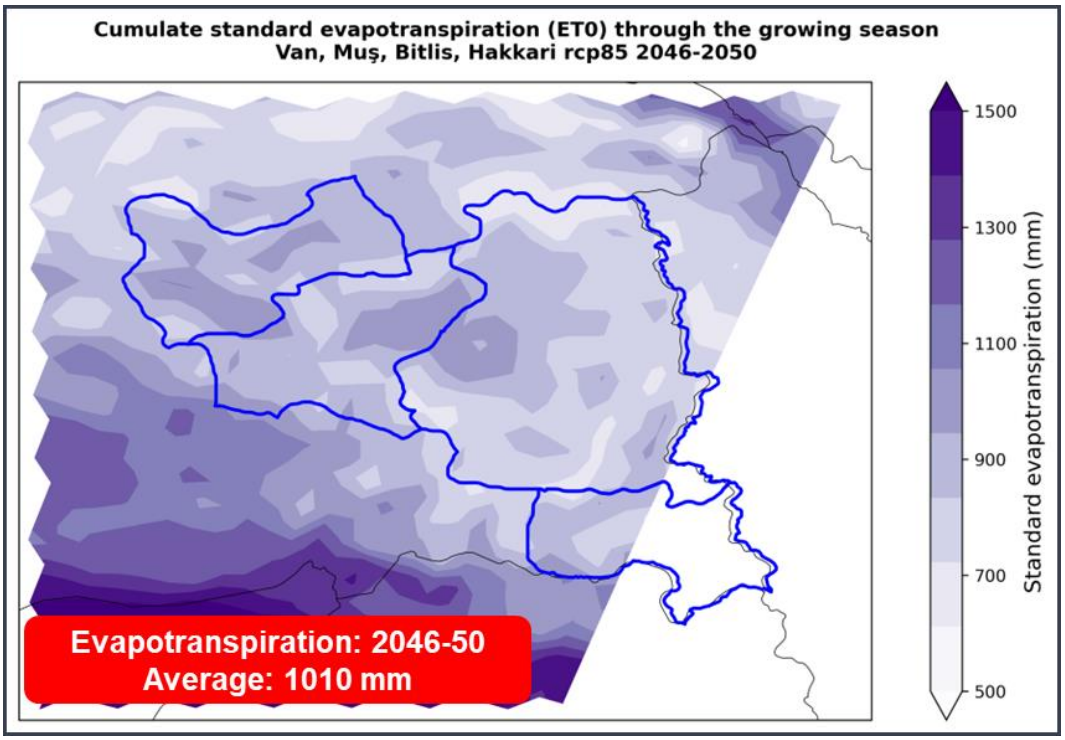


Figure 14: Annual Standart Evapotranspiration (ET0) in TRB2 Region

In this workflow, the effect of water deficit on crop yields has been assessed. The objective is to predict potential yield loss for a specific crop in the absence of an artificial irrigation system to compensate for precipitation shortages. This is particularly important for semi-arid region to compensate for precipitation shortages.

The starting point of the hazard assessment is the calculation of the soil's standard evapotranspiration (ET0) using the Penman-Monteith equation, as defined by FAO. The Penman-Monteith equation allows for the calculation of reference evapotranspiration and transpiration demand (i.e., how much water a standard plant needs to survive) by combining thermal radiation and wind data. ET0 does not contain crop-specific information; instead, it represents the climate-driven evapotranspiration and transpiration demand for a reference plant. The standard evapotranspiration value is then combined with a set of crop-specific information to derive the crop standard evapotranspiration (ETc). The crop-specific parameters used to calculate ETc vary depending on the evaluated thermal climate zone. Thus, ETc represents the maximum evapotranspiration and transpiration potential for each crop in a specific thermal climate zone. Based on ETc, the actual evapotranspiration and transpiration value (ETa) of the crop can be calculated using precipitation data to predict the local water availability for the plant. Therefore, ETa represents a portion of ETc. Using the equations from the FAO I&D 33 document, the ratio between precipitation-driven and maximum evapotranspiration potential can be correlated with crop yield loss (%) under rain-fed conditions.

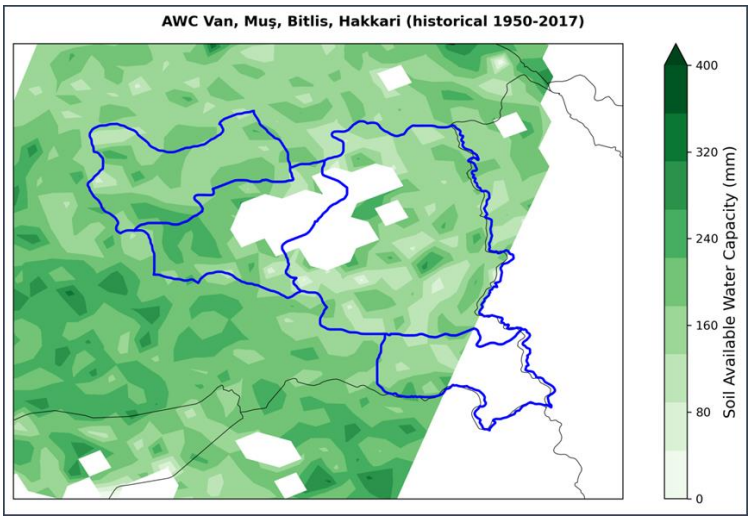


Figure 15: Available Soil Water Capacity in TRB2 Region

The hazard assessment was performed for 8 major crops; wheat, maize, sugar beet, potato, barley, alfalfa, sainfoin and meadow grass. Below are the workflow outputs for major crops in the TRB2 region. Based on the outputs of the workflow program, it has been calculated that reduced irrigation capabilities and a reliance solely on rainfall, the yield loss for sugar beet, wheat and maize production in 2050 would range around 21%, 10% and 34% respectively.

In case of irrigation deficit, potential yield losses by 2050 were estimated as shown in below figures:

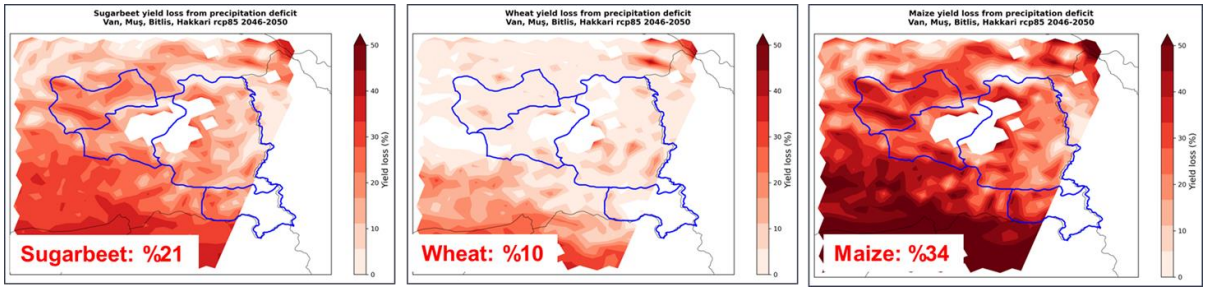


Figure 16: Expected Yield Loss in Sugarbeet, Maize and Wheat in case of irrigation Deficit

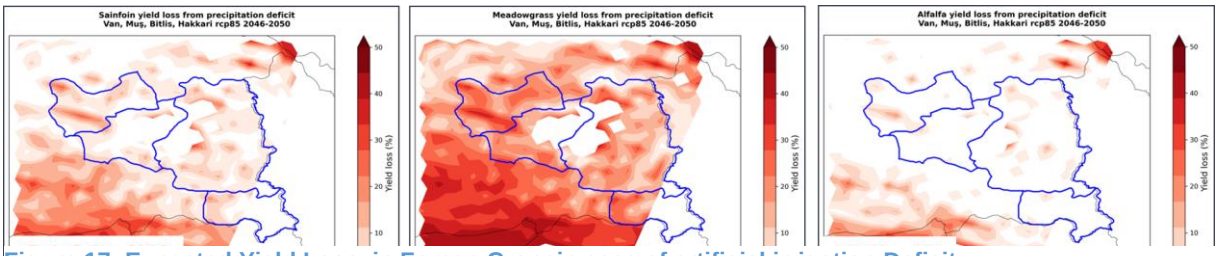


Figure 17: Expected Yield Loss in Forage Cropsin case of artificial irrigation Deficit

Additional irrigation water requirements for wheat in the Van region (as an example) were estimated using reference evapotranspiration (ET_0), crop coefficients (Kc) and effective precipitation. Crop evapotranspiration was calculated as ETc = Kc × ET_0, and the net irrigation requirement was determined as ETc − Effective Precipitation.

