CLIMAAX
climate ready regions

Deliverable Phase 1 – Climate risk assessment

Multi – Risk assessment of climate change for Goriska region (MRA - GO)

Goriška region, Slovenia

Version 1.0 | September 2025

HORIZON-MISS-2021-CLIMA-02-01 - Development of climate change risk assessments in European regions and communities based on a transparent and harmonised Climate Risk Assessment approach

Funded by the European Union

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101093864. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Document Information

Deliverable Title	Phase 1 – Climate risk assessment
Brief Description	This deliverable presents the outcomes of Phase 1 of the project aimed at strengthening climate resilience in Slovenia's Goriška region. During Phase 1, the CLIMAAX common methodology for climate risk assessments was applied, utilizing standardized European climate data to establish a baseline for the region's climate impacts. The work was carried out by a multidisciplinary team from the Goriška region, incorporating knowledge and expertise. The primary goal of this phase was to assess regional vulnerabilities using data and methods recommended by CLIMAAX, providing a foundation for the next phase, where national datasets will be applied to refine and develop targeted adaptation strategies.
Project name	Multi – Risk assessment of climate change for Goriška region
Country	Slovenia
Region/Municipality	Goriška region
Leading Institution	PRC, Posoški razvojni center (Soča valley development centre)
Supporting Institutions	GOLEA, Goriška local energy agency
Author(s)	• Ivana Kacafura (GOLEA) • Marta Stopar (GOLEA) • Matej Pahor (GOLEA) • Žiga Črv (GOLEA external expert)
Deliverable submission date	29/09/2025
Final version delivery date	29/09/2025
Nature of the Deliverable	R – Report
Dissemination Level	PU - Public

Version	Date	Change editors	Changes
1.0	29/09/2025	GOLEA & PRC	Deliverable submitted
2.0	…	CLIMAAX's FSTP team	Review completed
3.0	…		Final version to be submitted

Table of contents

List of figures

List of tables

Abbreviations and acronyms

Abbreviation / acronym	Description
ACC	Adaptation to Climate Change
PRC	Soča valley development centre (Posoški razvojni center)
GOLEA	Goriška local energy agency
MRA	Multi Risk Assessment
GCM	Global Climate Models
HW	Heatwave
CRA	Climate Risk Assessment
ARSO	Slovenian environment Agency (Agencija Republike Slovenije za Okolje)
TNP	Triglav National Park
CDS	Climate Data Store
SECAP	Sustainable Energy and Climate Action Plan
RATF	Regional Adaptation Task Force
EU	European Union
RCP	Representative Concentration Pathway
LST	Land Surface Temperature
UHI	Urban Heat Island
SPI	Standardized Precipitation Index
SPEI	Standardized Precipitation Evapotranspiration Index
GAEZ	Global Agro-Ecological Zones database
RRA	Regional Development Agency (Regionalna razvojna agencija)
ICRA	Regional Development Agency ICRA (Idrija-Cerkno)

Executive summary

This deliverable presents the outcomes of Phase 1 of the multi-risk climate change assessment for the Goriška region, Slovenia, conducted within the CLIMAAX project framework. The objective was to establish a regional baseline of climate risks by applying the common CLIMAAX methodology and standardized European datasets, thereby enabling future development of a targeted adaptation action plan.

The assessment confirmed that the Goriška region faces **two priority climate hazards**:

- **Heatwaves**, which are becoming longer, more frequent, and more severe, with increasing impacts on vulnerable populations, agriculture, ecosystems, and infrastructure.
- **Agricultural droughts**, which already cause significant crop losses and economic damages, and are projected to intensify further, threatening food security, water supply, and rural livelihoods.

The findings underline that both hazards are **high in severity and urgency**, with strong evidence that they will worsen under climate change scenarios (RCP4.5 and RCP8.5). While adaptive capacity is gradually improving—through municipal SECAPs, the Regional Climate Adaptation Strategy (2025), and participation in the EU Mission on Adaptation—significant gaps remain in local data, infrastructure preparedness, and financial resources required for systematic adaptation.

An important basis for Phase 1 was stakeholder engagement, with more than 60 regional actors involved in identifying risks and priorities. This participatory approach fostered cross-sectoral collaboration and created a strong basis for further activities.

The main conclusion is that Phase 1 successfully created a **foundational, practical and forward-looking baseline CRA** for the region. It provides actionable knowledge for municipalities and regional institutions, while also identifying the data and capacity gaps to be addressed in future phases. Importantly, Phase 1 sets the foundation for **Phase 2**, which will refine risk assessments using local datasets, and **Phase 3**, which will co-design adaptation measures with stakeholders and integrate them into the Regional Adaptation Action Plan. Together, these steps will guide long-term resilience building in the Goriška region.

1 Introduction

1.1 Background

The Goriška region, located in the western part of Slovenia, comprises 13 municipalities: Ajdovščina, Bovec, Brda, Cerkno, Idrija, Kanal ob Soči, Kobarid, Miren-Kostanjevica, Renče-Vogrsko, Nova Gorica, Šempeter-Vrtojba, Tolmin, and Vipava. This diverse region, characterized by a range of geographical features, experiences significant climate variability. Some municipalities, including Ajdovščina, Idrija, and Nova Gorica, have developed Sustainable Energy and Climate Action Plans (SECAPs), which represent important milestone in climate change consideration. However, the region as a whole lacked a coherent and integrated framework for assessing and managing climate risks, establishing Regional Adaptation Task Force (RATF). The adoption of the *Regional Strategy for Climate Change Adaptation of the Goriška Development Region* in June 2025 marked the first coordinated effort across all 13 municipalities to systematically assess climate impacts and design joint responses (GOLEA et all., 2025). Nevertheless, the region as a whole still faces considerable challenges in addressing climate change at a broader level.

The climate of the Goriška region has experienced noticeable changes in recent decades. Between 1981 and 2005, the average air temperature increased by +0.33°C per decade, with a total rise of +1.0°C over the 30-year period. Precipitation patterns have also been altered, showing a decreasing trend of 2.7% per decade. As a result, the region is experiencing a growing number of heatwaves, rising temperatures, and extended drought periods in the summer, while winter sees more extreme rainfall events, particularly in the form of storms and flooding. These climate impacts, including increasing temperatures, drought, wildfires, and changing precipitation patterns, have profound implications for the region's natural environment, agriculture, public health, and infrastructure. (GOLEA et all., 2021)

Climate change is also altering seasonal dynamics, with longer summers, warmer winters, and shorter snowfall periods. These shifts in climate patterns bring challenges to agriculture, biodiversity, and water resources, creating a need for immediate action to build resilience in the region. Addressing these issues at the regional level is critical, given the interconnectedness of the municipalities, where climate impacts can transcend local borders and affect entire communities. (GOLEA et all., 2021)

1.2 Main objectives of the project

The primary objective of the project is to enhance the climate resilience of the Goriška region by applying the CLIMAAX common methodology for climate risk assessments. This initiative aims to strengthen the region's ability to mitigate and adapt to the impacts of climate change by considering the specific vulnerabilities and risks faced by local communities and further upgrading activities into a comprehensive regional climate change adaptation strategy.

One of the key goals of the project is to assess the climate-related risks in the region, focusing on the most pressing issues such as rising temperatures, prolonged heatwaves, water scarcity, and extreme rainfall events. By utilizing standardized European climate data and the CLIMAAX Toolbox, this project will establish a solid baseline for the region's climate risk profile, allowing for a more refined analysis in subsequent phases. This baseline will be crucial for upgrading existing and developing targeted adaptation strategy and enhancing the region's long-term climate resilience.

The significance of this project to the Goriška region lies in its ability to provide actionable insights into climate risks, which can inform regional planning and decision-making. By applying the CLIMAAX Handbook, the project will help local municipalities better understand the specific vulnerabilities they face and identify tailored adaptation measures to address these challenges. The benefits of using the CLIMAAX methodology include the following:

- **Improved Climate Risk Assessment:** The project will provide a clear understanding of the region's exposure to climate change, including heatwaves, and drought.
- **Localized Adaptation Strategies:** The integration of high-resolution local data and projections will allow for the development of strategies tailored to the unique needs of the Goriška region, ensuring that the proposed measures are practical and effective in mitigating the region's climate vulnerabilities.
- **Enhanced Stakeholder Engagement:** The project will involve local stakeholders in the adaptation planning process, ensuring that the perspectives of both decision-makers and residents are considered. This participatory approach is crucial for fostering collaboration and building a sense of ownership over the climate resilience strategies developed.
- **Long-Term Climate Resilience:** By addressing both immediate and long-term risks, the project aims to create a more resilient Goriška region, capable of adapting to future climate conditions and mitigating the most pressing risks associated with climate change.

In addition to the direct benefits of applying the CLIMAAX methodology, the project will also help raise awareness about the impacts of climate change and the need for adaptation. It will demonstrate the value of coordinated, multi-municipality climate action and serve as a model for other regions in Slovenia and beyond. Through the application of CLIMAAX tools and stakeholder engagement, this project will contribute to the development of a more resilient, sustainable, and climate-adaptive Goriška region.

