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Deliverable Phase 1 – Climate risk assessment

„ClimateREADY Ruse: Planning for Resilience and Sustainability"

Bulgaria, District of Ruse/Ruse Municipality

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5. Abbreviations and acronyms

Abbreviation / acronym	Description
CRA	Climate Risk Assessment – a systematic process for identifying, assessing, and evaluating climate-related risks in a defined area.
NUT	Nomenclature of Territorial Units for Statistics – EU geocode standard for referencing subdivisions of countries for statistical purposes.
PM10	Particulate Matter with a diameter of 10 micrometers or less – an air pollutant harmful to human health, commonly monitored in environmental assessments.
FWI	Fire Weather Index – a numerical rating of fire danger used to estimate the potential for wildfire based on weather conditions.
RCP	Representative Concentration Pathway – greenhouse gas concentration trajectories adopted by the IPCC to model future climate scenarios.
SSP	Shared Socioeconomic Pathway – scenarios describing potential global futures based on socio-economic trends and policy choices.
AMDP	Annual Maximum Daily Precipitation – a climate index representing the highest daily rainfall within a year, used for flood and rainfall analysis.
PFRA	Preliminary Flood Risk Assessment – an EU-mandated national-level flood risk mapping and reporting framework.
EU	European Union
EEA	European Environment Agency – an EU agency providing independent environmental data and analysis.
C3S	Copernicus Climate Change Service – provides climate data and tools for adaptation and risk assessment.
DEM	Digital Elevation Model – a 3D representation of a terrain’s surface used in spatial hazard modeling.
LISFLOOD	A hydrological model used by the European Commission for flood simulation and analysis.
CORINE	Coordination of Information on the Environment – an EU land cover and land use inventory.

6. Executive summary

This deliverable presents the results of Phase 1 of the Climate Risk Assessment (CRA) for Ruse Municipality, Bulgaria, conducted under the CLIMAAX project, which aims to support European regions in developing harmonized, science-based, and actionable assessments of climate risks. The CRA follows the methodology outlined in the CLIMAAX Handbook and Toolbox and is tailored to Ruse's geographical, socio-economic, and environmental context. The objective is to identify and evaluate the municipality's climate-related hazards, assess exposure and vulnerability across sectors, and inform strategic planning to enhance local climate resilience. This assessment also supports Bulgaria's national adaptation goals and contributes to the broader EU Green Deal and climate adaptation mission.

The assessment was developed in response to growing climate-related pressures in Ruse, which include increasing frequency and intensity of floods, pluvial rainfall, wildfires, and others. The deliverable offers readers a comprehensive analysis of these priority risks using hazard-specific workflows provided by CLIMAAX. The document includes scenario-based modeling for short-, medium-, and long-term horizons, geospatial mapping of hazard zones, exposure analysis of infrastructure and vulnerable populations, and institutional capacity assessment. It draws on historical records, regional climate projections (EURO-CORDEX, Copernicus C3S), and socio-economic datasets (NSI, SSPs, CORINE Land Cover) to generate an initial risk profile of the municipality. This phase also incorporates a participatory dimension, including stakeholder engagement with local institutions, technical agencies, and civil society organizations.

Main actions during this phase included the scoping of hazards and relevant systems, selection of climate and socio-economic scenarios (RCP2.6, RCP4.5, SSP2, SSP3), execution of three CLIMAAX workflows for fluvial flooding, extreme rainfall, and wildfire, and the identification of critical vulnerabilities in infrastructure, governance, and public services. The risk analysis concluded that pluvial flooding due to heavy rainfall represents the most severe and immediate threat, especially in densely populated neighborhoods with aging stormwater systems. The Rusenski Lom River presents a high flood risk to several peri-urban communities, while wildfire risk is growing in peri-urban zones and unmanaged rural areas due to increased fire weather conditions and land-use change.

Key findings of the CRA indicate a shift toward more frequent, compound, and spatially extensive hazards that disproportionately impact vulnerable groups and critical systems. Risk severity and urgency are highest for heavy rainfall, followed by riverine flooding and wildfires. Adaptive capacity is constrained by limited municipal funding, fragmented governance, and outdated infrastructure, but opportunities exist through the CLIMAAX platform, EU funding mechanisms, and technical partnerships.

In conclusion, this deliverable provides Ruse Municipality with a comprehensive baseline for climate risk planning. It equips decision-makers with evidence-based tools to prioritize adaptation measures and integrate climate resilience into land-use, infrastructure, and emergency planning. The outputs of Phase 1 will inform the next stages of the CLIMAAX process, including the design of targeted interventions, performance monitoring, and the institutionalization of climate adaptation within local governance frameworks. The assessment underscores the urgent need to align planning efforts with future climate risks and ensure the protection of people, infrastructure, and ecosystems in the face of accelerating environmental change.

1 Introduction

1.1 Background

Ruse Municipality, located in northern Bulgaria along the Danube River, is part of the North-Central (NUTS 2 – BG32) region. As the largest urban center in the area, the city of Ruse is a key administrative, economic, and cultural hub, often referred to as "Little Vienna" for its 19th-century architecture. The municipality spans a diverse terrain, including river valleys, floodplains, loess plateaus, and steep slopes, which contribute to a complex risk profile and environmental dynamics.

Ruse's proximity to the Danube makes it highly susceptible to floods, particularly of the "rainy-river" type, resulting from prolonged rainfall and snowmelt in spring and summer. Additional climate-related risks include heavy snowfall, icing, strong winds, landslides, forest fires, and air pollution, particularly from fine particulate matter (PM10). With 30 officially registered landslides and many unmonitored ones, soil stability is a growing concern.

The region's climate vulnerability index is high, with notable economic and physical sensitivities. These are exacerbated by aging infrastructure, limited local funding, and insufficient technical capacity. Ruse has a moderately developed disaster risk reduction framework, but lacks comprehensive, localized multi-risk assessments. The CLIMAAX project aims to bridge this gap, enhancing adaptive capacity through climate-informed policies, stakeholder engagement, and targeted risk governance improvements.