The Table indicates that annual irrigation requirements increase from 488 mm in 2021–2025 to 574 mm in 2046–2050 under the bias-adjusted RCP8.5 scenario, an increase of 17.7%. This reflects higher crop water demand and lower effective rainfall, with the greatest monthly requirements occurring in May and June. These estimates represent net water requirements; actual irrigation withdrawals would be higher when application and conveyance losses are included.

Table 7: Additional irrigation water requirements for wheat in the Van Region

Irrigation requirement Change between 2025 and 2050 Projection for Wheat Production in VAN			
Parameters	**2021-2025 (Historical) VAN**	**2046-2050 (BIAS Adj, RCP8.5)**	**% Difference**
ET0 mm	1206	1269	5.2%
ETc. mm	726	789	8.7%
Precipitation, mm	345	283	-18.0%
Precip_effective mm	313	263	-16.1%
Irrigation_requirement, mm	488	574	17.7%

The analysis also translated potential yield losses into economic terms. Based on 2024 TÜİK production data and producer price assumptions, the total potential revenue loss for 8 major crops could exceed EUR146 million if irrigation resources become insufficient. Total annual revenue and revenue losses in case of possible irrigation deficits were calculated as follow:

Table 8: Total annual revenue and revenue losses in case of possible irrigation deficits

Major Crops	Annual production, ton	Annual revenue, Euro	Annual revenue loss, Euro	Revenue loss percentage
Wheat	624,000	189,000,000	18,900,000	10%
Sugar beet	883,000	64,300,000	13,500,000	21%
Maize	102,000	47,600,000	16,200,000	34%
Potato	326,000	97,800,000	21,500,000	22%
Barley	216,000	52,300,000	1,800,000	3%
Forage Crops	4,031,000	693,000,000	74,500,000	11%
Total		**1,144,000,000**	**146,400,000**	**13%**

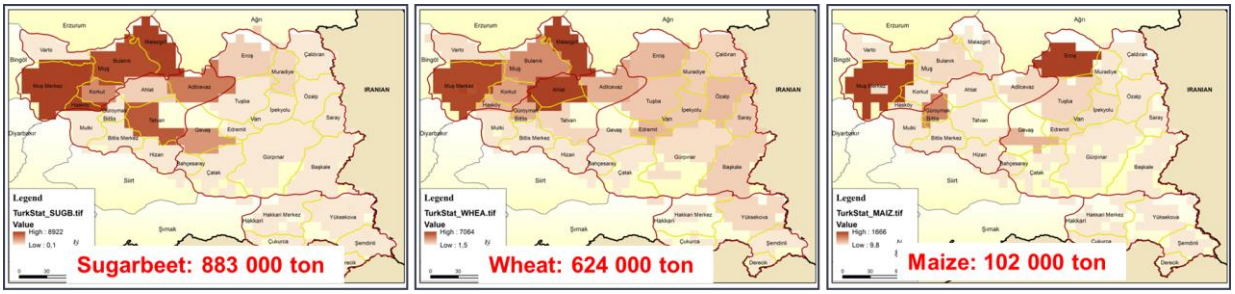


Figure 18: Agricultural areas of majör cropsand annual productions.

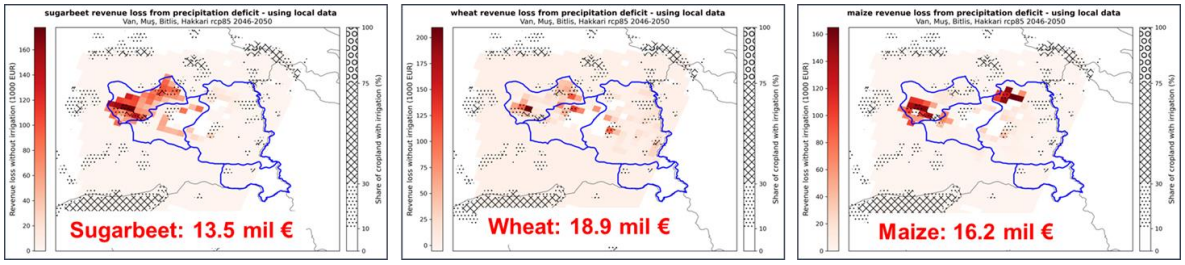


Figure 19: Potantial revenue lösse for sugarbeet, wheat and maize in case of irrigation deficit.

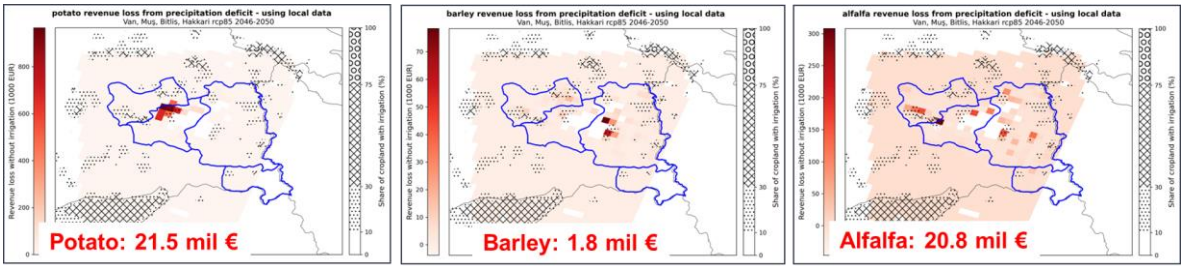


Figure 20: Potantial revenue lösse for potato, barley and alfalfa in case of irrigation deficit.

3.4 Data-Based Heavy Winter Conditions Risk Assessment

In recent decades, Europe has faced numerous weather-related natural disasters, with 95% of reported events linked to hydrological, climatological, or meteorological phenomena**..** Snowstorms and blizzards are particularly significant, especially in northern and mountainous regions. These events are characterized by strong wind gusts, considerable precipitating or blowing snow, and reduced visibility, often resulting in widespread disruption to transportation, energy infrastr**ucture, and economic activities.**

According to the Intergovernmental Panel on Climate Change (IPCC, 2021) projections, extreme winter storms, including snow and blizzards, may increase in intensity and impact despite a general trend toward lower snow cover with warming temperatures. These extreme events are expected to become more frequent in certain regions where cold air masses persist, particularly in areas vulnerable to rap**id shifts in weather conditions.** Additionally, the combined effects of urbanization and inadequate storm preparedness will likely compound the risks of snowstorms, leading to further economic losses and potentially **more significant loss of life.** Understanding the dynamics of extreme snow and blizzards and assessing their risks is crucial for developing effective mitigation and adaptation strategies and building resilience in changing climatic conditions.
Climaax heavy snow and blizzards workflow was applied in assessing the risks due to heavy snowfall and blizzards. The objective is to understand the probability of severe snowfall and blizzards under the present climate most impacted by this hazard. Additionally, we have investigated how climate change may change this hazard in the future.

Blizzards

A blizzard is a severe storm condition defined by low temperature, sustained wind or frequent wind gusts, and considerable precipitating or blowing snow. To define blizzard conditions, we propose the use of the following impact indicator:
Blizzard days = Tmean ≤ 0 °C and Rs ≥ 10 cm and Wg ≥ 17 m/s , where:

Tmean - mean daily temperature
Rs - amount of snow
Wg - wind gust velocity
This impact indicator was defined taking into account the exposure of critical infrastructure, i.e., roads, rails, power lines, and telecommunication to the hazard, and is based on an extensive literature review, media reports, surveys conducted with European CI operators and case studies.