1.3 Project team

Ivana Kacafura holds a BSc in Environmental Sciences from the University of Nova Gorica (2009) and has worked at the GOLEA Agency since 2008. She specializes in energy efficiency and renewable energy sources, with a strong focus on environmental impacts and economic feasibility. She has extensive experience in energy management systems and has carried out several economic and feasibility studies for EE&RES implementation. In 2013 she completed the EUREM – European Energy Manager training and received the EUREM Award for excellence. Ivana has led and contributed to several EU projects and co-authored the of local energy concepts, SEAPs and SECAPs. She implemented different training courses and capacity building workshops for teachers, public administrators, children, as well as stakeholder workshops to support collaborative climate and energy planning. She actively contributed to the preparation of the Regional Climate Change Adaptation Strategy for Goriška.

Marta Stopar holds a BSc degree in Environmental Sciences from the University of Nova Gorica (2008). She began her career at the University, working on EU projects as a technical expert in the Laboratory for Environmental Research and as a teaching assistant in Waste Management, Marine

Ecology, and Environmental Impact Assessment. Since joining the GOLEA Agency in 2017, she has been led and contributed to several EU projects, both as a project manager and as an expert. Her work also includes the preparation of local energy concepts, SEAPs, and SECAPs, supporting municipalities in sustainable energy and climate planning. She actively contributed to the preparation of the Regional Climate Change Adaptation Strategy for Goriška.

Matej Pahor obtained a Degree in Mechanical Engineering (Energy and Process Engineering) at the University of Ljubljana in 2013. In 2016, he obtained a license as independent expert for energy performance certificate production. He is actively involved in monitoring and targeting as well as in energy accounting activities, elaboration of energy performance certificates, preparation of feasibility studies, technical documentation elaboration, building energy audits, among other. From 2025 on he is a director of GOLEA agency.

Žiga Črv holds a BSc in Computer and Information Science from the University of Ljubljana, Faculty of Computer and Information Science (2023), where he is currently pursuing his Master's degree. During his studies, he gained professional experience as a software developer at Marand d.o.o. in Ljubljana. He is currently employed at Arctur d.o.o. in Nova Gorica, where he works as a backend developer and AI researcher. His expertise lies in backend systems, distributed architectures, and the application of artificial intelligence for practical problem-solving. He has hands-on experience with cloud-based environments, microservices, and database systems, as well as in developing and integrating intelligent solutions into real-world applications. He is also engaged in developing AI models and adapting large language models (LLMs) to specific applications.

1.4 Outline of the document's structure

This document is structured in accordance with the CLIMAAX Phase 1 Deliverable guidelines and is organized into several key sections. After the Executive Summary and Introduction, the document focuses on the Climate Risk Assessment (CRA) for the Goriška region, which is the central element of Phase 1. The CRA is divided into the following main sections:

- Scoping: This section defines the project's objectives, governance context, stakeholder engagement, and provides an overview of the initial risk screening process.
- Risk Exploration and Risk Analysis: These sections outline the methods and tools used to assess climate-related risks in the region, with a particular focus on the climate hazards identified and their potential impacts.
- Preliminary Key Risk Assessment Findings: This section presents the key findings from the risk assessment, highlighting the most critical climate risks, such as heatwaves, water scarcity, and flooding, that the Goriška region faces.
- Preliminary Monitoring and Evaluation: Here, the lessons learned, challenges encountered, and initial feedback from stakeholders are discussed, along with recommendations for data needs and future improvements.
- Conclusions: The document concludes with a summary of the main findings of Phase 1 and outlines the next steps for the project.

In addition to the core sections, the document includes supporting documentation and references, which provide additional context and details to complement the main content.

2 Climate risk assessment – phase 1

This section outlines the steps taken in performing a first CRA using the CLIMAAX Framework[1] .

2.1 Scoping

In the scoping phase, the key objectives, context and stakeholders were identified and are described in the sections that follow.

2.1.1 Objectives

The objective of this CRA for the Goriška region is to identify and prioritize key climate-related risks and assess their impacts on vulnerable groups (populations, critical infrastructure, agriculture, and ecosystems). The purpose is to provide a solid evidence base for informed decision-making and targeted adaptation strategies.

The expected outcome of this CRA is to deliver robust, evidence-based insights that strengthen regional resilience and adaptation planning. By highlighting the most pressing climate risks, the assessment will support municipalities and regional bodies in upgrading targeted strategy and developing action plan, including regional spatial plan, and regional development plan.

This CRA aims to feed directly into policy and decision-making processes, providing decision-makers and stakeholders with actionable knowledge to prioritize adaptation measures, allocate resources efficiently, and foster cross-municipal cooperation. By addressing risks at a regional scale (where applicable), the CRA promotes cross-municipal cooperation and strengthens the region's overall capacity to adapt to climate change.

Limitations and boundaries

The CRA is constrained by limited availability of high-resolution local climate and socioeconomic data, gaps in historical hazard records, and varying levels of stakeholder engagement across municipalities. Uncertainties in future climate scenarios and the complexity of modelling vulnerabilities at fine scales also pose challenges. In addition, limited institutional capacity and resources may restrict the depth of the analysis. Nevertheless, these constraints also create opportunities for stronger collaboration and capacity building.

2.1.2 Context

Previous assessment and management of climate risks

Until recently, climate hazards in the Goriška region—such as heatwaves, droughts, floods, wildfires, and landslides—were mostly addressed at the local level, often through ad hoc measures or sector-specific strategies. Some municipalities, including Ajdovščina, Idrija, and Nova Gorica, have developed Sustainable Energy and Climate Action Plans (SECAPs), which represent important step (GOLEA et all., 2021). However, the region as a whole lacked a coherent and integrated framework for assessing and managing climate risks. The adoption of the *Regional Strategy for Climate Change Adaptation of the Goriška Development Region* in 2025 marked the first coordinated effort across all 13 municipalities to systematically assess climate impacts and design joint responses (GOLEA et

[1] Summary of the framework:
https://handbook.climaax.eu/CRA_steps/framework.html
Detailed description of the framework:
https://files.cmcc.it/climaax/Deliverables/CLIMAAX_D1.4_Climate%20Risk%20Assessment%20Framework_revised.pdf

all., 2025). Nevertheless, the region as a whole still faces considerable challenges in addressing climate change at a broader level.

Problem definition and broader context

The key problem this project addresses is the fragmented and uneven approach to climate risk management across municipalities. Climate hazards transcend administrative boundaries, and local responses alone are insufficient to address systemic risks to agriculture, forestry, water management, health, and infrastructure. By creating a shared evidence base and a coordinated framework, the CRA strengthens regional resilience and ensures alignment with national climate adaptation objectives and the European Green Deal. In this way, the project not only tackles immediate local vulnerabilities but also positions the region within the wider national and EU adaptation system, enabling better access to resources and integration into long-term development strategies.

Governance context

Slovenia is bound by the EU Climate Law and adaptation frameworks, while the region itself joined the EU Mission on Adaptation to Climate Change in 2023. The Regional adaptation strategy (adopted in June 2025) provides the policy foundation, coordinated by GOLEA and regional development agencies (PRC and 3 others), with technical support from the MIP4Adapt project. As Slovenia lack of regional governance, the 13 municipalities established Regional Adaptation Task Force to tackle climate change issues, which part are energy agency GOLEA and regional development agency PRC (and 3 other regional development agencies) (GOLEA et all., 2025).

The most exposed sectors to climate change in the region are following:

- **Agriculture and viticulture**: threatened by droughts, extreme heat, changing precipitation.
- **Forestry and biodiversity**: at risk from wildfires, pests, and habitat loss.
- **Water management**: facing stress from reduced summer flows and flooding.
- **Tourism**: vulnerable to loss of snow cover, heatwaves, and landscape degradation.
- **Public health**: affected by heat stress, air quality issues, and rising vulnerability for vulnerable groups.
- **Infrastructure and urban systems**: exposed to flooding, overheating and damage from extreme weather.
- **Ecosystems**: biodiversity loss, reduced water quality, higher fire risk.

External influences

The CRA is influenced by broader initiatives, including Slovenia's national climate adaptation strategy, EU-level policies, and cross-border cooperation with Friuli Venezia Giulia in Italy. Participation in the EU Mission on Adaptation has strengthened knowledge transfer, access to methodologies, and financial support opportunities, while also linking the region to international networks of climate-resilient regions.

Potential adaptation measures identified include:

- **Water management**: flood retention basins, improved stormwater systems, irrigation schemes.
- **Nature-based solutions**: afforestation, erosion control, and blue-green infrastructure in urban areas.
- **Agriculture**: climate-resilient crops, soil management, and water-saving techniques.
- **Urban planning**: shading, green roofs, and climate-sensitive spatial planning.

- **Health**: early warning systems, heatwave action plans, and targeted support for vulnerable groups.
- **Forestry**: diversified species composition, wildfire prevention corridors, and pest management.
- **Tourism**: diversification of activities, sustainable infrastructure, and adaptation of services to new climate conditions.