Ruse's strategic location as a Danube port city and cross-border gateway to Romania further underscores the importance of resilient infrastructure and environmental planning in the face of growing climate threats.

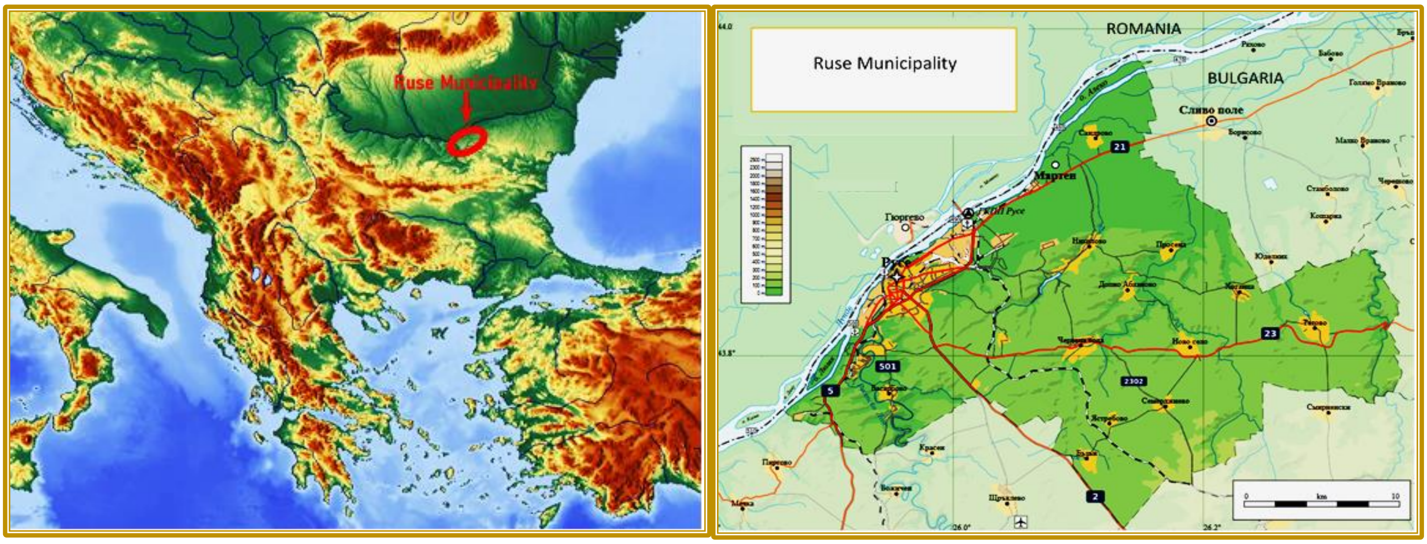

Figure 1-0 - Ruse Municipality: Global (Balkan) and Local Geographical Position

1.2 Main objectives of the project

The primary objective of the CLIMAAX Project in the Ruse Region is to conduct an inclusive and harmonized CRA tailored to the specific climatic challenges of the Ruse region. This involves identifying and evaluating the region's vulnerabilities to various climate hazards, such as floods, droughts, heatwaves, wildfires, windstorms, and heavy snowfall.

The project emphasizes the importance of involving local stakeholders, including government agencies, businesses, and community organizations, in the CRA process. This participatory approach ensures that the assessment reflects local knowledge and priorities, fostering community ownership of adaptation strategies.

By utilizing the CLIMAAX Toolbox, the project aims to enhance the technical capacity of local authorities and stakeholders as a key objective. Through training and the provision of user-friendly tools, the project seeks to empower local entities to independently conduct CRAs and implement effective climate risk management strategies.

By systematically assessing and understanding climate risks, the Ruse region can develop and implement adaptation strategies that mitigate the impacts of identified hazards, thereby enhancing the resilience of communities and infrastructure.The insights gained from the CRA can guide urban planning decisions, ensuring that new developments are designed with climate resilience in mind. This proactive approach can reduce future economic losses and safeguard public safety. A detailed understanding of climate risks enables local authorities to enhance emergency response plans, ensuring timely and effective actions during climate-induced events.

Participation in the CLIMAAX project aligns the Ruse region with broader EU climate adaptation initiatives, potentially unlocking access to additional funding and resources for climate resilience projects.

Application of the CLIMAAX Handbook provides a step-by-step framework for conducting CRAs, ensuring that all critical aspects—from hazard identification to risk evaluation—are systematically addressed. The Handbook emphasizes the importance of tailoring the CRA to the local context, encouraging the incorporation of region-specific data and stakeholder input. This ensures that the assessment is relevant and actionable for the Ruse region. Beyond assessment, the Handbook guides regions on integrating CRA findings into broader climate risk management and adaptation planning, promoting a holistic approach to building resilience.

The CLIMAAX project presents a valuable opportunity for the Ruse region to enhance its resilience to climate change. By engaging in a comprehensive climate risk assessment, involving local stakeholders, and utilizing the resources provided by the CLIMAAX Handbook, Ruse can develop informed and effective adaptation strategies. These efforts will not only mitigate the impacts of climate hazards but also promote sustainable development and align the region with broader European climate adaptation goals.

1.3 Project team

The team from the Municipality of Ruse, working on the project, consist of the following members: a manager, a financial expert and two environmental experts from the Municipality. For the purposes of the project, a contract has also been concluded with an external expert - Zoya Mateeva, Prof. Dr. of Climatology, Department of Climate at the Climate, Atmosphere and Water Research Institute (CAWRI) - Bulgarian Academy of Sciences (BAS).