Heavy snowfall

Heavy snowfall may cause many disruptions and impacts in various sectors; however, the impacts and consequences of this hazard depend on the affected sector, infrastructure, and also preparedness of society which varies over Europe. For example, already a few centimetres of snow can disrupt road traffic, but doesn't normally cause any harm to energy infrastructure. Many weather services have three warning levels based on the severity of expected impacts, which are typically different for different sectors of infrastructure. There is a large variation in the national warning criteria or thresholds.
Similarly to blizzards, the impact indicators for heavy snowfall were defined taking into account the exposure of critical infrastructure, i.e., roads, rails, power lines, and telecommunication to the hazard. The qualitative description of the two-level thresholds for daily snowfall amounts are:
1st threshold (> 6 cm): Some adverse impacts are expected, their severity depends on the resilience of the system, and transportation is mainly affected.
2nd threshold (> 25 cm): The weather phenomena are so severe that is likely that adverse impact will occur.

Hazard Assessment - annual probability

This workflow calculates the Annual probability (%) of a blizzard and heavy snowfall days during the specified period for the region of interest.
The annual probability is determined by dividing the count of events surpassing predefined thresholds within a year by the total number of days in that year. The result is then multiplied by 100 to express the probability as a percentage:
P = ((variable > threshold) / days in year) X 100

Risk assessment

The method involves visually representing the susceptible population exposed to intense snowfall and blizzards. This can be achieved by overlaying indicators for heavy snowfall and blizzards with population data. The objective is to understand the present probability of severe snowfall and blizzards, pinpointing the areas most impacted within TRB2 Region. Additionally, we investigated how climate change may modify this exposure over time.
Figure 21 represents the projected change in > 6 cm/day and >25cm/day snowfalls between 2000 and 2050.
The probability of precipitation exceeding 6 cm/day and snowfall exceeding 25 cm/day in the region is projected to decrease by 2–4% by 2050 compared with current conditions. This situation should be considered a risk factor for the water balance of the Van Lake Closed Basin.

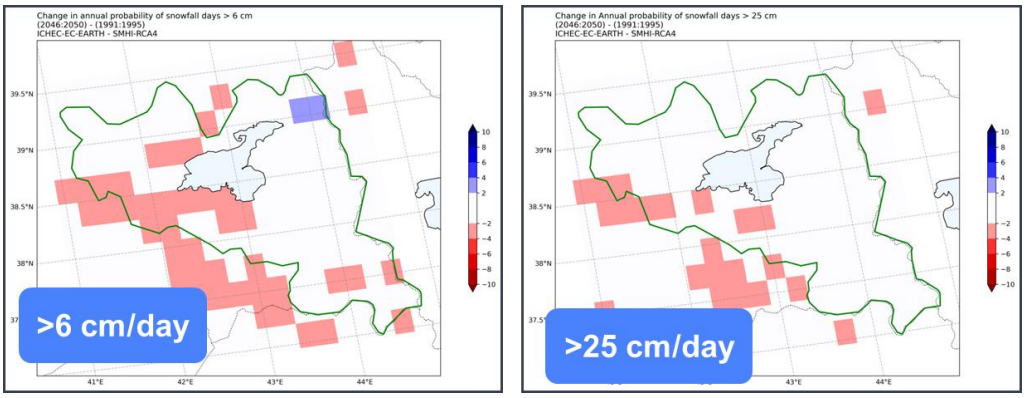


Figure 21: The projected change in > 6 cm/day and >25cm/day snowfalls 2000-2050.

Figure 22 represents the change in Blizzard Probability between 2000 and 2050.
In the region, the probability of blizzard conditions on snowfall days is expected to remain at a similar level to current conditions in 2050. No significant increase or decrease is anticipated.

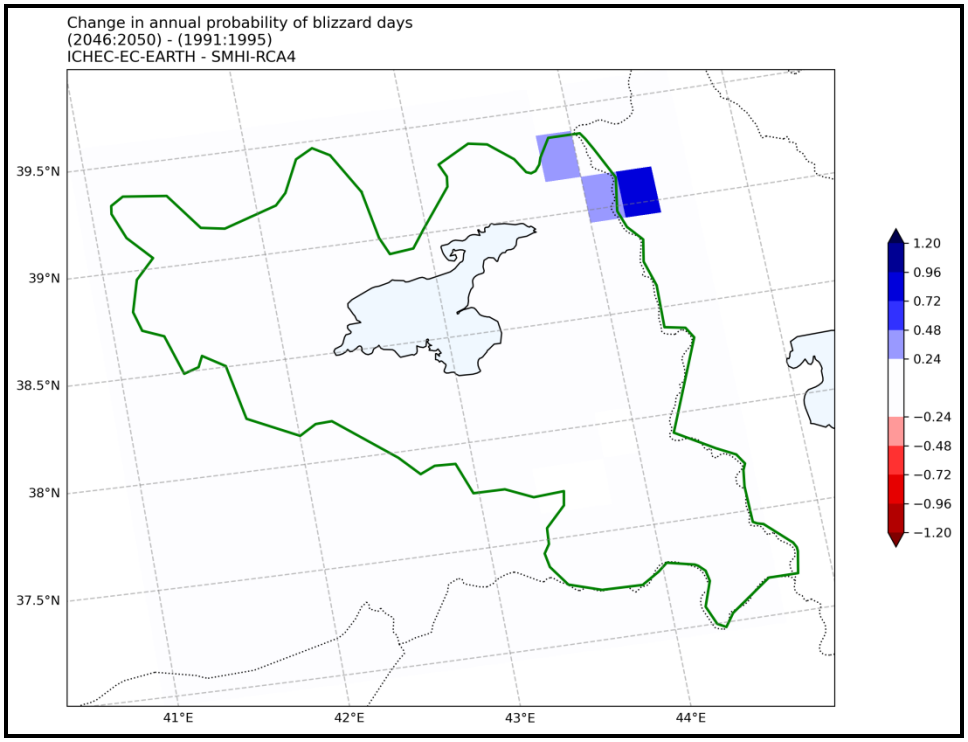


Figure 22: The change in Blizzard Probability between 2000 and 2050.

3.5 Data-Based Heavy Rainfall Risk Assessment

Regional Context

This assessment covers Bitlis, Hakkâri, Muş and Van and focuses on historical event location, rainfall intensity where documented, triggering mechanisms, consequences and affected areas.

Bitlis, Van, Muş and Hakkâri are located in the Upper Murat–Van sub-region of Eastern Anatolia. The region is characterised by highly rugged topography and extreme climatic conditions. Accordingly, heavy precipitation should not be understood only as intense rainfall.

In TRB2, hazardous precipitation processes also include heavy snowfall, rapid snowmelt and compound rain-on-snow conditions, which can contribute to floods, landslides and avalanches.

The source material reports the following provincial rainfall characteristics and observed maximum daily precipitation values: Bitlis has an annual average precipitation of 1,056 mm (average of 2021-25) and a documented daily maximum of 96.0 mm (15 December 2013); Hakkâri has an annual average of 685 mm and a daily maximum of 90.0 mm (20 November 2023); Muş has an annual average of 605 mm and a daily maximum in the approximately 60–86 mm range; and Van has a much lower annual average of 345 mm but a daily maximum of 122.0 mm (27 February 2014). These station records demonstrate that very high daily rainfall can occur even in the relatively dry Van environment.