These are some interventions that can help the Goriška region move from fragmented, local-level responses towards a coordinated, cross-sectoral adaptation strategy that supports long-term resilience and sustainable development.

2.1.3 Participation and risk ownership

First steps and process set-up

The stakeholder involvement process was initiated in December 2024 with the organization of a regional workshop in Nova Gorica, which brought together more than 60 representatives from municipalities, public institutions, NGOs, the private sector, academia, and civil society. This workshop served as the first step in mapping climate risks, exchanging local knowledge, and identifying key priorities for the Regional adaptation strategy and Climate Risk Assessment (CRA). It also highlighted two essential directions for further work: **strengthening cross-sectoral cooperation** and **raising public awareness**.

In March 2025, all 13 municipalities in the Goriška region reviewed the draft regional adaptation strategy. Their comments and proposals ensured that the document reflected local needs and aligned with municipal development priorities. The process was coordinated by GOLEA, in cooperation with regional development agencies (PRC, ICRA, RRA of Northern Primorska and RRA Rod). During the CLIMAAX project, this finding was further validated through continued engagement with stakeholders.

Relevant stakeholders

Stakeholders are engaged at multiple levels:

- **Local government**: the 13 municipalities of the Goriška region (Ajdovščina, Idrija, Nova Gorica, Tolmin, etc.) as primary decision-makers and implementers of adaptation measures.
- **Regional institutions**: GOLEA, PRC, ICRA, RRA of Northern Primorska and RRA Rod acting as coordinators and technical facilitators.
- **National level**: ministries responsible for environment, spatial planning, and agriculture, ensuring consistency with national frameworks.
- **Non-governmental organizations**: environmental NGOs, cultural and natural heritage groups, and civil initiatives advocating for climate action and protection of natural resources.
- **Private sector**: particularly actors in agriculture, forestry, tourism, and infrastructure, who are directly affected by climate impacts.
- **Academia and experts**: universities, research institutes, and local experts.
- **Citizens**: involvement through public consultations and awareness-raising activities.

Vulnerable groups and priority areas

The most exposed groups include elderly people (over 65) and those with health conditions (heat stress), farmers and winegrowers (drought, storms), residents of flood-prone (Cerkno, Vipava valley…) or landslide areas (Soča valley, Idrija, Ajdovščina, …), communities dependent on tourism (Bovec, Kobarid, Cerkno, …) and national heritage (Triglav national park). These groups are represented through municipal structures, farmers' associations, health institutions, and local organizations.

Risk ownership and acceptable risk

Risk ownership is primarily regulated through municipalities, which are responsible for local adaptation measures, supported by regional development agencies and GOLEA. National authorities provide regulatory guidance and co-financing. The community's acceptable risk level is low for high-impact hazards such as floods and wildfires, where prevention and protection measures are considered essential. For less severe but frequent hazards, such as seasonal droughts, a higher degree of residual risk is tolerated, with adaptation focused on resilience and preparedness.

Communication of results

The results of the CRA will be communicated through multiple channels:

- **Municipal and regional councils**, to ensure integration into spatial and sectoral planning.
- **Regional agencies and GOLEA**, to align measures with regional adaptation strategy.
- **National ministries**, to connect with national adaptation priorities and funding opportunities.
- **Stakeholders and the general public**, through workshops, online platforms, and awareness campaigns, emphasizing transparency and shared responsibility.

2.2 Risk Exploration

Risk exploration started with a broad screening of climate-related risks, focusing on their underlying hazards, exposures, and vulnerabilities. The Goriška region, with its diverse geography and climate, is exposed to a wide range of natural hazards, including **heatwaves, droughts, floods, wildfires, storms, strong bora wind, and hail**.

These trends mean that the Goriška region is increasingly vulnerable to **compound climate extremes**, where multiple hazards (heat, drought, fire, storm) interact within a single season. This reality was emphasized in the 2024 stakeholder workshop in Nova Gorica, where participants identified **heatwaves and droughts** as the most urgent and cross-cutting risks to address.

2.2.1 Screen risks (selection of main hazards)

Relevant hazards and potential risks

Based on scientific evidence and stakeholder input, the CRA focuses on **heatwaves** and **droughts** as priority hazards for the Goriška region. While floods, storms, and wildfires remain relevant, heat and drought are expected to have the **greatest long-term systemic impacts** across sectors.

Current situation and affected areas

- **Heatwaves**:
    - The Nova Gorica wider area is among the hottest in Slovenia.
    - Events in 2003, 2013, 2015, 2017, 2019, and 2022 reached extreme levels, with Bilje station recording up to 40 °C (ARSO, 2024).
    - Impacts include excess mortality among vulnerable groups, ozone pollution, agricultural losses (fruit, maize, vineyards), energy stress, and wildfire risk.
    - Urban areas such as Nova Gorica and Ajdovščina face the greatest health and infrastructure pressures (GOLEA et all., 2021).

- **Droughts**:
  - Severe droughts occurred in 1992–94, 2003, 2012, 2013, 2017, and 2022 (ARSO, 2024).
  - The 2012 drought caused around €4.5 million of agricultural damage (LIFE ViVaCCAdapt, 2019) in the Vipava Valley; in 2022, water shortages forced municipalities like Ajdovščina, Tolmin and Kanal ob Soči to deliver drinking water by tanker trucks (24ur.com, 2022; Občina Ajdovščina, 2022).
  - Agriculture (maize, wheat, vineyards, orchards), forestry, and water supply are most affected.

Observed and expected hazards (Copernicus Atlas and projections)

- **Observed**: ARSO records show rising maximum temperatures, more hot days, fewer cold extremes, longer droughts, and more frequent water shortages (ARSO, 2024).
- **Expected**: Copernicus Climate Atlas confirms that southern and western Slovenia will face:
  - A sharp rise in heat extremes, with up to 30+ tropical nights annually by 2050.
  - More frequent and severe drought episodes.
  - Increased seasonal variability in precipitation, with wet winters and drier summers.

Hazards selected for the CRA

The CRA will cover **heatwaves and droughts** because they:

- Are **observed** as intensifying events. Are **priority concerns** for local stakeholders.
- Cause **cross-sectoral damages** (health, agriculture, water supply, energy, ecosystems).
- Align with **climate projections**, identifying them as the fastest-growing risks for the region.

Data and knowledge availability/gaps

- **Available**:
  - ARSO climate and hazard archives (Bilje station, 1991–2025) (ARSO, 2024).
  - Stakeholder knowledge and reports (GOLEA, municipalities, civil protection).
  - Adaptation Strategy to Climate Change for Goriška region (GOLEA et all., 2025).
- **Gaps**:
  - High-resolution local vulnerability mapping (health, socio-economic groups).
  - Detailed modelling of agricultural drought (soil moisture, evapotranspiration).
  - Health impact statistics for heat-related mortality and morbidity.

2.2.2 Workflow selection

Considering the hazard selection in the previous step, two risk workflows have been identified as most relevant for the Goriška region: **heatwaves** and **droughts**. Both hazards have already caused significant impacts in the past, are projected to intensify in the future, and directly affect multiple sectors and vulnerable groups across the region.

2.2.2.1 Workflow #1 – Heatwaves

Hazard:

Increasing frequency, intensity, and duration of extreme heat events. Historical records show repeated heatwaves (2003, 2013, 2015, 2017, 2019, 2022) with temperatures reaching 38–40 °C in the Nova Gorica wider area (ARSO, 2024).

Exposure:

- Urban areas with high population density (Nova Gorica, Ajdovščina, Šempeter-Vrtojba).
- Outdoor workplaces (construction, agriculture, logistics).

Vulnerability:

- Elderly, children, and people with chronic illnesses (cardiovascular, respiratory).
- Outdoor workers directly exposed to high temperatures.
- Vulnerable ecosystem, especially in protected areas (TNP and other protected areas).

Impacts:

- Health: increased mortality and hospital admissions, heat stress, worsened air quality (higher ozone concentrations).
- Ecosystems: crop and forest stress, increased wildfire risk (Karst Plateau).
- Infrastructure: urban heat island effects, energy and transport system strain.

2.2.2.2 Workflow #2 –Agricultural droughts

Hazard:

More frequent and prolonged summer droughts, combined with declining precipitation and higher evapotranspiration. Severe droughts (1992–94, 2003, 2012, 2017, 2022) caused widespread agricultural damage and water shortages.

Exposure:

- Agriculture and viticulture in the Vipava Valley and Brda (maize, wheat, fruit, vineyards).
- Water resources: springs, municipal water supply systems.

Vulnerability:

- Farmers, winegrowers and agricultural households in the Vipava Valley and Brda, and livestock breeders in the Soča valley.
- Rural communities dependent on local springs and small water systems.
- Municipalities with limited water infrastructure and emergency reserves.

Impacts:

- Agriculture: catastrophic crop losses, reduced fodder, long-term economic damage.
- Water resources: drying springs, tanker supply for households (Ajdovščina, Tolmin, Kanal ob Soči in 2022).
- Economy: reduced yields in wine and fruit sectors, reduced availability of livestock feed.