1.4 Outline of the document’s structure

The document follows a clear and structured format consistent with the CLIMAAX project framework. It begins with a cover and administrative information section detailing the project name, versioning, institutional partners, and document metadata. An executive summary provides a one-page overview of the deliverable's content and conclusions. This is followed by a comprehensive introduction that sets the geographical, climatic, and institutional context of the municipality under assessment—Ruse in this case—and outlines the main project objectives and stakeholder composition. The core of the document is dedicated to the Climate Risk Assessment, divided into logically sequenced subchapters: scoping, risk exploration, scenario development, risk analysis, and preliminary findings. Each of these sections aligns with workflows provided by the CLIMAAX Handbook, focusing on key hazards such as river floods, heavy rainfall, and wildfires. Risk is assessed through detailed modeling, vulnerability mapping, and scenario planning using standardized indicators and datasets. The latter part of the document includes conclusions, progress evaluation for future phases, references, and instructions for document formatting. The structure ensures coherence, transparency, and replicability across different regions participating in the CLIMAAX initiative.

2 Climate risk assessment – phase 1

2.1 Scoping

2.1.1 Objectives

The Climate Risk Assessment (CRA) for Ruse Municipality aims to systematically identify, assess, and quantify the region's exposure and vulnerability to multiple climate-related hazards—specifically river floods, heavy rainfall, and wildfires—with the goal of informing and supporting climate-resilient urban and regional planning.

The CRA serves as a foundational tool to: understand the spatial and sectoral distribution of climate risks; enable evidence-based policy development and risk-informed decision-making; Support the design of adaptation strategies that reflect the local context; Foster community awareness and stakeholder engagement; Strengthen inter-sectoral coordination in climate risk management

The expected outcomes from the CRA include an integration of climate risk considerations into municipal strategic documents, including disaster risk reduction programs, land-use plans, and infrastructure development frameworks and increased stakeholder capacity to anticipate, manage, and adapt to climate risks.

The CRA is intended to act as a decision-support tool that provides a scientific and evidence-based foundation for municipal and regional authorities. It should directly inform Climate adaptation policy development, contributing to Bulgaria's national climate goals and EU adaptation targets. Through the participatory approach embedded in CLIMAAX, the CRA also supports collaborative governance, ensuring that policy decisions reflect stakeholder priorities, particularly those of vulnerable populations.

In the course of preparing the present report, it is important to acknowledge certain limitations and challenges inherent to the climate risk assessment process. These include, but are not limited to: limited access to real-time monitoring systems for water levels, precipitation, and fire risks; incomplete datasets on social vulnerability indicators and private infrastructure exposure; fragmented coordination between national and local government entities; lack of dedicated funds for climate adaptation in the municipal budget.

2.1.2 Context

Until now, Ruse Municipality has approached climate-related hazards primarily through conventional disaster risk management (DRM) strategies and emergency response mechanisms. These frameworks are articulated in several municipal and national documents addressing both natural and anthropogenic risks, including floods, snowstorms, wildfires, landslides, and industrial incidents. However, these risk assessments have generally lacked a comprehensive, multi-hazard, climate-informed perspective. In particular, they have not been supported by integrated modeling that accounts for long-term climate projections, socio-economic vulnerabilities, or systemic interdependencies. A partial exception is the Flood Risk Management Plan developed under the Danube River Basin District Framework, which identifies certain zones within Ruse Municipality as having significant flood potential. Yet even this plan does not incorporate climate change scenarios, cumulative risks, or adaptive capacity considerations.

Recognizing these limitations, the municipality is now transitioning toward a CLIMAAX-based climate risk assessment (CRA) framework. This new approach promotes a harmonized, structured methodology for evaluating risks under various climate scenarios and socio-economic conditions. It is designed to improve strategic planning by aligning local assessment practices with EU-level adaptation guidance.

Ruse operates within the broader governance structure defined by national Bulgarian legislation and EU directives on climate adaptation, disaster risk reduction, and environmental protection. Key policy instruments include the National Climate Change Adaptation Strategy and Action Plan, the Municipal Development Plan 2021–2027, and sectoral regulations concerning water, forestry, civil protection, and health. Although the municipality has established legal obligations for risk assessment and planning, implementation capacity is limited by funding shortfalls, institutional fragmentation, and technical gaps. Currently, no dedicated municipal budget is allocated to climate adaptation. Project financing is dependent on national and European Union co-financing mechanisms. Human resource capacity exists but remains constrained in terms of technical skills related to hazard modeling, spatial analysis, and climate data interpretation—areas that the CLIMAAX project seeks to strengthen.

The capacity of Ruse Municipality to achieve strategic targets is at risk if climate hazards are not systematically assessed and addressed. At the local level, Ruse's Municipal Development Plan outlines ambitions to reduce environmental pollution, enhance the quality of life, and improve urban resilience—goals that are vulnerable to disruption in the absence of proactive climate adaptation measures.

Within the CRA framework, Ruse's relevant system encompasses urban and rural communities, municipal and critical infrastructure, natural ecosystems, and economic sectors such as agriculture, energy, and transport. Key actors affected by climate risk include households, local authorities, emergency services, and utility operators. The processes most at risk are those related to water supply, mobility, land-use planning, emergency response, food production, and energy distribution. These functions are highly interdependent, and many are vulnerable due to aging infrastructure, limited redundancy, and exposure to multiple hazards. The CRA is spatially defined at the municipal level but emphasizes hazard-prone zones such as floodplains along the Danube and Rusenski Lom rivers, steep terrain prone to landslides, and peri-urban areas exposed to wildfire risks. Temporally, the CRA considers both short-term risks (within 5 years) and medium- to long-term planning horizons, extending to 2050 and beyond.

Multiple sectors are identified as particularly vulnerable. Agriculture is exposed to extreme precipitation events, seasonal droughts, and temperature volatility that affects crop productivity. Water and sanitation services are sensitive to fluctuations in Danube water levels and the dual risks of flooding and scarcity. Public health is increasingly threatened by extreme heat, declining air quality—particularly due to PM10 exceedances—and the secondary effects of climate events on disease patterns and mental well-being. Transport infrastructure is at risk from snow accumulation, flooding, landslides, and storm damage. The tourism and cultural heritage sector faces degradation from rising temperatures, humidity, and occasional extreme weather events.