Flood-Hazard Mechanisms Relevant to TRB2

- **Short-duration convective rainfall and flash flooding:** Localised summer convective storms can generate rapid runoff and flash flooding, particularly in steep catchments and settlements located close to stream channels.
- **Rainfall combined with snowmelt:** Winter precipitation may be stored as snow and subsequently contribute to high runoff during spring. A relatively ordinary spring rainfall can become hazardous when combined with rapid temperature-driven snowmelt.
- **River and plain flooding:** Muş Plain and other low-gradient areas can be affected when rivers and tributary streams exceed their conveyance capacity. Agriculture is particularly exposed in these settings.
- **Topography, drainage and infrastructure:** Steep slopes can accelerate runoff, while constrained stream corridors, undersized culverts, blocked drainage and development close to waterways can increase local flood impacts.

Historical heavy rainfall and flood events recorded in TRB2 Region are explained in the following table:

Table 9: Historical Heavy Rainfall and Flood Events

Province	Date / period	Location	Rainfall intensity	Event Consequences
Van	17 July 2011	Özalp and Çaldıran	Not reported	Event type: Intense summer convective rainfall / flash flooding Main cause / trigger: Sudden heavy rainfall generated flooding; lightning was also reported. Main consequences: Four fatalities were reported; cultivated agricultural land was inundated; village bridges were destroyed; hundreds of animals were reported killed. Affected area: Boğazkesen and Hacıkışlak villages and surrounding agricultural areas in Özalp; Çaldıran area.
Bitlis	2 May 1995	Bitlis city	Not	Event type: Prolonged rainfall and stream

		centre	reliably reported; rainfall continued for ~36 h	overflow Main cause / trigger: Approximately 36 hours of rainfall caused Bitlis Stream to overflow; constrained stream corridor and development increased exposure. Main consequences: Roads and streets were inundated; businesses, vehicles and houses/lower floors were damaged; casualties occurred. Affected area: Bitlis city centre, particularly the Bitlis Stream corridor.
Bitlis	27 August 2000	Bitlis centre – Arifbey and Kazım Dirik streets	Not reported	Event type: Sudden urban flooding Main cause / trigger: Intense rainfall / rapid surface runoff. Main consequences: 30 businesses were reportedly completely inundated; major urban economic damage was recorded. Affected area: Central Bitlis, especially Arifbey and Kazım Dirik streets.
Muş	30 March 2015	Yoncalıöz / Muş Plain	31.4 mm/day at Muş station	Event type: Rainfall + snowmelt / river and local flooding Main cause / trigger: Rainfall occurred while snow cover remained, accelerating snowmelt and runoff; tributaries exceeded conveyance capacity. Main consequences: Houses, barns and haylofts were flooded/damaged; residents were evacuated; livestock died; no human fatalities were reported. Affected area: Yoncalıöz village and surrounding Muş Plain / Karasu drainage area.
Hakkâri	27 June 2012	Hakkâri centre – Berçelan	16 mm/day	Event type: Stream overflow / local flash flooding Main cause / trigger: Sudden overflow of the stream channel following heavy rainfall. Main consequences: Floodwater entered houses, wood stores and extensions were swept toward Zap River. Affected area: Berçelan neighbourhood and adjacent stream corridor.
Hakkâri	24 June 2016	Çanaklı village	28 mm/day; rainfall reportedly lasted ~20 min	Event type: Short-duration convective flash flood / mudflow Main cause / trigger: Very short intense rainfall generated rapid runoff from mountain slopes. Main consequences: 10 houses were heavily damaged; about 300 sheep and 200 beehives were reportedly swept away and lost; vehicles and agricultural areas were affected. Affected area: Çanaklı village, approximately 15 km from Hakkâri centre.

Hakkâri	28 October 2018	Kırıkdağ	65 mm/day	Event type: Prolonged rainfall and river/stream flooding Main cause / trigger: Three days of continuous heavy rainfall caused Beyaz Su Stream to overflow. Main consequences: Özdemir Hydroelectric Power Plant was flooded and heavily damaged; village roads and drinking-water lines sustained major damage. Affected area: Kırıkdağ and Beyaz Su Stream corridor.
Van	30 June 2020	Başkale and Erciş	Not reported	Event type: River/stream overflow Main cause / trigger: Watercourses exceeded capacity following heavy rainfall. Main consequences: Dozens of houses and workplaces were inundated; extensive agricultural areas were covered by mud; small livestock were swept away and killed. Affected area: Başkale and Erciş, including adjacent agricultural areas.
Muş	24 March 2021	Muş centre	44 mm/day	Event type: Heavy rainfall + extreme wind / urban flooding Main cause / trigger: Heavy rainfall coincided with extreme wind; urban drainage became blocked/overloaded. Main consequences: Urban waterlogging occurred; roofs were blown off and fell onto parked vehicles. Affected area: Muş urban area.
Van	16 July–3 August 2021	Multiple districts	Event-specific 24-h value varies spatially; not assigned	Event type: Widespread rainfall-driven flooding Main cause / trigger: Heavy rainfall and local runoff affected multiple catchments and settlements. Main consequences: Roads, bridges, culverts and drainage infrastructure were damaged; houses, agricultural land and livestock were affected. Municipal response/rehabilitation covered 69 locations. Affected area: Baş-kale, Çaldıran, Özalp, Gürpınar, Muradiye, İpekyolu, Erciş and Saray; >35 neighbourhoods/settlements reported.
Bitlis	16 March 2023	Tatvan – Yolalan / Düzköy	Not reported	Event type: Rainfall + snowmelt / drainage failure associated with pond failure Main cause / trigger: Heavy rainfall and snowmelt contributed to failure of an agricultural irrigation pond embankment. Main consequences: 210 decares of agricultural land destroyed; 8 barns and 8 haylofts

				damaged; agricultural machinery flooded; mature walnut trees uprooted. Affected area: Yolalan / Düzköy, Tatvan.
Bitlis	26 May 2023	Mutki	Not reported	Event type: Heavy rainfall + landslide/flood Main cause / trigger: Heavy rainfall triggered flooding and landslides in steep terrain. Main consequences: 15 village roads were completely closed; approximately 50 culverts were destroyed; drinking-water and agricultural irrigation networks were severely damaged. Affected area: Mutki and affected surrounding villages.
Hakkâri	30 August 2023	Yüksekova – Köycük	Not reported	Event type: Short-duration heavy rainfall / flash flooding Main cause / trigger: Sudden rainfall generated rapid runoff. Main consequences: Approximately 2,000 bundles of harvested hay and tonnes of agricultural products were buried in mud. Affected area: Köycük village, Yüksekova.
Bitlis	7–23 September 2024	Güroymak – Gölbaşı	Not reported	Event type: Repeated flooding Main cause / trigger: Repeated heavy rainfall and local drainage/stream capacity limitations. Main consequences: Three separate floods affected the locality; three houses were severely damaged/destroyed; by the end of the month, the entire sewage, road and drinking-water networks were reported unusable. Affected area: Gölbaşı settlement, Güroymak.
Van	11 August 2025	Saray and Özalp	Not reported	Event type: Extreme summer convective rainfall / flash flooding Main cause / trigger: Extreme summer rainfall caused streams to overflow. Main consequences: Neighbourhoods and streets were inundated; infrastructure networks failed; substantial material damage was reported. Affected area: Saray and Özalp.

Rainfall intensity is reported at event level only where MGM provides a measurement. For events for which an exact event-specific 24-hour total is unavailable, the table explicitly states "Not reported" rather than substituting a provincial rainfall record. This distinction is important because a station's maximum daily precipitation may have occurred on a different date and therefore cannot be assumed to have caused a particular flood. The values in Table 10 are presented solely as indicators of the magnitude of historical daily precipitation extremes.