2.2.3 Choose Scenario

In this project's first phase, we followed the **basic settings and recommendations of the CLIMAAX Handbook**.

For **heatwaves**, as Europe is the continent experiencing the most accelerated warming, we identified as the most relevant climate change scenarios the **moderate RCP4.5** and the **pessimistic RCP8.5**. These scenarios were applied for the **medium-term (2030-2050)** and **long-term (2050-)**, using available datasets from EURO-CORDEX, accessed via the CDS.

For **droughts**, projections are particularly important for agriculture, forestry, and water management, where even small changes in climate conditions can lead to significant socio-economic consequences. We followed the basic settings and recommendations for **agricultural drought**. For vulnerability and exposure, we used **RCP4.5 and RCP8.5** and choose the period **2046–2050 (near future) and 2066-2070 (mid-century)**.

2.3 Risk Analysis

During the first phase of CLIMAAX we implemented a few workflow enhancements, which are described in supporting material, chapter 1.1.1.

2.3.1 Workflow #1 Heatwaves

We applied all methodologies described in the heatwave workflow of the CLIMAAX CRA toolbox for hazard and risk assessment. This first-phase assessment had a twofold objective: firstly, to explore the applicability of the CLIMAAX heatwave workflow in our region, and secondly, to assess the impact of climate change on the heatwave hazard and define the most affected areas, both currently and in the future, under the RCP4.5 and RCP8.5 climate change scenarios.

For this initial phase, we decided to access data on hazard, exposure, and vulnerability using pre calculated European/large-scale datasets available in the CLIMAAX Handbook about hazard (heatwave), exposure (population), and vulnerability (population). Table 2-1 presents the datasets used for implementing the CLIMAAX heatwave workflow.

Table 2-1 Data overview workflow #1

Hazard data	*Vulnerability data*	*Exposure data*	*Risk output*
EUROHEAT (heatwave days, 1986–2085; EURO-CORDEX ensemble dataset RCP4.5 & RCP8.5; Copernicus Atlas)	*Population age structure (≤5, ≥65; WorldPop 2020)*	*Population density & distribution (WorldPop); Land Surface Temperature (Landsat-8 / RSLab)*	*Heatwave occurrence from 1986 to 2085; Hotspot maps; Projected risk to vulnerable groups*
Xclim (custom indices: Tmax, Tmin, thresholds, 1971–2050; EURO-CORDEX RCP4.5 & RCP8.5, GCM: mpi_m_mpi_esm_lr; RCM: CLCcom-CLM-CCLM4-8-17(EU), Copernicus Atlas)	*Population age structure (≤5, ≥65; WorldPop 2020)*	*Population density & distribution (WorldPop)*	*Heatwave frequency & duration trends; Refined local hazard indicators*

2.3.1.1 Hazard assessment

For the HW hazard assessment, we applied both methodologies available: EuroHEAT methodology and the methodology based on Euro-Cordex dataset and Xclim library.

<u>EUROHEAT – Hazard Assessment</u>

This workflow, adapted from the CLIMAAX Handbook, applies the EuroHEAT methodology using EURO-CORDEX climate projections (12×12 km resolution) to assess heatwave occurrence in Goriška region. It defines the hazard component of climate risk by estimating the frequency, duration, and spatial extent of heatwaves under present and future scenarios. The analysis uses pre-processed data from the Copernicus Climate Data Store (CDS), covering the period from 1986 to 2085. Since Slovenia lacks a national heatwave definition, the study adopted the EU-wide health-based threshold: two or more consecutive days where both the maximum apparent temperature (Tappmax) and the minimum temperature (Tmin) exceed their respective monthly 90th percentiles. This combined day/night criterion enhances relevance for public health planning. The workflow's strengths include the availability of pre-calculated indicators, extended temporal coverage, and the use of both maximum and minimum temperatures to better reflect severity. However, it also has limitations—such as fixed thresholds, values aggregated per year, and exclusion of the Urban Heat Island (UHI) effect—which may lead to underestimating urban heat stress. Key outputs include annual projections of heatwave frequency and duration, time-series trends for RCP4.5 and RCP8.5 scenarios. Although UHI effects were not included, EUROHEAT provided a standardized, health-oriented hazard baseline that informed the exposure and vulnerability phases of the CRA. In practice, the following steps were completed:

- Required packages were imported.
- Heatwave occurrence data were retrieved from the CDS.
- Health-related heatwave datasets were downloaded for RCP4.5 and RCP8.5.
- Plot results based on EU-wide health thresholds were generated (Figure 2-1).

The results for the historical and future decades (1986-2085), corresponding to the two RCPs selected, are presented in Fig 2-1. The difference between the two pathways gradually increases until 2055. After that, the HW occurrence seems to stabilize to values around 25 per year under the moderate scenario (RCP4.5), where as it continues to dramatically increase based on pessimistic scenarios data (RCP8.5), reaching an occurrence of a value of more than four times compared with the historical period.

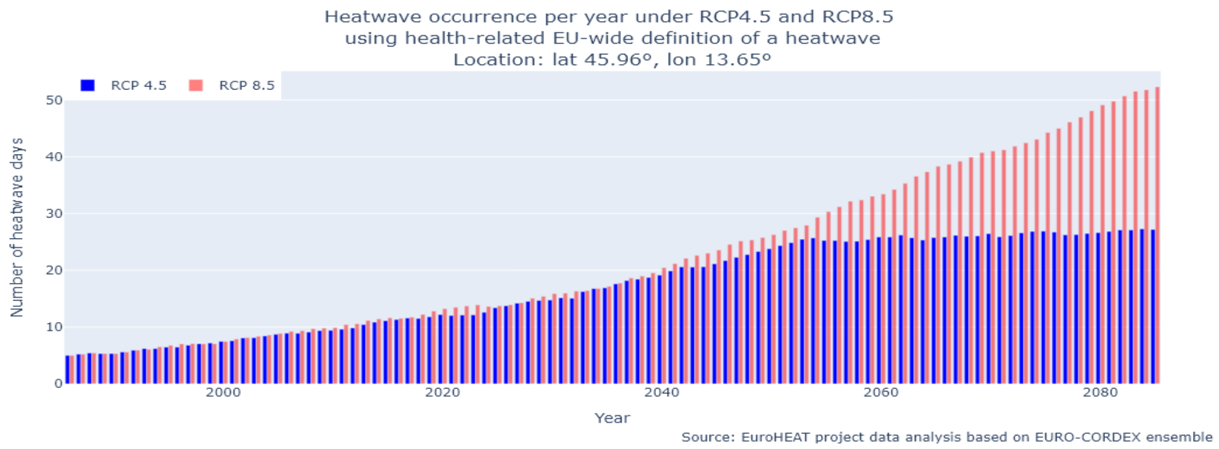

Figure 2-1HW occurrence per year based on EuroHEAT methodology (the location is Nova Gorica city centre).

<u>Xclim – Custom Hazard Assessment</u>

The second workflow used in our study applied the Xclim Python package to conduct a tailored hazard analysis based on EURO-CORDEX climate projections. This approach allowed for the creation of custom heatwave indices aligned with Goriška climatic and public health needs. Data at 12 km resolution were retrieved from the Copernicus Climate Data Store (CDS) for historical (1971–2005) and future (2006–2050) periods under RCP4.5 and RCP8.5 scenarios. A bounding box was defined to focus the analysis on our region.

Heatwaves were defined as 3 consecutive days exceeding a temperature threshold 25 °C, as Slovenian environment Agency defines a heatwave in the Goriška region (which has an ameliorated Mediterranean climate) as a period of at least three consecutive days when the daily mean air temperature is equal to or above 25 °C. This threshold corresponds to the 97th percentile of the reference period 1986–2015 and is used specifically for the Goriška climate zone. (ARSO, 2025)

Using Xclim, various indices such as frequency, cumulative exposure, and a composite heatwave index were calculated. This enabled more granular examination of year-on-year variation and improved local adaptability compared to the standard EUROHEAT workflow.

The workflow enabled full control over index creation and scenario-sensitive projections, offering a second layer of hazard analysis. In this workflow:

- Climate datasets were downloaded from CDS including daily maximum and minimum 2m air temperatures.
- Heatwave occurrence was calculated based on the Xclim methodology.
- Temperature thresholds initially followed CLIMAAX recommendations, and after that adapted to Goriška-specific values (in future reporting period a calculation will be made using national meteorological data received from ARSO).
- Plot results based on CLIMAAX recommendations for Heatwave index, Heatwave frequency, and Heatwave total length of the selected location were generated (Figure 2-2).

The XCLIM results for the Goriška region up to 2050 (presented on Figure 2-2) show a consistent increase in heatwave index. Additional figures for heatwave frequency and heatwave total length are in presented in supporting material. Heatwave frequency is projected to rise after 2030, with a stronger increase under RCP8.5. The heatwave index highlights a sharp growth in the number of days within heatwave conditions, with values exceeding 70–80 days per year by mid-century in the pessimistic scenario. Similarly, the total number of heatwave days indicates longer and more persistent events, particularly from 2035 onward. Although the exact values depend on the chosen definition, the overall trend is clear: heatwaves will become more frequent, longer, and more severe, significantly raising risks for health, agriculture, infrastructure, and ecosystems in the region. Finally, it appears that despite some variations, the results from both hazard assessments generally follow the same trend.