Key regional values that underpin resilience and should be protected include human health and safety, the reliability of critical infrastructure systems (especially water, energy, and transport), economic productivity in agriculture and services, ecological integrity and biodiversity, and overall social cohesion. Outcomes to be avoided include loss of life or mass displacement, major infrastructure failures, prolonged economic disruption or food insecurity, degradation of ecosystem services, and loss of public confidence in institutional capacity.

In high-impact climate scenarios, severe fluvial and pluvial flooding, as well as wildfires, could isolate communities and overwhelm emergency services. Compound risks such as coinciding snowstorms and power outages could lead to cascading infrastructure failures. The risk of socio-political destabilization may also rise if institutional responses are perceived as inadequate. Anticipated future hazard trends include a marked increase in the frequency and intensity of floods due to both extreme precipitation and seasonal snowmelt. Fire risk is expected to escalate, especially in peri-urban areas and unmanaged forested land, due to longer dry periods and rising temperatures. Rainfall patterns are also projected to become more erratic, contributing to both drought and flash flood scenarios.

Institutional tolerance for risk in Ruse remains low, particularly in relation to hazards such as floods and snowstorms that threaten basic services and mobility. Although awareness is growing, the municipality's evolving risk perception still limits proactive planning. Nonetheless, this constrained tolerance may support arguments for greater investment in infrastructure resilience, early warning systems, and strategic planning tools—opportunities that the CLIMAAX project directly facilitates through its technical and financial framework.

2.1.3 Participation and risk ownership

The stakeholder involvement process began during the early phase of the Climate Risk Assessment (CRA) through preliminary consultations with municipal authorities consideration of the key groups of stakeholders that should be included in the process of the project activity - municipal authorities, representatives of climate-dependent economic sectors - agriculture, construction, transport, territorial planning, civil protection, tourism, water sector, forestry sector, ecology, social sector, science and education. The goal was to map key actors, identify knowledge holders, and initiate dialogue around climate-related hazards relevant to Ruse Municipality. Initial outreach was conducted via meetings (the Ruse municipality team organized a kick-off meeting, media press conference, workshop), informal interviews, and data-sharing with departments responsible for urban planning, water management, and emergency response**.** At this stage, a targeted survey (Supporting document No 5.3.4.1 / 5.3.4.2.) was developed regarding the attitudes and understandings of respondents from various stakeholder groups. Its completion has already begun among representatives of municipal authorities, and in the next project phase it will continue through a broad completion by the largest possible number of representatives of all groups involved in the climate process.

This foundational step supported the identification of priority risks (river floods, heavy rainfall, wildfires, and others) and served to align local concerns with the analytical scope of the CLIMAAX workflows. It also helped initiate conversations about data access, vulnerability mapping, and long-term planning integration**.**

The following categories of stakeholders have been identified as essential for the CRA process and subsequent climate adaptation planning: Local Government (*Ruse Municipality Administration*; *Ruse Civil Protection Directorate (Ministry of Interior); Water Supply and Sewerage Company – Ruse (ViK)*); National and Regional Government **(***Bulgarian Ministry of Environment and Water (MOEW); Danube River Basin Directorate (BD-Dunav)*; *National Institute of Meteorology and Hydrology (NIMH)*); Scientific and Technical Institutions: (*Ruse University "Angel Kanchev"; Bulgarian Academy of Sciences*); Local Non-Governmental Organizations; Private Sector**,** Citizens and Community Organizations**.**

Risk ownership is currently fragmented across municipal and national institutions. Legally, the municipality is responsible for local disaster prevention, infrastructure resilience, and emergency response, but funding and technical standards are defined by national ministries. River flood management is shared with the Danube River Basin Directorate and MOEW, while fire risk management falls under the General Directorate Fire Safety and Civil Protection**.**

In practice, ownership of climate-related risks is diffuse, with insufficient coordination between land-use planning, civil protection, and environmental policy**.** The CLIMAAX process is an opportunity to promote integrated risk governance by clarifying roles, streamlining data sharing, and strengthening interdepartmental communication.

2.2 Risk Exploration

2.2.1 Screen risks (selection of main hazards)

Ruse Municipality, situated in Northern Bulgaria along the Danube River, encompasses a diverse landscape shaped by both natural and human systems, all of which are increasingly sensitive to the effects of climate variability and long-term climate change. Drawing from historical data, future climate projections, and multi-sectoral vulnerability assessments, the region is subject to a broad spectrum of climate-related hazards with varying spatial and temporal impacts.

Fluvial flooding (Supporting document No 5.2.4.1), primarily associated with the Danube River and its tributary the Rusenski Lom, presents a significant hazard, particularly during periods of prolonged rainfall and snowmelt (Supporting document No 5.2.4.2). This risk is compounded by the municipality's geomorphology and hydrological dynamics. Pluvial flooding is another pressing concern, especially in urban and peri-urban areas where impermeable surfaces and outdated drainage infrastructure increase susceptibility to high-intensity, short-duration rainfall events. Landslides and soil instability, prevalent in the region's loess-based terrain and steep slopes, are often triggered by extreme precipitation and can lead to infrastructure disruption and property damage.

Droughts (Supporting document No 5.2.4.3) have become more frequent and severe, threatening agricultural productivity, biodiversity, and water supply systems. Rising evapotranspiration rates and reduced summer precipitation have led to multi-year soil moisture deficits, especially affecting rainfed agricultural zones and vineyards. Extreme temperatures (Supporting document No 5.2.4.4) - including heatwaves, tropical nights, and cold spells—are occurring more often and with greater intensity, adversely impacting public health, labor productivity, and energy demand. Although heavy snowfall and icing events are becoming less frequent overall, they continue to disrupt critical services and transport when they occur. Wildfires particularly in forested and peri-urban areas, have also become more frequent, driven by extended dry periods, increased temperatures, and land-use change. Windstorms and convective storms cause further damage to infrastructure, while air pollution episodes—especially elevated PM10 and NOx levels—pose significant health risks during summer heatwaves and winter inversions.