Table 10: Maximum historical heavy rainfall intensities recorded in TRB2 Region

Province	Maximum daily precipitation	Date
Van	122 mm/day 48 mm/day 46 mm/day	27 February 2014 26 October 2016 20 March 2024
Bitlis	96 mm/day 95 mm/day 90 mm/day	15 December 2013 26 October 2018 04 March 2025
Hakkâri	90 mm/day 85 mm/day 82 mm/day	20 November 2023 23 April 2011 08 December 2025
Muş	86 mm/day 68 mm/day 60 mm/day	22 February 2004 26 October 2015 15 December 2016

Province-Level Risk Characteristics

- **Bitlis** combines relatively high precipitation with steep terrain and constrained stream corridors. Historical flooding has affected urban areas, roads, culverts, agricultural land and utility networks. The historical record indicates that rainfall-driven floods can be compounded by snowmelt, particularly in spring.
- **Hakkâri** is characterised by steep valleys and high relief. Short-duration intense rainfall can rapidly generate destructive runoff, mud and debris flows. Flood exposure is particularly relevant in stream corridors around Hakkâri centre, Yüksekova,Şemdinli and Çukurca.
- **Muş** Plain is a large low-gradient basin surrounded by mountains. Flooding is strongly influenced by the interaction of spring rainfall and snowmelt, with agricultural land being particularly exposed. The 30 March 2015 event illustrates that a moderate daily rainfall total can still produce significant flooding when antecedent snow conditions are present.
- **Van** has the lowest annual precipitation of the four provinces but can experience intense local convective rainfall and widespread flood impacts. The 2021 flood sequence demonstrates the potential for multi-district impacts affecting settlements, transport, drainage, agriculture and livestock.

Key Findings for the TRB2 Climate Risk Assessment

- Flood hazard in TRB2 is spatially heterogeneous and is not restricted to major river channels or provincial centres.
- An mm/24h threshold alone is insufficient to characterise flood risk. Antecedent rainfall, snowpack, snowmelt, catchment slope, drainage capacity, stream morphology and settlement location can substantially modify impacts.
- Compound rainfall–snowmelt processes are particularly important for Bitlis and Muş and should be considered explicitly in climate-risk and adaptation planning.
- Short-duration convective rainfall is a major concern for Hakkâri and Van, where steep terrain and rapid runoff can produce flash flooding.

- Agriculture, livestock, transport infrastructure, drainage systems, drinking-water and irrigation networks, buildings and energy infrastructure have all been affected by historical events.
- The 2021 Van flood sequence demonstrates that a single meteorological period can generate impacts across multiple districts and dozens of settlements, highlighting the need for regional-scale preparedness and coordinated response.
- Historical event inventories should be combined with high-resolution precipitation data, hydrological modelling, exposure mapping and critical-infrastructure data when defining future flood-risk priorities.
- Although extreme rainfall intensities in the TRB2 Region are relatively lower than in other parts of Türkiye, even relatively low rainfall amounts, such as 40–50 mm/24 hours, can cause flash flooding, particularly in districts.

  This situation demonstrates that the storm water drainage infrastructure in both urban centres and districts across the TRB2 Region is highly vulnerable and that urgent investments are needed to increase drainage capacity and improve the resilience of storm water management systems.



4. Climate Risk Management

4.1. Structure, organization and risk ownership

The climate risk assessment undertaken for the TRB2 Region demonstrates that climate change management needs to be addressed through a coordinated, multi-level governance structure covering Van, Muş, Bitlis and Hakkâri. The assessment identifies drought, extreme heatwaves and urban heat island effects, heavy rainfall and flooding, and heavy winter conditions among the principal climate risks, with particularly high vulnerabilities in agriculture and livestock, energy and water systems, transportation and public health. The P2R assessment also emphasises the importance of strengthening the capacity of local and regional stakeholders to understand, assess and manage climate-related risks through an evidence-based and participatory approach.

This governance framework has become more clearly defined with the Regulation on Local Climate Change Action Plans and Provincial Climate Change Coordination Boards, published on 4 August 2026. The Regulation establishes a provincial-level governance mechanism for the preparation, implementation, monitoring, evaluation and reporting of Local Climate Change Action Plans (YİDEP). Each province is required to establish a Provincial Climate Change Coordination Board (İl İklim Değişikliği Koordinasyon Kurulu – İl İDKK) under the coordination of the Governor by 31 December 2026. The first YİDEPs will cover the 2028–2032 period and must be approved by the relevant Provincial Coordination Board by 31 December 2027. YİDEPs will subsequently be updated every five years.

For the TRB2 provinces, the Governorates and Provincial Climate Change Coordination Boards should therefore constitute the principal institutional owners of climate risk coordination, while municipalities and other responsible institutions retain ownership of the actions falling within their respective mandates. The YİDEP process is intended to involve provincial branches of relevant ministries, AFAD, DSİ, municipalities, development agencies, chambers of commerce and industry and other relevant institutions, while universities,

professional organisations, civil society and, where appropriate, private-sector representatives can contribute to the process.

The Doğu Anadolu Kalkınma Ajansı (DAKA) should play an important regional coordination and enabling role within this structure. DAKA covers all four TRB2 provinces and is mandated to strengthen cooperation among the public sector, private sector and civil society and to support sustainable regional development. Its role in climate risk management can therefore include maintaining a regional perspective across the four provincial YİDEPs; supporting the harmonisation of climate-risk data and indicators; facilitating cooperation between municipalities, public institutions, universities and economic actors; supporting preparation of investment concepts and feasibility studies; and helping align climate actions with regional development priorities and available national and international financing mechanisms. This role is particularly relevant given DAKA's current involvement in the P2R process and its support for climate-resilience initiatives in TRB2.

The institutional responsibilities should be translated into a clear risk-ownership structure. The institution responsible for a service, asset, sector or vulnerable population should normally be identified as the action owner for the corresponding climate risk. For example, municipalities should take ownership of risks associated with urban infrastructure, land-use planning, municipal services and local transport; water-management institutions should lead risks concerning water availability and drought; agricultural institutions and producer organisations should address agricultural drought and livestock vulnerability; health authorities should lead heat-health risks; AFAD and relevant emergency institutions should coordinate disaster preparedness; and transport and infrastructure authorities should address risks associated with heavy winter conditions, avalanches and flooding. Each YİDEP action should consequently identify a responsible institution, implementation period, performance indicator, budget and potential financing source, creating a direct link between climate risk assessment and implementation.

Role of Municipalities in Preparing YİDEP

For the TRB2 provinces, the role of municipalities can be defined as follows:

- **Active participation in the preparation of the YİDEP:** Municipalities participate in the provincial YİDEP preparation process and provide the data, plans, projects and technical information required for assessing local climate risks, GHG emissions, vulnerability and adaptation needs.
- Identification of municipal climate risks and priorities: Each municipality should identify the climate risks affecting its jurisdiction and municipal services, including water supply, wastewater, transport, land use, buildings, waste management, green infrastructure, public health and emergency services. This is particularly important for TRB2 because the regional assessment identifies drought, heatwaves, flooding and heavy winter conditions as significant risks.
- **Development and ownership of municipal actions:** Municipalities should propose concrete mitigation and adaptation measures falling within their legal responsibilities. Each action should have a clearly identified responsible municipal department/unit, implementation period, performance indicator, estimated cost and financing source. Thus, municipalities are not simply stakeholders consulted during preparation; they are action owners for measures under municipal responsibility.

- **Integration with existing municipal plans and investments:** YİDEP measures should be integrated into municipal strategic plans, investment programmes, spatial planning, infrastructure programmes, transportation plans, water-management programmes, disaster-risk plans and annual budgets. This is important to ensure that climate actions become part of routine municipal investment and service delivery rather than remaining as stand-alone projects.
- **Data and monitoring responsibilities:** Municipalities should periodically provide information on implementation progress, indicators, emissions, climate impacts and adaptation measures to the provincial coordination mechanism. The existing TRB2 P2R assessment already provides a useful baseline because it combines stakeholder information with quantitative analysis of heatwaves, agricultural drought and heavy winter conditions.
- **Stakeholder engagement:** Municipalities should contribute to the participatory dimension of YİDEP by involving relevant municipal departments, utilities, district municipalities, universities, professional organisations, civil society, businesses and vulnerable groups.
- **Implementation and annual review:** Following approval of the YİDEP, municipalities should implement the actions for which they are responsible and report progress through the provincial monitoring mechanism. The Ministry already provides an Action Plan Monitoring System, which can support this monitoring process.