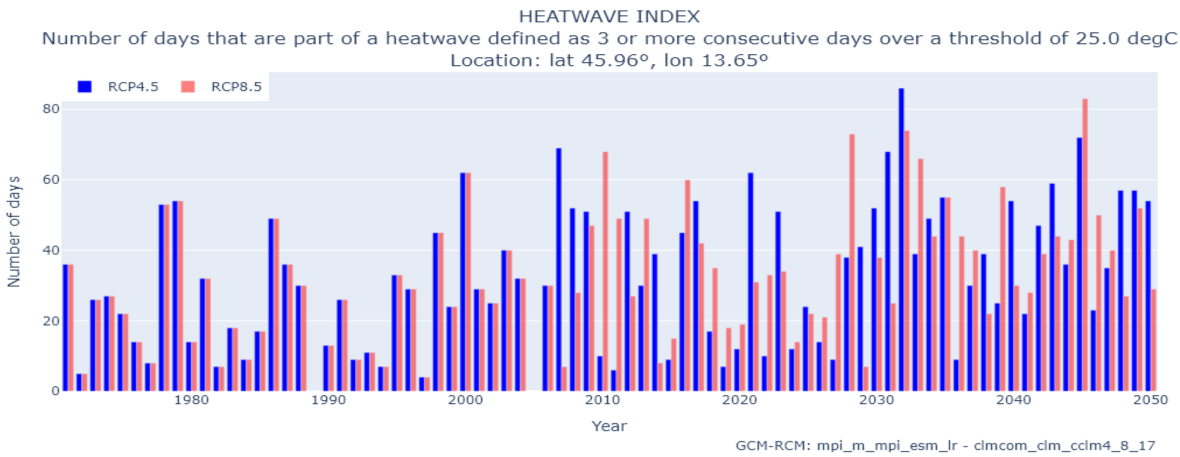

Figure 2-2 Heatwave index of the selected location (Nova Gorica city centre).

2.3.1.2 Risk assessment

Risk assessment for heatwaves based on satellite-derived data

This procedure was developed to assess heatwave hazards at fine spatial resolution by integrating satellite-derived Land Surface Temperature (LST) data with layers representing vulnerable populations. The analysis focused on Nova Gorica, a densely populated and heat-exposed city in Goriška region (figure in supporting material). Unlike climate projections, this method relies on observed, high-resolution thermal data, offering actionable insights for local planning.

LST data were obtained from Landsat 8 via the RSLab Portal (Parastatidis et al., 2017), covering July 2022. Three images were selected (4th and 20th of July and 5th of 24 August) as July 2022 has the highest recorded heatwaves in history for location of Nova Gorica. These surface temperatures were then classified into five major categories—Very Low (<25°C), Low (25–35°C), Medium (35–45°C), High (45–55°C), and Very High (>55°C)—and further refined into 10 sub-classes to better capture urban heat hotspots (figure in supporting material).

In parallel, high-resolution population data from WorldPop (2018; DOI: 10.5258/SOTON/WP00646) were used to identify vulnerable groups, focusing on male and female populations aged 5, 65, 70, 75, and 80. The data, representing the year 2020, were processed and classified into 10 vulnerability categories using the same classification method to ensure compatibility and sensitivity in urban settings (figure in supporting material).

These two layers—thermal exposure and demographic vulnerability—were then merged into a 10×10 spatial risk matrix to generate a composite heat risk index. This index highlighted areas where high surface temperatures and vulnerable populations intersect, revealing urban heat risk hotspots (figure in supporting material).

The results were plotted interactively (Figure 2-3), providing stakeholders with a user-friendly tool to visualize heat exposure and spatial vulnerability. While the workflow does not rely on future projections, it serves as a real-time baseline that complements model-based assessments which help to identify the places that are the most exposed to the effects of heat in combination with the map of areas with high density of vulnerable groups of population (based on age). This high-resolution, satellite-based approach has been instrumental in identifying priority intervention zones and informing locally specific strategies—such as cooling centre placement, green infrastructure design, and urban planning adaptations.

Cross-validation of the satellite-based approach with EUROHEAT results confirmed existing risks and revealed deviations from long-term trends in the probability of future heatwave occurrence.

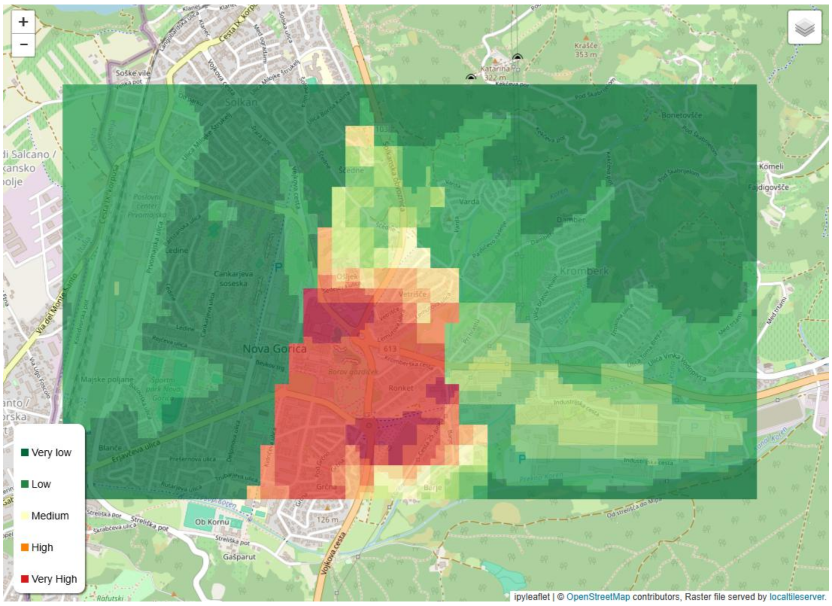

Figure 2-3 Risk data on the interactive map for Nova Gorica

Risk assessment for heatwaves based on climate projections

The results of the risk workflow help us identify the places that are the most exposed to the effects of heat in combination with the map of areas with high density of vulnerable groups of population (based on age). Risk Analysis aligns with the CLIMAAX structure—combining **hazard**, **exposure**, and **vulnerability** data to produce actionable risk outputs (Risk = Hazard × Exposure × Vulnerability).

The workflow follows a stepwise scheme: hazard quantification (via EuroHEAT data), integration with exposure (population distribution within GADM regional units, based on WorldPop data) and vulnerability (demographic sensitivity via World pop data), and final risk visualizations. This process assesses future heatwave risk in Goriška by integrating EUROHEAT hazard projections with demographic vulnerability data through a spatially explicit, matrix-based risk model.

Two future periods—near future (2016–2045) and far future (2046–2075)—were compared to a baseline historical period (1986–2015) to evaluate projected changes in heatwave frequency. The EUROHEAT data were accessed via API, clipped to Goriška administrative boundaries (figure in supporting material) and reclassified into ten categories ranging from "very low change" to "very high change" to enable spatial analysis and integration with population data. Vulnerability was assessed using age-segmented population datasets (1, 65+, 70+, 75+, 80+), filtered for the Goriška region and also classified into ten density-based groups (figure in supporting material). The combination of hazard and vulnerability layers produced a 10x10 risk matrix, yielding high-resolution spatial outputs that highlight areas where intensifying heatwave patterns coincide with vulnerable populations (figure in supporting material).

The resulting maps visualize relative change in heatwave occurrence to vulnerable population and the spatial distribution of projected risk (Figure 2-9). These outputs offer critical insights for long-term adaptation planning, particularly in older urban areas, and support localized decision-making for infrastructure, public health interventions, and early warning systems.

Note: While the current workflow highlights risks for vulnerable population groups, it does not yet account for *ecosystem vulnerability*. This is particularly relevant in the Goriška region, where the highest projected heatwave risk overlaps with the northern part of the region (Figure 2-8), including the protected Triglav National Park (TNP). Here, sensitive ecosystems face significant stress under extreme heat conditions, making the integration of ecosystem risk a valuable extension of the methodology.