These hazards frequently interact, generating compound risks such as flood-related contamination, post-fire erosion, or drought-heatwave sequences, amplifying their impact on human and ecological systems. The region has a well-documented history of such climate-related events. For example, the Danube River has caused repeated overflows affecting industrial and transportation corridors along its western banks, while the Rusenski Lom has produced localized but intense flooding in several rural settlements. Historical flood data from the Preliminary Flood Risk Assessment (PFRA, 2011–2019) confirm multiple high-intensity events, with inundation depths recorded in excess of 2.5 meters in some locations. Similarly, more than 30 landslide-prone zones have been officially identified across the municipality, though many events remain undocumented. These landslides pose serious risks to transport infrastructure, utilities, and hillside settlements.

Vulnerable groups—such as elderly residents in high-density districts, economically disadvantaged households, and outdoor workers—are particularly exposed to heatwaves, air pollution, and climate-induced health stressors. Critical infrastructure, including energy distribution systems and healthcare facilities, faces growing exposure to multi-hazard events, particularly during winter storms that combine snow, icing, and power outages. Data from national meteorological authorities (NIMH) and local environmental monitoring stations reveal persistent exceedances of air pollution thresholds, with PM10 concentrations regularly surpassing safe levels during the winter season and under summer inversion conditions.

Observed climate trends in the region reinforce these concerns. Precipitation variability is increasing, with more frequent extreme rainfall events reflected in indices such as Rx1day and Rx5day. Heatwaves lasting multiple days are becoming more common, with daily maximum temperatures exceeding 40°C in recent years. Although the overall number of snow cover days is declining, the intensity of snowfall events remains a risk due to rare but disruptive occurrences. Tropical nights and extended warm spells are on the rise, while the frequency of wildfires is increasing in both rural and peri-urban areas, particularly under prolonged dry summer conditions.

Looking ahead to the 2020–2050 period and beyond, fluvial and pluvial flood hazards are projected to increase in both frequency and magnitude, especially under climate scenarios aligned with RCP4.5 and RCP8.5, as reflected in regional flood risk projections. Drought episodes are expected to become more severe and persistent, particularly during the growing season, as the local climate gradually shifts toward semi-arid conditions under revised Köppen classifications. Heatwaves are projected to become longer and more intense, exacerbating urban heat island effects and health risks. The likelihood of compound climate events—such as heatwaves followed by convective storms triggering flash floods—is also projected to rise. According to Fire Weather Index (FWI) models from Copernicus Emergency Management Services, days with high wildfire danger will increase significantly, particularly in unmanaged or forested areas.

To sum up, this synthesized overview of dangerous climatic phenomena manifested on the territory of the Ruse municipality identifies the following as key for the municipality: river floods, heavy rainfall, wildfires, heat waves, droughts and snow.

Within the CLIMAAX framework, the Climate Risk Assessment for Ruse Municipality focuses initially, on this first phase of the project, on three primary hazards: fluvial and pluvial flooding, heavy rainfall, and wildfires. These hazards have been prioritized based on their historical frequency, future projected trends, stakeholder input, and their relevance to vulnerable sectors such as health, agriculture, and infrastructure.

The assessment is supported by an extensive set of data sources. These include historical flood records from the PFRA (2011–2019) and projected flood scenarios (APP08); vulnerability assessments provided by the Ministry of Environment and Water (MOEW) and the national adaptation framework; climate and hazard datasets from NIMH, WorldClim, Meteoblue, and ClimateData.eu; population and infrastructure exposure data from the National Statistical Institute (NSI); and geospatial hazard susceptibility layers for landslides and wildfires from national geological and forestry services. Additional spatial datasets from the European Environment Agency and Copernicus EMS support detailed analysis of flood zones, fire perimeters, and drought indices.

Despite the availability of robust baseline data, several key gaps remain. These include the need for high-resolution climate downscaling at the urban and sub-regional scale; integrated vulnerability indicators that incorporate socio-economic dimensions such as income, age, health status, mobility, and housing quality; tools to assess cascading and compound risks; real-time sensor networks for hydrological and meteorological monitoring; and data on ecosystem services related to natural climate buffers, such as the flood attenuation capacity of wetlands. There is also a lack of sector-specific loss and damage data, particularly for agriculture, small enterprises, and socially vulnerable groups.

2.2.2 Workflow selection

2.2.2.1 River Floods:

- Historical records and Preliminary Flood Risk Assessments (PFRAs) identify parts of the municipality — especially **coastal industrial zones and settlements along the Lom** — as flood-prone. Even though the opposite Romanian bank has lower elevation and greater flood vulnerability, Ruse's **low-lying coastal districts**, especially those with dense infrastructure or limited natural buffers, remain at **high exposure**, especially during **seasonal snowmelt or transboundary flood peaks.**

  This workflow is essential to: Quantify inundation depth and extent under different return periods and climate scenarios; Assess cross-border dynamics and hydrological dependencies; identify critical infrastructure at risk from riverine overflow.

- The **key vulnerable groups and exposed areas are:**
  - Industrial and transport infrastructure in the western riverbank zones (e.g., port terminals, logistics centers, rail yards).
  - Low-income communities or informal housing along the Rusenski Lom floodplain.
  - Elderly residents in low-elevation districts with limited mobility during flood events.
  - Public utilities and energy infrastructure exposed to prolonged inundation or erosion.
  - Agricultural land and ecosystems near the Lom confluence, especially in peri-urban zones.

2.2.2.2. Heavy Rainfall:

Recent analyses show an increasing frequency of high-intensity, short-duration rainfall events, particularly during summer. This elevates the risk of pluvial flooding, which is not driven by rivers but by stormwater runoff exceeding drainage capacity — a serious concern for urbanized municipalities like Ruse with aging infrastructure.

This workflow is crucial to evaluate urban flood dynamics and flash flood risk; map rainfall return periods and intensity-duration thresholds; support stormwater infrastructure planning and early warning systems.