The TRB2 Climate Risk and Vulnerability Analysis provides an important technical foundation for this process. It already applies the GCoM Common Reporting Framework and combines stakeholder surveys with quantitative assessments of heatwaves, agricultural drought and heavy winter conditions. The 16 July 2026 stakeholder workshop, involving 100 participants from 34 institutions, also provides a useful basis for maintaining a permanent stakeholder network around four priority thematic areas: water resources, agriculture, ecosystems and health.

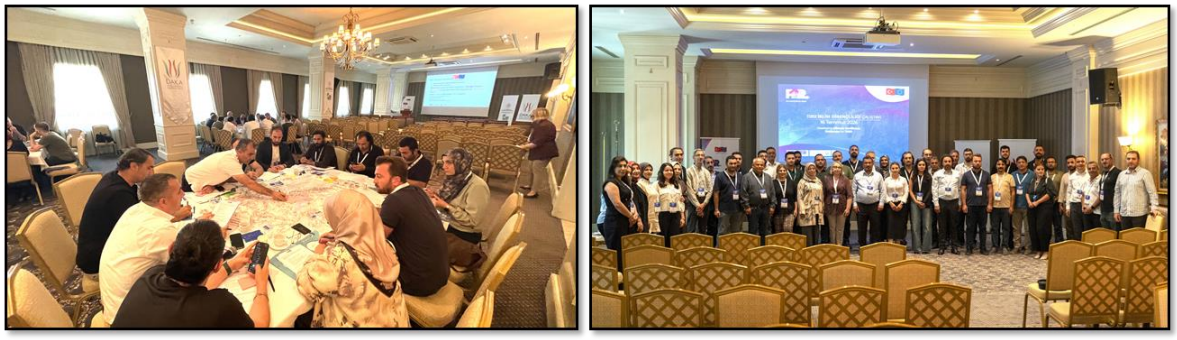


Figure 23: P2R Workshop held in 16 July 2026

The implementation of the YİDEP framework should be supported by an annual monitoring and review cycle.. CDP- Carbon Disclosure Project Cities Program can provide a structured annual opportunity for the TRB2 cities to update climate-risk information, report progress on mitigation and adaptation actions, disclose climate-related projects and investment needs, and identify changes in institutional capacity and climate impacts. The annual CDP cycle should not replace the formal monitoring and reporting requirements of the YİDEP

Regulation; rather, it can function as a practical annual performance review and external disclosure tool supporting the formal five-year YİDEP cycle.

A common monitoring framework should therefore be established across the four TRB2 cities, linking YİDEP actions → responsible institutions → indicators → annual implementation status → budget and finance → CDP disclosure → annual review and corrective action. This would enable the results of the present risk assessment to be progressively updated as new climate data, impacts and implementation results become available. It would also provide DAKA and the Provincial Coordination Boards with a consistent regional evidence base for identifying common risks, cross-provincial priorities, investment opportunities and areas requiring additional technical or financial support.

In this way, climate risk management in TRB2 can evolve from the preparation of individual plans towards a continuous risk-management cycle: assessment of hazards and vulnerabilities, assignment of risk ownership, prioritisation and financing of actions, implementation, annual monitoring and CDP disclosure, periodic review by the Provincial Coordination Boards, and comprehensive YİDEP revision every five years. This approach would strengthen the connection between the P2R findings, the new national YİDEP governance framework and the long-term climate resilience objectives of the TRB2 Region.

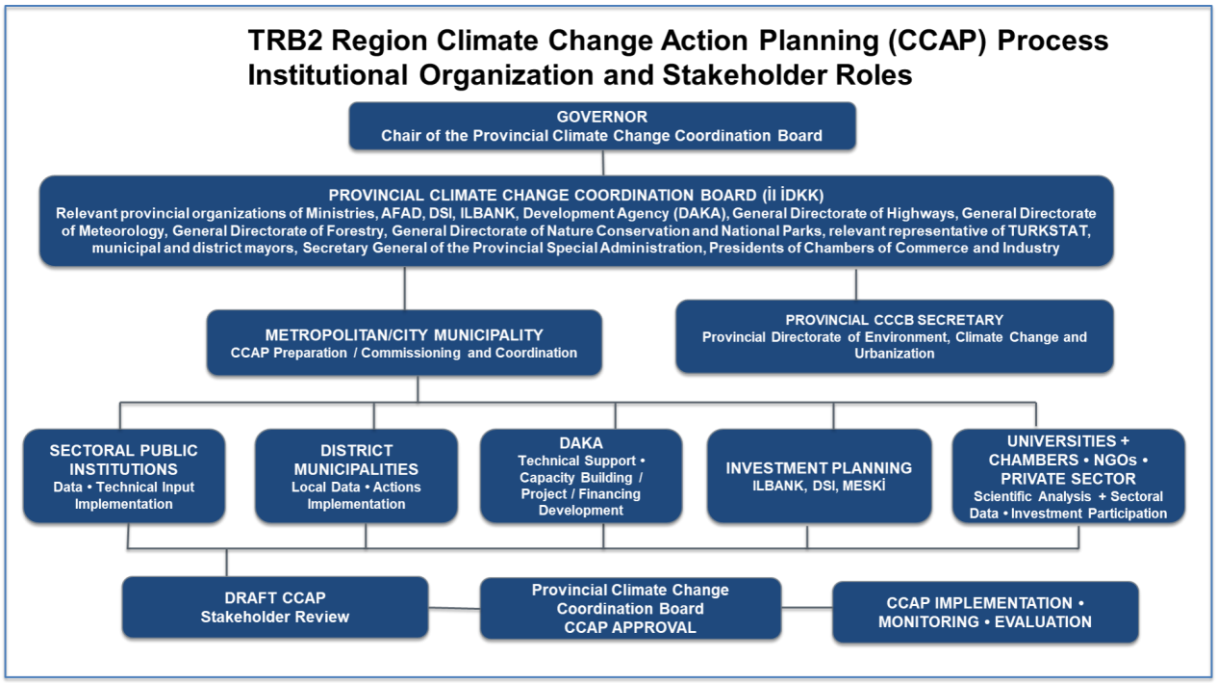


Figure 24: TRB2 Region Climate Change Action Planning (CCAP) Proces- Institutional Organization and Stakeholder Roles

4.2. Prioritised Possible Adaptation Strategies

During the P2R workshop, DAKA facilitated a participatory prioritisation exercise to identify and assess possible climate adaptation strategies for the TRB2 Region. The process combined spatial, experience-based discussion using the A0 TRB2 Regional Map with a subsequent digital prioritisation exercise using the Mentimeter application.

In the table-round discussions, participants worked around the TRB2 Regional Map and identified past climate-related events, their locations and observed impacts, based on their institutional knowledge and local experience. Participants then discussed the, existing response capacities and possible preventive/adaptation actions that could reduce future risks. This approach enabled participants to relate climate hazards and their impacts directly to specific locations and sectors within the region, while also identifying gaps in existing prevention and preparedness measures.