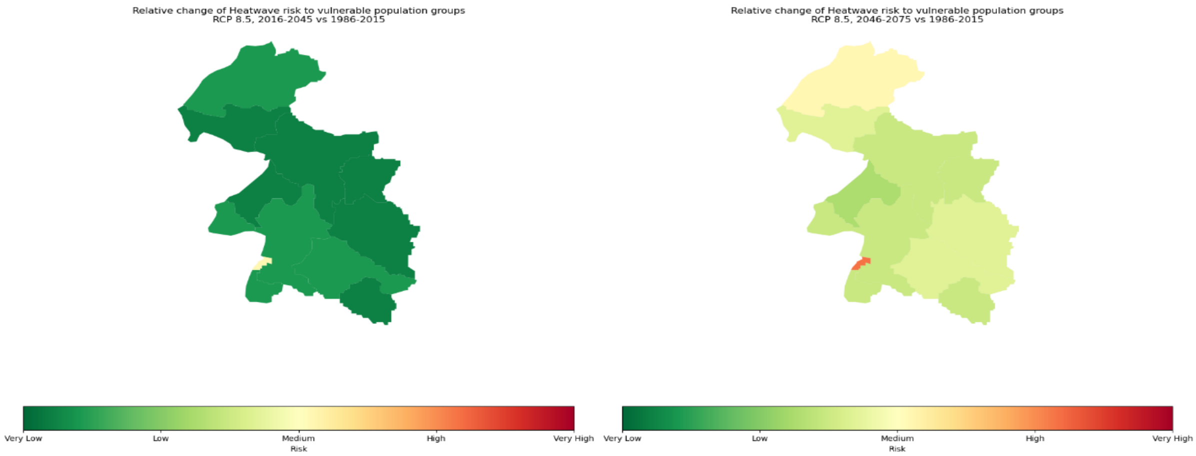

Figure 2-4 The picture above shows the potential projected increase of the heatwave risk for RCP 8.5 to vulnerable population groups for Goriška region. This result is based on the combination of the projected magnitude of change in the heatwave occurrence with the distribution of the vulnerable groups of the population.

2.3.2 Workflow #2 Agricultural drought

Drought can be defined as a prolonged period of abnormally low rainfall, leading to a shortage of water over a specific region for a given period of time. Droughts are characterized by a deficit between water supply and demand, and can have important consequences for society, ecosystems, and agriculture.

Climate change poses a growing risk to agriculture in the Goriška region, where longer droughts and reduced water availability increasingly threaten crops such as maize, etc. These conditions jeopardize yields, raise production costs, and put local farmers and the regional economy under pressure. To support adaptation, it is important to assess potential revenue losses linked to precipitation deficits by combining yield projections, crop revenues, and existing irrigation coverage. Such an approach helps identify the most vulnerable areas in Goriška and highlights the economic risks of not investing in resilient water management and farming practices.

The main limitation of this approach is the fact that the crop production, aggregated value and irrigation distribution datasets refer to 2010 values and might not be accurately representative of current conditions. From a methodological point of view, the main limitation derives from the yield loss calculation procedure. In essence, the accuracy of the yield loss calculation is limited by the global parameters used in the crop growth modelling part of the workflow.

Agricultural drought is a medium-term phenomenon, characterized by reduced soil moisture content and is caused by a prolonged period of meteorological drought. The lack of soil moisture can have a significant impact on crop growth. Statistical indices help assess agricultural drought conditions.

Table 2-2 Data overview workflow #2

Hazard data	*Vulnerability data*	*Exposure data*	*Risk output*
EURO CORDEX RCP4.5 & RCP8.5, used mpi_m_mpi_esm_lr as the GCM and smhi_rca4 as the RCM, precipitation flux, max/min T, relative humidity, wind speed and solar downward radiation at 12 km spatial resolution and daily temporal resolution.	Crop selection (Climate zones) – vulnerable crops (important crops for the region), distribution of fully irrigated cropland	GAEZ v5 data for irrigated land from 2015	Maps of agricultural drought risk zones, Revenue losses

2.3.2.1 Hazard assessment

Drought is reducing forage crop production, which raises crop prices and even has an influence on quality. As main crops for Goriška region we define maize, wheat, barley and temperate fruits (e.g.; vineyards). In this analysis we will present maize, wheat and barley.

Maize, wheat, and barley are important field crops in the Goriška region, providing staple food and feed (SURS, 2023). Their sensitivity to drought, however, varies with the length of the growing season. Maize has the longest and most water-demanding season (April–October), making it especially vulnerable to dry spells (European Commission, JRC, 2021). A lack of rainfall during flowering and grain filling often causes smaller cobs, forced ripening, and yield losses of up to 50 % (Webber et al., 2017). In Slovenia, the average maize grain yield in 2022 was only 6.7 t/ha, one of the lowest in the last decade (SURS, 2023). When drought stress occurs early in the season (e.g., in May), it can explain more than 40 % of yield variability (Webber et al., 2017).

Barley (winter type October–June, spring type March–July) is somewhat more tolerant, but prolonged dry periods during critical growth stages (heading, grain filling) significantly reduce both yield and quality (European Commission, JRC, 2021).

Wheat (October–July) is particularly sensitive to drought during heading and grain filling. In 2022, the average yield in Slovenia was 5.5 t/ha, slightly below the long-term average, showing the impact of weather fluctuations (SURS, 2023).

Together, these crops highlight how critical rainfall patterns and soil water retention are for the stability of agriculture in the region (LIFE ViVaCCAdapt, 2019). In the Vipava Valley, where soils are often shallow and prone to quick drying, every drought episode poses a serious risk. Especially maize and wheat remain fragile pillars of local agriculture when soil moisture is insufficient. Soil cultivation – maintaining depth, organic matter, and water retention – is therefore crucial to mitigate these risks.

Therefore, Climate data is sourced from the CDS. For this analysis, EURO-CORDEX climate projections for precipitation flux, maximum temperature, minimum temperature, relative humidity, wind speed and solar downward radiation at 12 km spatial resolution and daily temporal resolution have been employed. These projections are readily accessible to the public through the Climate Data Store (CDS) portal.

In our case, historical data based on years 1950-2017. We used two timeframes of years data from 2046 to 2050 (mid-century) and 2066-2070 (end-century) and the emission scenarios are RCP4.5 and RCP 8.5. We used mpi_m_mpi_esm_lr as the GCM and smhi_rca4 as the RCM. To calculate the crop evapotranspiration potential (ETc) we used information about the local Available Water Capacity, elevation and thermal climate zone (4).

In hazard assessment, the impact of precipitation deficits on yield loss for three crops: maize, wheat and barley, which are important crops cultivated in the region.

For period 2046–2050, the model (MPI–SMHI) indicates smaller relative yield losses under RCP 8.5 than under RCP 4.5; for wheat, the difference is about ≈ 5 percentage points. For 2066–2070, RCP 4.5 shows a milder drought impact on yield, typically −5 to −10% decrease of yield relative to the 2046-2050 period. Figures are in the supporting material to CRA and present maize, wheat and barley yield loss due to precipitation deficit in the region between period 2046-2050 (mid-century) and 2066-2070 (late century) under the RCP4.5 and RCP8.5 scenarios.

RCP8.5 2046-2050, for maize, wheat and barley, the yield loss is projected to be substantial, and localized variations suggest differences in sensitivity to precipitation deficit. For wheat and barley yield loss approximately 15 % across the Goriška region is experienced. For maize yield loss, the yield reduction is slightly different but follows a similar pattern and loss approximately 20 %. All three crops will experience severe yield reductions in region due to precipitation deficits, with yield losses exceeding 25 % in many areas, posing a substantial challenge to future agricultural productivity in the region.

For RCP 8.5, there is a maximum difference of +/- 5% in yield loss between the periods 2046-2050 and 2066-2070 for all three crops, indicating increasing vulnerability to drought.

2.3.2.2 Risk assessment

The risk assessment analysis estimates potential revenue losses for selected crops in the region due to irrigation deficits under the RCP 8.5 emission scenario for 2046–2050 and 2066-2070. These revenue losses represent the lost opportunity cost (in thousands of euros) if crops are cultivated without irrigation. The Agricultural Drought Risk Assessment (CLIMAAX handbook, DROUGHTS repository) evaluates this by combining production and revenue data with yield loss projections, producing a "lost opportunity" map that highlights vulnerable areas depending on existing irrigation systems. The method is based on 2010 data, assumes a linear relationship between yield and revenue, and may be less accurate for high-value crops. In general, farms with minimal irrigation infrastructure, and water-dependent crops are expected to face the greatest risk of reduced productivity. The areas of the region that are expected to suffer the greatest losses are the South and west part of region for maize (approx. 100.000 EUR), wheat (approx. 100.000 EUR), and barley (approx. up to 40.000 EUR) under RCP8.5 (2046-2050) (figures in supporting material). In period 2066-2070 (RCP8.5) the losses are even higher: Maize above 100.000 EUR, wheat approx. up to 125.000 EUR and barley approx. 50.000 EUR (more figures in supporting material).