The **key vulnerable groups and exposed areas are:**

- Dense residential neighborhoods with inadequate drainage, particularly Central Ruse, Druzhba, and Zdravets**.**
- Underground facilities (basements, parking garages, underpasses) vulnerable to flash flooding.
- Schools, hospitals, and public buildings on or near sloped terrain.
- Municipal transport infrastructure, including roads and railways frequently disrupted by runoff and debris.
- Urban poor and elderly residents, often in areas without adequate flood-proofing or insurance coverage.

2.2.2.3 Fire Weather Index

The analyses show a notable increase in both the number of high-risk fire days and the spatial extent of fire-prone zones, particularly in peri-urban forested regions near the Rusenski Lom Nature Park and in areas with dry grasslands or unmanaged woodland. Drought conditions and land-use change further aggravate the hazard.

This workflow is important to analyze FWI time-series trends under climate scenarios, identify fire-prone vegetation zones, fuel buildup areas, and high-risk weather periods and support emergency services, public health, and forest management strategies.

The **key vulnerable groups and exposed areas are:**

- Residents of rural and peri-urban settlements adjacent to forests or scrubland (e.g., areas around Nikolovo, Basarbovo, and Obraztsov Chiflik).
- Tourists and recreational users in and near Rusenski Lom Natural Park**,** where seasonal dryness and accessibility issues increase exposure.
- Farmers and landowners near combustible agricultural residues or overgrown buffer zones.
- Firefighters and emergency personnel, especially under conditions of limited access and high temperature.
- Critical infrastructure near vegetation, such as transmission lines**,** water reservoirs, and communication towers**.**

2.2.3 Choose Scenario

2.2.3.1. Floods:

For Ruse Municipality, scenario development considers both climatic drivers (e.g., precipitation, snowmelt, river dynamics) and socio-economic pressures (e.g., land use, urbanization, economic activity) that affect flood risk exposure and vulnerability. Scenario assumptions should be organized across three time horizons as follows:

- **Short-term (0–5 years; to ~2030)**:

  Climatic assumptions: *Observable climate variability is already leading to increased flood frequency linked to intense precipitation events and seasonal river swells (especially spring and early summer). The Danube is experiencing increased hydrological extremes: alternating between record low water levels (drought stress) and high water events with bank overflow potential.*

  Socio-economic assumptions: *Moderate population decline in rural areas, but concentration of population and economic activity in Ruse city, increasing exposure in flood-prone urban zones. Urban expansion in areas with outdated drainage infrastructure increases pluvial flood vulnerability. Limited local funding capacity for structural flood defenses (e.g., levee upgrades), with reliance on EU financing.*

  Implication: *Risk is likely to increase due to urban pressure and climate intensification, while institutional and infrastructural capacity remains static or slow-moving.*

- **Medium-term (20–30 years; to ~2050)**

  Climatic assumptions: *Based on RCP4.5 and RCP8.5 scenarios (EU-wide standard), regional climate models (e.g., EURO-CORDEX) project, the expectations are: Increased intensity of extreme precipitation (Rx1day, Rx5day); Higher runoff variability and earlier spring snowmelt, leading to compound flood events; Slight increase in annual rainfall but with greater concentration in fewer, more intense episodes.*

  Socio-economic assumptions: *Continued urban densification near industrial and logistical hubs along the Danube (port areas, intermodal zones); Implementation of floodplain restoration projects and green infrastructure may begin under EU Green Deal and nature-based solutions (NBS) initiatives; Technological improvements in flood forecasting and risk governance.*

__Implication:__ While adaptive measures may begin to take effect, residual risk remains high due to structural inertia and climate intensification. Focus on resilient land-use planning and integrating early warning systems becomes essential.

- **Long-term (50–100 years; to ~2100)**

  __Climatic assumptions:__ Regional warming of 3–4°C expected by 2100; Anticipated increase in flood hazard magnitude and frequency, particularly from Danube overflows, intensified convective storms and compound risk from simultaneous upstream and local runoff events; Sea-level rise may affect lower Danube basin dynamics, depending on interactions with backwater effects

  __Socio-economic assumptions:__ Demographic uncertainty: possible population stabilization or slight growth due to EU in-migration, economic revival, or return migration; Potential transformation of land use along the Danube for ecosystem-based flood regulation

  __Implication:__ Long-term resilience depends on adaptive urban design, strategic retreat from high-risk zones, and systemic investment in multi-functional flood plains and socio-technical systems.

The CLIMAAX River Floods workflow recommends using a mix of climate-hydrological and socio-economic scenario layers. For Ruse, the following are especially applicable:

- **Climate Scenarios (Hazard layers):**
  - RCP4.5 and RCP8.5 projections for river discharge and extreme rainfall events (Rx1day, Rx5day) - Suitable datasets: EURO-CORDEX, Copernicus C3S, WorldClim v2.1
  - Flood recurrence intervals (10, 50, 100-year) from the National PFRA (APP08) and EEA flood hazard maps
  - Climate indices such as CDD (Consecutive Dry Days), SDII (Simple Daily Intensity Index) to assess runoff generation potential
- **Socio-economic Scenarios (Exposure/Vulnerability layers):**
  - Shared Socioeconomic Pathways (SSPs):
    - SSP2 (“Middle of the road”) fits Bulgaria’s moderate-growth trajectory with limited institutional reforms.
    - SSP3 (“Regional rivalry”) can serve as a worst-case scenario with poor governance and low adaptation.
  - Urbanization and land-use change models: CORINE Land Cover change detection for peri-urban sprawl
  - Demographic projections from NSI (National Statistical Institute) and Eurostat: population ageing, urban concentration
  - Economic trends: NSI regional GDP and employment data to model asset exposure

Ruse’s river flood risk analysis should be underpinned by multi-scenario, multi-hazard modeling, incorporating both physical drivers (climate change) and social dynamics (urbanization, economic pressure, policy inertia). The combination of RCP4.5/8.5 for climate and SSP2/3 for socio-economic development provides a robust basis for scenario building within the CLIMAAX CRA framework. This enables strategic planning across temporal horizons and supports informed decision-making for resilient regional development.