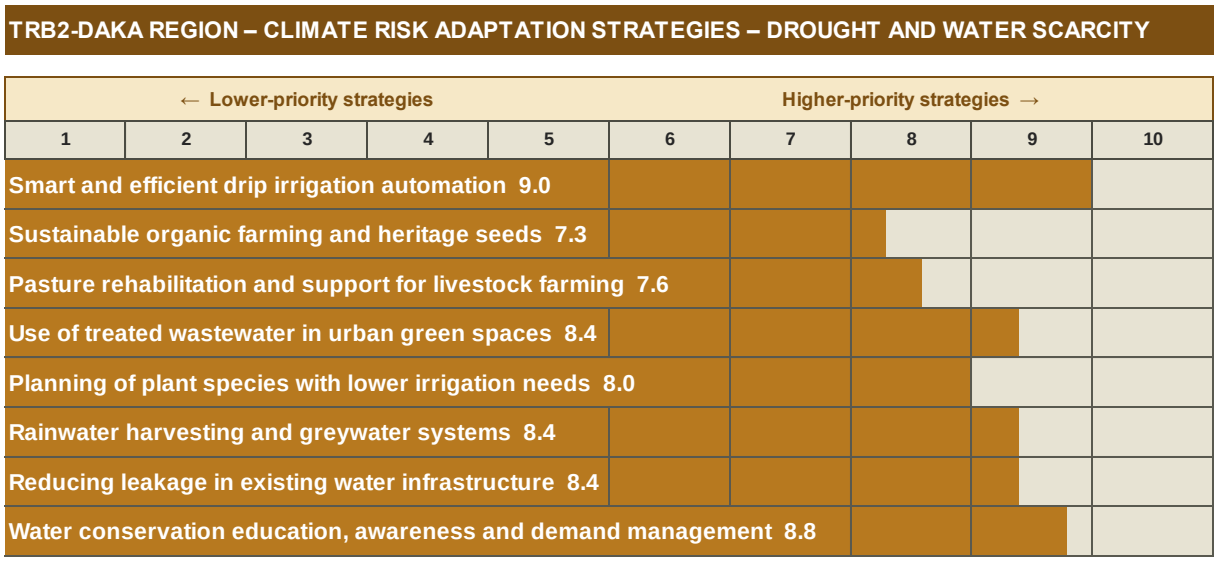


Figure 25: Possible Adaptation Strategies for Drought Hazard in TRB2 Region

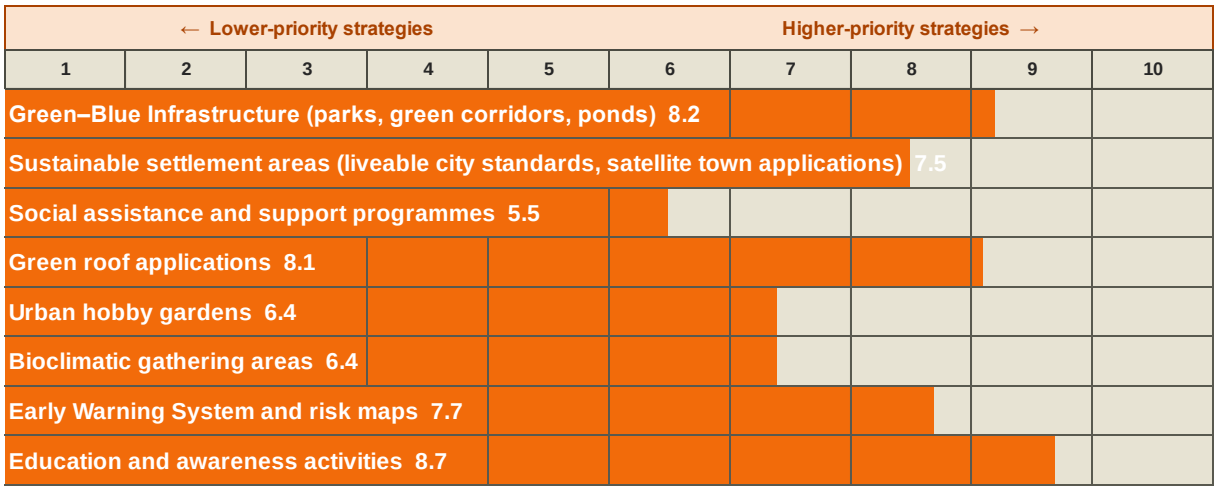


Figure 26: Possible Adaptation Strategies for Heatwaves Hazard in TRB2 Region

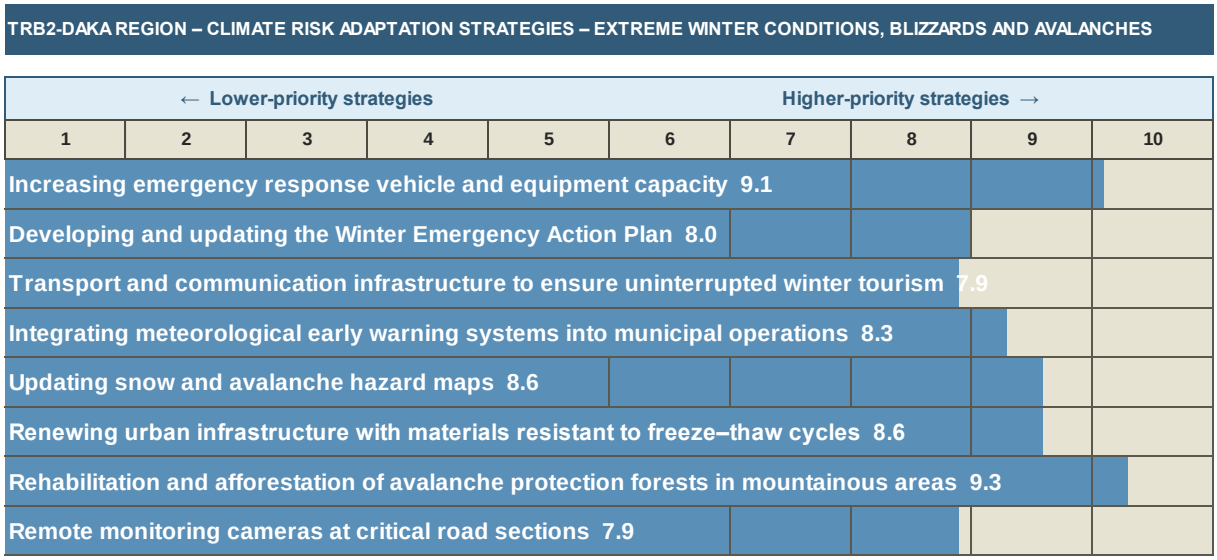


Figure 27: Possible Adaptation Strategies for Heavy Winter Conditions in TRB2 Region

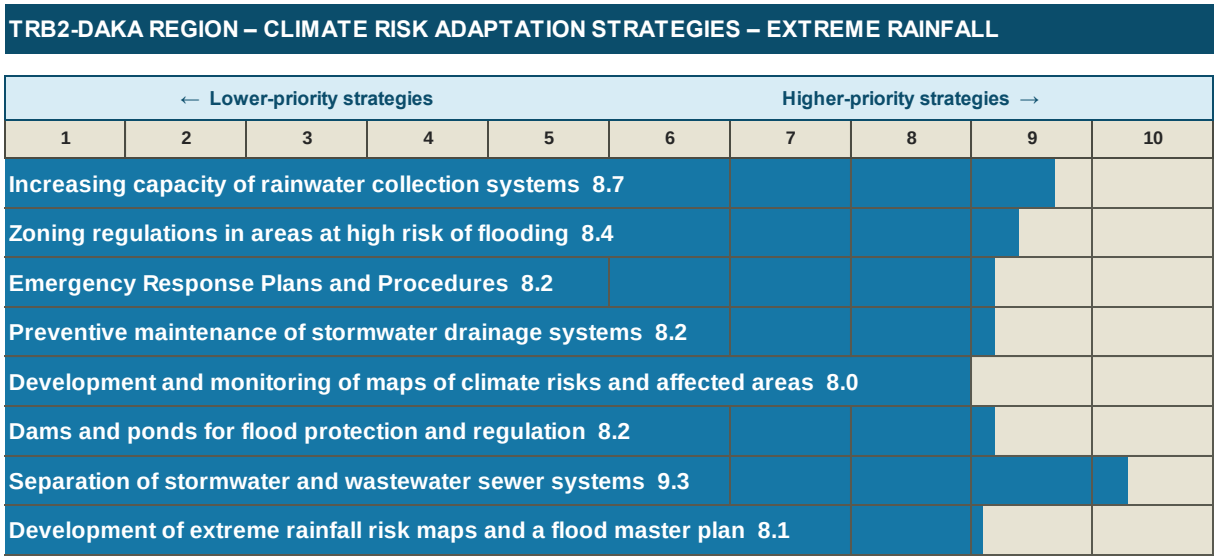


Figure 28: Possible Adaptation Strategies for Heavy Rainfall Hazard in TRB2 Region

The combined approach allowed DAKA to move from past events and observed impacts → existing preventive actions → identified gaps → possible adaptation strategies → stakeholder prioritisation. The resulting priorities provide an important stakeholder-based input for the P2R resilience pathways and for the subsequent development of climate adaptation measures and investment proposals for the TRB2.