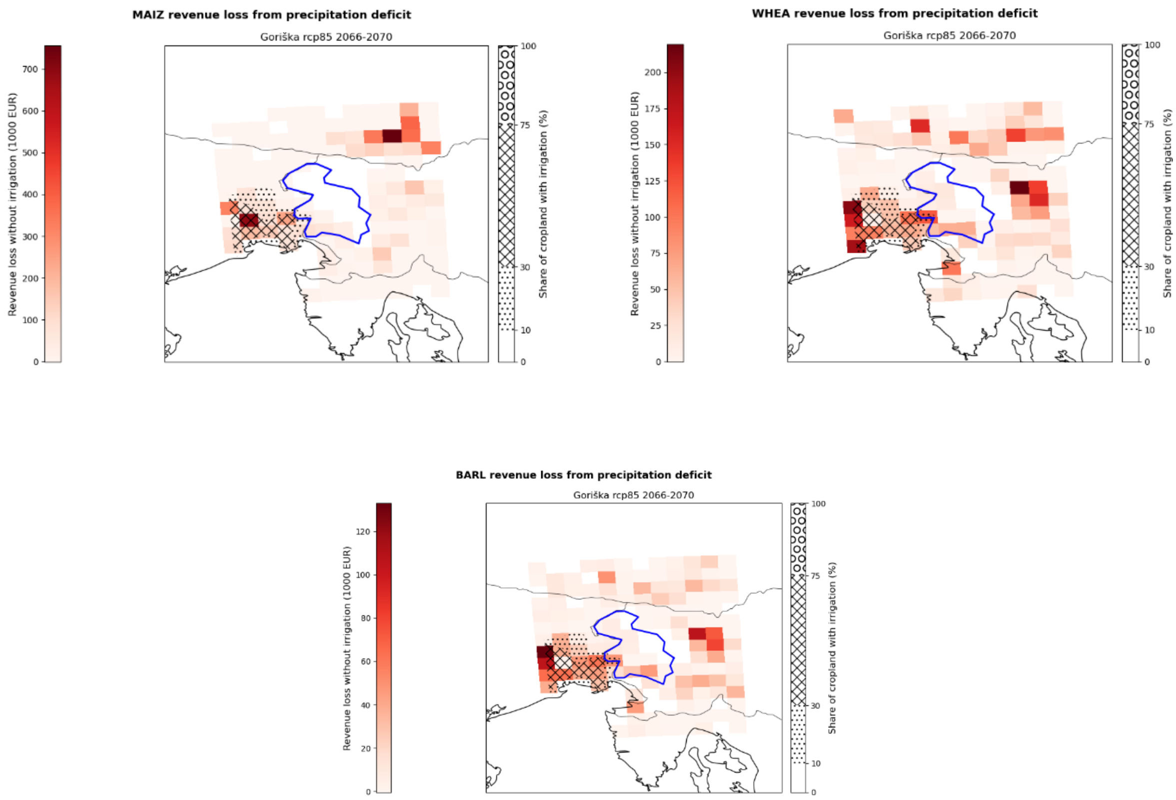

Figure 2-5 Revenue losses for the RCP8.5 scenario 2066-2070 in Goriška Region for maize, wheat and barley.

2.4 Preliminary Key Risk Assessment Findings

The preliminary assessment confirms that **heatwaves and agricultural droughts** represent **severe and pressing climate risks for the Goriška region**. Both hazards have already produced substantial impacts and are projected to intensify under future climate scenarios, with consequences that span public health, agriculture, water management, forestry, and regional development.

2.4.1 Severity

Heatwaves already reach extreme levels in the region, with observed temperatures reaching almost 40 °C in the Bilje meteorological station (e.g., summer 2022), causing health stress, excess mortality among vulnerable groups, and pressure on agriculture, energy and infrastructure. The EUROHEAT methodology, based on EURO-CORDEX projections, shows a strong increase in annual heatwave occurrence between 1986 and 2085. Under RCP4.5, the number of events rises and then stabilizes around 25 per year after mid-century, while under RCP8.5, the increase continues, with more than four times the historical occurrence by the end of the century. Complementary analyses using the Xclim library confirm the intensification of heatwave frequency, duration, and cumulative exposure, and satellite-derived Land Surface Temperature data highlight persistent hotspots in Nova Gorica. The combination of these datasets clearly demonstrates that heatwaves are both **high in frequency and high in impact**, with cascading consequences that include health crises, elevated mortality among vulnerable groups, increased ozone levels, power disruptions during peak cooling demand, wildfire escalation, long-term urban liveability challenges, etc.

Agriculture droughts are projected to worsen significantly, impacting agricultural productivity through reduced crop yields and increased water stress. This can lead to substantial economic losses for farmers. All three crops (maize, wheat and barley) will experience severe yield reductions in region due to precipitation deficits, with yield losses exceeding 25% in many areas, posing a substantial challenge to future agricultural productivity in the region. In the long term, repeated agricultural droughts may drive irreversible consequences, including land abandonment, biodiversity loss, and economic decline in one of the region's most important sectors.

2.4.2 Urgency

The urgency to address both hazards is immediate.

Heatwaves are already a recurring hazard in the region and are expected to intensify further in the short term, particularly within the next decade. As sudden-onset events with high intensity, they demand early preparedness and rapid response capacities, such as effective early-warning systems, cooling infrastructure, and communication strategies for vulnerable groups. Projections for 2030–2050 indicate that the situation will worsen significantly even under moderate scenarios, while under pessimistic assumptions (RCP8.5) the acceleration is dramatic. This underscores the need for **urgent and sustained adaptation measures** for urban and health system resilience.

Agricultural droughts have persistent and compounding impacts, requiring immediate attention to **water management actions, irrigation efficiency, and drought preparedness**, as delayed interventions will amplify long-term losses and conflicts between sectors. Measures to promote resilient agricultural practices, efficient irrigation, and drought preparedness are crucial in the short term. The continuous decline in water availability means these risks have the potential to persist and worsen over time, making long-term planning for water conservation and alternative water sources highly urgent.

Both hazards have the potential to persist and increase the likelihood of multi-hazard crises.

2.4.3 Capacity

Adaptive capacity in the region is developing, but remains **insufficient to fully address the scale of the risk**. Municipalities benefit from national ARSO warning systems (ARSO, 2025) and have begun integrating adaptation measures into Sustainable Energy and Climate Action Plans (SECAPs). The Regional Adaptation Strategy (2025) provides a broader governance framework, and workshops in 2024–2025 fostered cross-sectoral awareness and stakeholder engagement.

For heatwaves, capacities exist in crisis communication and early warning, but remain insufficient for comprehensive risk reduction, particularly in terms of urban planning and healthcare preparedness. For droughts, capacities are weaker: water infrastructure in several municipalities is underdeveloped, and emergency water deliveries have been needed repeatedly in recent years.

Adaptive capacity is improving but remains insufficient for the scale of risk.

- Financial: constrained; high reliance on national/EU project funding.
- Human: improving via training, yet limited technical staffing at municipal level.
- Natural: ecosystem health and water-retention functions are unevenly managed.
- Physical: ARSO warnings and crisis communication work for heatwaves, but urban planning, healthcare surge capacity, monitoring, and water infrastructure can be improved.
- Social: community engagement varies; vulnerable groups are not consistently covered.

Planned/ongoing interventions

A Regional Adaptation Action Plan will be developed, including all findings from CRA and Regional Adaptation Strategy. Financial provisions exist but remain fragmented across projects and annual budgets.

2.5 Preliminary Monitoring and Evaluation

The first phase of the CRA demonstrated that the CLIMAAX workflows can be successfully applied in the Goriška context. For heatwaves, the combination of the EUROHEAT methodology, custom indices developed with Xclim, and high-resolution LST mapping provided a robust picture of both historical trends and future risks. For droughts, the use of SPI and SPEI indices from the Copernicus Atlas, combined with ARSO precipitation records and agricultural land cover data, confirmed the scale of current and projected risks. The workflows proved complementary: EUROHEAT and Xclim provide standardized and customizable hazard baselines, while satellite-based LST and WorldPop datasets offer fine-scale hotspot mapping for immediate local planning.

At the same time, the analysis revealed important challenges. The lack of a nationally standardized heatwave definition required reliance on EU-wide thresholds. For droughts, the main limitation is the lack of detailed agricultural data — such as precise crop calendars and irrigation statistics — which constrains the accuracy of agricultural drought modelling. Additional data are needed to improve the analysis. These include ARSO-based thresholds for heatwaves specific to the Primorska climate zone for heat wave workflow. Potential improvements to the drought workflow include incorporating the local length of the growing season and the seasonal start and end dates, updating and refining irrigation data, and extending the crop list beyond the existing repository to include vineyards, fruit trees, and other locally relevant crops.

Developing these data sources will strengthen both the scientific basis and the policy relevance of the CRA. Phase 1 concentrated on tracking progress, while direct evaluation of adaptation measures and full stakeholder engagement are planned for later phases.

2.6 Work plan

The work plan for the subsequent phases of the project will build upon the foundational work completed in Phase 1. Phase 2 will focus on refining the climate risk assessment for heatwaves and droughts by incorporating more localized, high-resolution data and conducting in-depth analyses of specific vulnerabilities. This will involve detailed mapping of exposed assets and populations, and further engagement with local communities to gather granular insights.

Phase 3 will then focus on refining the adaptation strategy based on the results of risk assessment. This will include co-designing solutions with stakeholders, integrating adaptation measures into regional and municipal planning, and developing robust monitoring and evaluation frameworks for long-term resilience. The project will continue to emphasize multi-stakeholder collaboration, knowledge sharing, and capacity building throughout all phases to ensure sustainable and effective climate adaptation in the Goriška Region.

These outputs will directly inform the design of a Regional Adaptation Action Plan. The immediate priority remains to strengthen local resilience to heatwaves and droughts, ensuring that the CRA delivers actionable knowledge for municipalities and stakeholders in the Goriška region.