2.2.3.2. Heavy rainfall

The assessment of heavy rainfall risk in Ruse Municipality integrates both climate-driven hazard dynamics (extreme precipitation trends, return periods, and seasonal concentration) and socio-economic pressures (urban expansion, infrastructure vulnerability, population exposure). The CLIMAAX Heavy Rainfall workflow supports scenario development over multiple time horizons to enable structured planning and targeted resilience actions.

- **Short-term (0–5 years; to ~2030)**

  Climatic assumptions: *Observable climate variability already indicates an increase in short-duration, high-intensity rainfall events (pluvial flood triggers), especially during spring and summer; Inter-annual variability is increasing, with shifts in rainfall onset and seasonality.; Historical observations already show record AMDPs and exceedance of the 50 mm/day threshold****,*** *forming a solid reference baseline.*

  Socio-economic assumptions: *Urban densification in central and peri-urban areas continues, increasing impervious surfaces and overloading drainage infrastructure****.*** *Aging sewer systems and insufficient stormwater retention capacity in older districts exacerbate vulnerability; Limited budgetary capacity at municipal level delays large-scale grey infrastructure upgrades, but early adoption of green-blue infrastructure (e.g., permeable pavements, rain gardens) may begin.*

  Implication: *The risk of flash flooding and drainage failures in urbanized zones is likely to rise, driven by both changing rainfall intensity and static infrastructure. Early interventions must focus on non-structural adaptation (e.g., planning regulations, public awareness, local retention measures).*

- **Medium-term (20–30 years; to ~2050)**

  Climatic assumptions: *RCP4.5 and RCP2.6 projections indicate: Increased frequency of days with AMDP > 50 mm/day, higher summer rainfall under RCP4.5, leading to convective storm clusters and urban heat-rainfall coupling and* ***e****nhanced seasonal asymmetry: wetter winters and more volatile summers; Climate indices (Rx1day, Rx5day, SDII) indicate an upward trend in rainfall intensity per event, not necessarily in annual totals.*

  Socio-economic assumptions: *Continued urban sprawl and land-use pressure, especially in peri-urban zones with inadequate drainage. Growing economic activity and infrastructure density in vulnerable areas (e.g., logistics hubs, residential complexes). Gradual integration of nature-based solutions supported by EU funding (e.g., LIFE, Green Deal).; Deployment of early warning systems, yet with uneven data integration across sectors.*

  Implication: *Risk remains high due to lag in infrastructural adaptation* ***and*** *non-linear increase in hazard severity. Planning must integrate stormwater-sensitive urban design (SSUD)* ***and*** *land-use zoning to reduce exposure.*

- **Long-term (50–100 years; to ~2100)**

  Climatic assumptions: *Under RCP8.5, extreme rainfall events may exceed historical benchmarks by 2–3x in terms of both intensity and frequency; Enhanced convective storm regimes in summer and compound events (e.g., storm-flood-drought cycles) likely; Shifts in climate zones (e.g., temperate to semi-arid transition) impact soil infiltration, runoff behavior, and flash flood risk.*

  Socio-economic assumptions: *Demographic uncertainty: stabilization or moderate growth due to return migration or cross-border dynamics (Danube economic corridor).; Strategic urban transformation toward climate-resilient design, including sponge cities, multifunctional landscapes, and digital flood control systems; Possibility of technological leap-frogging in sensor networks, remote sensing, and AI-enabled flood forecasting.*

  Implication: *Extreme rainfall will pose systemic risks to mobility, housing, and emergency services****.*** *Ruse must consider transformational adaptation including urban retreat from low-lying zones, deep retrofit of infrastructure, and climate-proof urban governance****.***

Relevant CLIMAAX Scenarios and Datasets:

- **Climate Scenarios (Hazard Layer Selection):**
  - **RCP2.6 and RCP4.5**:
    - RCP2.6 offers a lower-bound projection (moderate risk, higher uncertainty).
    - RCP4.5 is highly policy-aligned for Bulgaria and shows marked increases in AMDP and summer rainfall intensity.
  - **Precipitation Indices**:
    - Rx1day, Rx5day (extreme precipitation duration)
    - SDII (Simple Daily Intensity Index) – evaluates per-event intensity
    - CDD (Consecutive Dry Days) – compound risk (e.g., drought-flood feedback)
  - **Sources**: EURO-CORDEX, Copernicus C3S, ClimateData.eu, WorldClim v2.1
- **Socio-economic Scenarios (Exposure and Vulnerability Layers):**
  - **Shared Socioeconomic Pathways (SSPs):**
    - **SSP2** ("Middle of the Road"): Best reflects Ruse's current trajectory with moderate adaptation and economic continuity.
    - **SSP3** ("Regional Rivalry"): Represents fragmented governance and low investment — a stress-testing scenario.
  - **Urbanization & land use**:
    - CORINE Land Cover transitions, impervious surface expansion.
    - Spatial models of flood-exposed population using NSI demographic data.
  - **Infrastructure vulnerability data**:
    - Drainage capacity, road elevation models, public building exposure

The heavy rainfall risk assessment in Ruse should rely on RCP2.6 and RCP4.5 scenarios for climate hazard modeling**,** and SSP2 and SSP3 for socio-economic vulnerability**.** This combined approach allows scenario-based planning that is temporal (2030–2100)**,** sectoral (urban, infrastructure, population)**,** and scalable (municipal to regional)**.** The use of high-resolution AMDP, seasonal rainfall trends, and socio-demographic overlays ensures the CRA aligns with the CLIMAAX objective of harmonized, data-driven, and context-sensitive risk analysis.