5. Conclusion

The Climate Change Risk and Vulnerability Analysis provides a common evidence base for adaptation planning across the TRB2 Region, comprising Bitlis, Hakkâri, Muş and Van. By combining stakeholder assessments, spatial analysis, climate projections and historical impact records, the report identifies four priority areas for climate resilience: drought and water scarcity, extreme heat and urban overheating, heavy rainfall and flooding, and heavy winter conditions. Their consequences are interconnected, particularly through agriculture and livestock, water and energy systems, transportation, public health and ecosystem services.

Drought and water scarcity are central concerns for regional resilience. The stakeholder assessment identifies agriculture and water-dependent services among the sectors most vulnerable to drought. The agricultural analysis further demonstrates that crop production can be substantially affected when rainfall and soil moisture are insufficient and supplementary irrigation is unavailable. Under the assessed future conditions, indicative yield losses under rain-fed conditions are approximately 34% for maize, 24% for potato, 21% for sugar beet and 10% for wheat, with losses also affecting barley and forage crops. These results highlight the dependence of agricultural livelihoods and livestock production on reliable water availability.

The additional MPI-based, bias-adjusted RCP8.5 analysis for Van strengthens the evidence for increasing water stress. Between 2021–2025 and 2046–2050, average minimum and maximum temperatures increase by approximately 1.5°C and 1.7°C, respectively. Annual precipitation decreases by 17.9%, from 345 to 283 mm, while ET_0 rises by 5.2%, from 1,206 to 1,269 mm. Lower relative humidity and reduced rainfall in several crop-growing months reinforce the potential for soil-moisture deficits. These Van results provide a local example of the pressures requiring assessment across the four provinces, rather than a uniform projection for the whole TRB2 Region.

The wheat irrigation case study translates these climatic changes into an indicative agricultural water requirement. Using $ETc = Kc \times ET_0$ and the positive monthly deficit after effective precipitation, the reported annual net irrigation requirement increases from 488 to 574 mm, approximately 17.7%. May and June have the largest requirements. Irrigation planning should therefore assess seasonal supply reliability as well as annual availability,

and combine efficient application, soil-moisture conservation and crop-calendar management with limits on total water use. The estimate is a simplified crop-water balance under the adopted coefficients and effective-rainfall assumptions; it is not a complete soil-water balance or a measure of gross abstraction.

The economic assessment indicates potential annual agricultural revenue losses exceeding EUR 146 million under the production, price and water-deficit assumptions used in the report. This estimate should be interpreted as a conditional measure of economic exposure to inadequate irrigation rather than a forecast of realised losses in 2050 or a calculation of the additional damage attributable solely to climate change. Production quantities, crop prices and the aggregation of forage crops should be reconciled before this estimate is used for investment appraisal. Nevertheless, the analysis establishes a clear case for improving irrigation efficiency, reducing water losses, protecting soil moisture and aligning crop selection with available water resources.

Urban heat requires targeted interventions in densely populated areas. The combination of Landsat-based land surface temperature and WorldPop population data identifies locations where elevated surface temperatures coincide with concentrated population exposure. The projected increase in Van's average minimum and maximum temperatures adds evidence of greater heat exposure and reduced night-time cooling, but does not quantify future heatwave frequency or duration. The maps provide a practical screening tool for prioritising urban cooling and protecting hospitals, schools and community facilities. Daily air-temperature indicators, locally appropriate heatwave thresholds and information on age, health and socioeconomic vulnerability should support heat-health warnings and detailed risk estimates.

Flood impacts depend on catchment conditions and infrastructure as well as rainfall. Historical events demonstrate that damaging flooding can occur following daily rainfall totals of approximately 40–50 mm, particularly where rainfall coincides with snowmelt, rapid runoff, constrained stream corridors or drainage limitations. Rainfall+snowmelt interactions are especially relevant in Bitlis and Muş, while steep terrain and short-duration rainfall create concerns for flash flooding in Hakkâri and parts of Van. Documented impacts extend across buildings, agricultural land, livestock, roads, bridges, culverts, drinking-water networks, irrigation systems and energy infrastructure.

These findings support catchment-based flood management that combines drainage maintenance and capacity assessments with land-use controls, stream-corridor protection, early warning and emergency preparedness. Historical event records provide a valuable foundation, but future flood-risk estimates require additional precipitation analysis, hydrological modelling and detailed mapping of exposed people and assets.

Changing snowfall conditions do not eliminate winter-related risks. The assessed projections indicate decreases in the frequency of days exceeding the selected snowfall thresholds in several parts of the region, while changes in blizzard conditions are more limited and spatially variable. These findings do not justify reducing winter preparedness. Transportation disruption, isolation of settlements, avalanches and interruptions to essential services remain important concerns, especially in mountainous areas. The potential implications of changing snow conditions for seasonal water availability, including the Van Lake Closed Basin, should be investigated using snow-water-equivalent, runoff and water-balance analyses.

Stakeholder priorities provide a clear starting point for adaptation planning. The map-based discussions and Mentimeter exercise identify strong support for efficient irrigation, water conservation, green and blue infrastructure, drainage improvements, early warning and

winter emergency capacity. Highly rated measures include smart irrigation, separation of storm water and wastewater systems, rehabilitation of avalanche-protection forests and strengthening emergency response equipment. These preferences constitute stakeholder input to the P2R process; they should subsequently be assessed against technical effectiveness, feasibility, costs, environmental safeguards and benefits for vulnerable groups before being selected for implementation.

Implementation depends on clear ownership, financing and monitoring. The assessment should inform the provincial YİDEP processes and the development of P2R resilience pathways. Responsible institutions need to translate identified risks into actions with defined owners, implementation schedules, budgets and measurable indicators. DAKA can support this process by facilitating cooperation across the four provinces, harmonising data and helping develop investment proposals. Annual CDP disclosure can complement the formal YİDEP monitoring arrangements by supporting regular review of progress, investment needs and emerging risks.

The TRB2 Region faces a combination of persistent winter hazards, agricultural dependence on water availability, urban heat exposure and locally severe flood impacts. These risks require a coordinated approach that connects provincial and municipal planning with catchment management, agricultural development, public health and infrastructure investment. Shared regional priorities should be accompanied by locally differentiated actions reflecting the contrasting conditions of the four provinces.

The assessment supports immediate progress on measures with benefits under a range of future climate conditions: reducing leakage and unnecessary water demand, improving irrigation management, maintaining drainage systems, protecting natural retention areas, expanding urban shade and vegetation, strengthening early warning and maintaining winter emergency readiness. Measures should be designed together to avoid transferring risk between sectors or locations. Irrigation improvements, for example, should be accompanied by controls on total water use, while flood-protection investments should consider downstream effects.

The next stage of the P2R process should convert these priorities into resilience pathways and a sequenced investment portfolio. Each proposed intervention should specify the risk addressed, target area and beneficiaries, responsible institution, expected outcome, financing requirements and monitoring indicators. Prioritisation should consider the continuity of essential services, protection of vulnerable populations, ecosystem benefits and long-term operation and maintenance needs.

The report provides a foundation for these decisions while identifying the need to strengthen the evidence base. The additional Van analysis uses five-year mean daily profiles and empirical quantile mapping; values beyond the model reference range are capped at observed extrema, which may suppress future extremes, and the method does not explicitly preserve the modelled climate change signal. Subsequent work should harmonise calendars and reference periods, validate irrigation assumptions against local crop calendars and soil-water conditions, and use individual daily series and multiple models and scenarios. Agricultural production and price inputs should also be reconciled before investment appraisal. Updated observations, impact records and implementation results should inform regular review.

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