3 Conclusions Phase 1- Climate risk assessment

Following the CLIMAAX framework, Phase 1 of the project has successfully established a climate risk assessment for the Goriška Region with an overview of the region's climate vulnerabilities, identifying heat waves and agricultural droughts. The CLIMAAX procedures have provided a valuable starting point, and the analysis has shown the need to incorporate higher-resolution local data to improve risk assessments and increase the accuracy of adaptation planning in future phases.

Heatwaves already cause severe impacts on public health, ecosystems, and infrastructure, with projections showing that their frequency, duration, and intensity will rise significantly under future climate scenarios. Agricultural droughts pose a serious threat to food production, economic stability, and water resources, with modelled yield losses exceeding 25 % in many areas for key crops under pessimistic pathways.

Among the main achievements of Phase 1 are the establishment of a baseline climate risk assessment tailored to the regional context. In future Phase 2, improvements will be done using high-resolution local data and integrating ecosystem vulnerability into future assessments.

GOLEA will continue the process in Phase 2 in cooperation with regional development agencies. Additionally, the stakeholder engagement process initiated during this phase has laid a solid foundation for a collaborative climate adaptation approach, emphasizing the importance of multi-level governance and community involvement.

In summary, Phase 1 successfully addressed the challenge of establishing a scientific basis for understanding climate risks in Goriška Region and identified key climate hazards and sectoral vulnerabilities. Building on this baseline, Phase 2 will refine risk assessments with localized datasets, while Phase 3 will co-design adaptation measures with stakeholders. The outcomes of CLIMAAX project will be integrated into a Regional Adaptation Action Plan. Together, these steps will strengthen the region's preparedness for intensifying climate risks and support resilient and sustainable development in the Goriška region.

4 Progress evaluation and contribution to future phases

The progress achieved in Phase 1 of the project has been substantial, laying a solid foundation for subsequent phases and contributing significantly to the overall project objectives. The successful application of the CLIMAAX framework for climate risk assessments in the Goriška Region represents a key milestone. This initial assessment has provided critical insights into the region's climate vulnerabilities.

Phase 1 has directly contributed to future phases by:

- **Establishing a baseline:** The risk assessments developed in Phase 1 serve as a key reference point for assessing future changes and the effectiveness of adaptation measures.
- **Identifying data gaps:** The assessments revealed the need for more localized, high-resolution data, particularly to enable more precise risk analyses. This insight will guide data collection in Phase 2 and ensure that subsequent analyses are more accurate and tailored to local conditions.
- **Guiding the development of adaptation action plan:** The key risks have been identified, providing clear direction for the formulation of targeted adaptation measures.
- **Strengthening regional capacity:** The climate risk assessment has contributed to building technical expertise in the Goriška Region – both in understanding climate risks and in applying advanced assessment methodologies. This enhanced capacity will be essential for long-term climate resilience planning.

Table 4-1 Overview key performance indicators

Key performance indicators	*Progress*
External experts selection: Successful selection of 1 external expert (consortium) through a transparent public procurement process (according to Slovenian public procurement legislation). Phase 1	Completed
Successfully applied 1 workflow for assessment using the supporting Toolbox. Phase 1.	Completed
Dissemination activities: Completion of at least 5 publications and dissemination actions, including updates on our website. Phase 1, 2 and 3.	2 dissemination actions: Webpage post FB post

Table 4-2 Overview milestones

Milestones	*Progress*
M1: Test of the CLIMAAX supporting tool (D1). Phase 1.	Done

5 Supporting documentation

The additional documents and datasets have been uploaded to the Zenodo platform. The contents of the folder are as follows:

- Phase 1 Deliverable:
  - Main report
  - Supporting material – document includes charts, figures and dissemination outputs
- Workflows Outputs:
  - Heatwaves Workflow:
    - Hazard Assessment (EuroHEAT, XCLim)
    - Risk Assessment (satellite-derived data, climate projections)
  - Droughts Workflow
    - Agricultural drought Workflow

6 References

GOLEA, UL NTF, UL FGG, UL BF, NIJZ, Gozdarski inštitut Slovenije, Umanotera.: SECAP - Sustainable energy and climate action plan for municipality of Nova Gorica, part II, Climate risk and vulnerability assessment, https://www.nova-gorica.si/file/15807786525994411_analiza-tveganje.pdf, 2021.

GOLEA, UL NTF, UL FGG, UL BF, NIJZ, Gozdarski inštitut Slovenije, Umanotera.: SECAP -Sustainable energy and climate action plan for municipality of Ajdovščina, part II, Climate risk and vulnerability assessment, https://www.ajdovscina.si/mma/secap_iidel_ajdovscina_spletpdf/2023052209321994/?m=1684740739, 2021.

GOLEA, UL NTF, UL FGG, UL BF, NIJZ, Gozdarski inštitut Slovenije, Umanotera.: SECAP -Sustainable energy and climate action plan for municipality of Idrija, part II, Climate risk and vulnerability assessment, https://www.idrija.si/DownloadFile?id=584251, 2021.

GOLEA, LEA Pomurje, UL NTF, UL FGG, UL BF, NIJZ, Gozdarski inštitut Slovenije, Umanotera.: SECAP - Sustainable energy and climate action plan for municipality of Nova Gorica, part III, Action plan, https://www.nova-gorica.si/file/15807801324593185_akcijski-nacrt.pdf, 2022.

GOLEA, LEA Pomurje, UL NTF, UL FGG, UL BF, NIJZ, Gozdarski inštitut Slovenije, Umanotera.: SECAP - Sustainable energy and climate action plan for municipality of Ajdovščina, part III, Action plan, https://www.ajdovscina.si/mma/secap_iiidel_ajdovscina_spletpdf/2023052209323973/?m=1684740759, 2022.

GOLEA, LEA Pomurje, UL NTF, UL FGG, UL BF, NIJZ, Gozdarski inštitut Slovenije, Umanotera.: SECAP - Sustainable energy and climate action plan for municipality of Idrija, part III, Action plan, https://www.idrija.si/DownloadFile?id=595580, 2022.

ARSO – Agencija Republike Slovenije za okolje, https://www.arso.gov.si, 2025.

ARSO – Agencija Republike Slovenije za Okolje, Archive of natural hazards events up to 2024, https://meteo.arso.gov.si/met/sl/climate/natural-hazards/archive/, 2024.

ARSO – Agencija Republike Slovenije za Okolje, Natural hazards events in 2025, https://meteo.arso.gov.si/met/sl/climate/natural-hazards/, 2025.

GOLEA, PRC, ICRA, RRA NG, RRA ROD: Strategija prilagajanja Severno Primorske (Goriške) regije na podnebne spremembe, https://www.golea.si/wp-content/uploads/2025/06/Strategija-prilagajanja-Severno-Primorske-Gori%C5%A1ke-RR-na-podnebne-spremembe_koncna.pdf, 2025.

LIFE ViVaCCAdapt: Climate Change Adaptation Strategy for the Vipava Valley, Regional Development Agency ROD Ajdovščina, https://www.life-vivaccadapt.si/en/results/climate-change-adaptation-strategy-for-the-vipava-valley, 2019.

European Commission, JRC: Drought Impact Indicators and Crop Monitoring in Europe, https://publications.jrc.ec.europa.eu/repository/bitstream/JRC127964/JRC127964_01.pdf, 2021.

SURS – Statistical Office of the Republic of Slovenia: Crop Production, Slovenia, 2022, https://www.stat.si/StatWeb/en/News/Index/11012, 2023.

CLIMAAX Handbook: Methods for Climate Adaptation Applications, CLIMAAX Project, https://www.climaax.eu/handbook , 2023.

Webber, H., Ewert, F., Olesen, J.E., Müller, C., Fronzek, S., Ruane, A.C., Bourgault, M., Martre, P., Ababaei, B., Bindi, M., Ferrise, R., Finger, R., Fodor, N., Gao, Y., Gaiser, T., Jabloun, M., Kersebaum, K.C., Lizaso, J.I., Lorite, I.J., Nendel, C., Rodríguez, A., Ruget, F., Semenov, M.A., and Wolf, J.: Impacts of water availability and drought on maize yield – a comparison of 16 indicators, https://doi.org/10.1016/j.ecolind.2017.04.045, 2017.

Jacob, Daniela, Juliane Petersen, Bastian Eggert, Antoinette Alias, Ole Bøssing Christensen, Laurens M. Bouwer, Alain Braun, et al. 2014. "EURO-CORDEX: New High-Resolution Climate Change Projections for European Impact Research." Regional Environmental Change 14 (2): 563–78. https://doi.org/10.1007/s10113-013-0499-2.

24ur.com: Presušena tudi Severna Primorska: poziv k skrajnemu varčevanju s pitno vodo, https://www.24ur.com/novice/slovenija/presusena-tudi-severna-primorska-poziv-k-skrajnemu-varcevanju-s-pitno-vodo.html, 2022.

Občina Ajdovščina (Municipality of Ajdovščina): Varčujmo z vodo, https://www.ajdovscina.si/novice/2022071913210785/, 2022.