2.2.3.3. Wildfires

For Ruse Municipality, scenario development considers both climatic drivers (and socio-economic pressures that affect risk exposure and vulnerability. Scenario assumptions should be organized across three time horizons as follows:

- **Short-term (0–5 years; to ~2030)**

  Climatic Assumptions: *Rising incidence of high fire danger days, especially in late spring to early autumn, associated with prolonged dry spells and high temperatures; Based on recent NIMH observations, Bulgaria is experiencing more days with critical fire weather conditions, especially during May–September, with average maximum temperatures rising.*

  Socio-Economic Assumptions: *Urban sprawl into peri-urban green zones increases the Wildland-Urban Interface (WUI) exposure; Depopulation of rural areas reduces land management, increasing fuel accumulation (deadwood, dry vegetation); Limited funding for fire* *prevention infrastructure and early detection systems; reliance on EU/national support; Rising recreational use of natural areas (e.g., forests, riverbanks) introduces accidental ignition risks.*

Implication: *High short-term fire exposure in the outskirts of Ruse city, forest patches near Basarbovo and Koshov, and along dry riparian zones of the Rusenski Lom.*

- **Medium-term (20–30 years; to ~2050)**

  Climatic Assumptions: *According to EURO-CORDEX and C3S projections under RCP4.5 and RCP8.5, there will be: Increases in FWI values, especially in southern and eastern Bulgaria, including parts of Ruse region; A projected expansion of the fire season into March and October; Higher frequency of heatwaves and extreme dryness, intensifying ignition potential and fire spread.*

  Socio-Economic Assumptions: *Continued mechanization of agriculture, leading to abandonment of marginal land and increased wildfire fuel load; Moderate economic growth, with potential for increased infrastructure development in WUI areas; Some advances in early warning systems and fire-resilient land-use planning, though unevenly implemented.*

  Implication: *Increased fire risk in forested areas, abandoned farmland, and tourism-intensive zones; higher exposure of critical infrastructure in WUI.*

- **Long-term (50–100 years; to ~2100)**

  Climatic Assumptions: *Under RCP8.5, projections indicate: significant rise in average summer temperatures by 3–4°C; Up to 50% increase in FWI levels, with fire-prone days doubling in frequency; More frequent compound events: drought + heat + wind*

  Socio-Economic Assumptions: *Potential landscape transformation under climate and economic pressures: either reforestation (EU CAP support) or increased desertification in unmanaged zones; Urban areas may expand further into WUI, driven by demographic shifts and economic centralization; Implementation of nature-based solutions (fire belts, green infrastructure) becomes more critical, but requires long-term policy stability and investment.*

  Implication: *Chronic fire exposure in rural and peri-urban areas if no active fuel management and adaptation strategies are implemented.*

For assessing wildfire risk in Ruse Municipality, the CLIMAAX Fire Weather Index (FWI) workflow provides multiple Representative Concentration Pathway (RCP) climate scenarios, each with distinct value depending on the planning horizon and risk tolerance. The following scenarios are particularly relevant for the region:

- **RCP2.6 – Low Emission Scenario (mitigation-focused)**
  - This scenario assumes strong global action to reduce greenhouse gas emissions, resulting in a limited rise in global temperatures (below 2°C). For Ruse:
  - It reflects a best-case planning scenario, where fire risk increases are modest but still non-negligible**.**
  - FWI analysis for Ruse under RCP2.6 shows a modest increase in fire-prone days and a slight spatial expansion of high-risk zones.
  - This scenario is most useful for long-term strategic planning, under the assumption of global climate stabilization efforts.

Usefulness: Ideal for *low-regret adaptation*, ecosystem-based mitigation, and integration into biodiversity and land-use planning.

- **RCP4.5 – Intermediate Emission Scenario (realistic mid-range pathway)**

This scenario reflects partial mitigation and stabilization of emissions after 2050. For Ruse:

- It is arguably the most policy-relevant scenario for the region, reflecting Bulgaria's current trajectory and commitments under the EU Green Deal.
- Under RCP4.5, there is a clear increase in high-FWI days, particularly during the summer season, and a significant territorial expansion of wildfire-susceptible areas.
- The results show **a** greater concentration of high fire danger in peri-urban forested areas, especially near Rusenski Lom and surrounding rural municipalities (e.g., Basarbovo, Nikolovo, Obraztsov Chiflik).

Usefulness: Best suited for municipal and regional adaptation planning through 2050, targeting land-use regulation, fuel management, and wildfire emergency response.

2.3 Risk Analysis

2.3.1 River Flood

Table 2-1 - Data overview workflow River floods

Hazard data	***Vulnerability data***	***Exposure data***	***Risk output***
Flood extent and depth maps (1-in-10, 1-in-100, 1-in-250 year return periods) from PFRA and CLIMAAX	Social vulnerability: population density, age structure (elderly, children), income levels	Location of residential, industrial, and public infrastructure within flood	Spatial flood risk index combining flood depth with exposed vulnerable assets
Historical flood events data (2011–2019), including frequency and magnitude	Health vulnerability: access to healthcare, mobility limitations	Road networks, rail lines, energy grids, hospitals, and water systems located in inundation zones	Identification of critical infrastructure at high flood risk
Climate scenarios (RCP4.5, RCP8.5) with hydrological impact projections	Institutional capacity: civil protection coverage, local emergency response capability	Land use types: urban, peri-urban, agricultural, and industrial land in floodplain areas	Hotspot maps highlighting priority zones for adaptation and protective measures
Flood hazard maps derived from EURO-CORDEX or LISFLOOD modeling (future scenario)	Housing vulnerability: presence of informal or substandard housing near riverbanks	Demographic exposure: # of people living within 50m, 100m, 200m of river course	Quantitative risk metrics (e.g., number of people/infrastructure units affected under each flood scenario)
Topographic and hydrological data (DEM, slope, watershed flow paths)	Environmental sensitivity: soil erosion susceptibility, land degradation risks in floodplain ecosystems	Economic exposure: estimated asset value of buildings and crops in risk zones	Composite flood risk index per zone (e.g., low/medium/high) for use in spatial planning and early warning systems

2.3.1.1 Hazard assessment

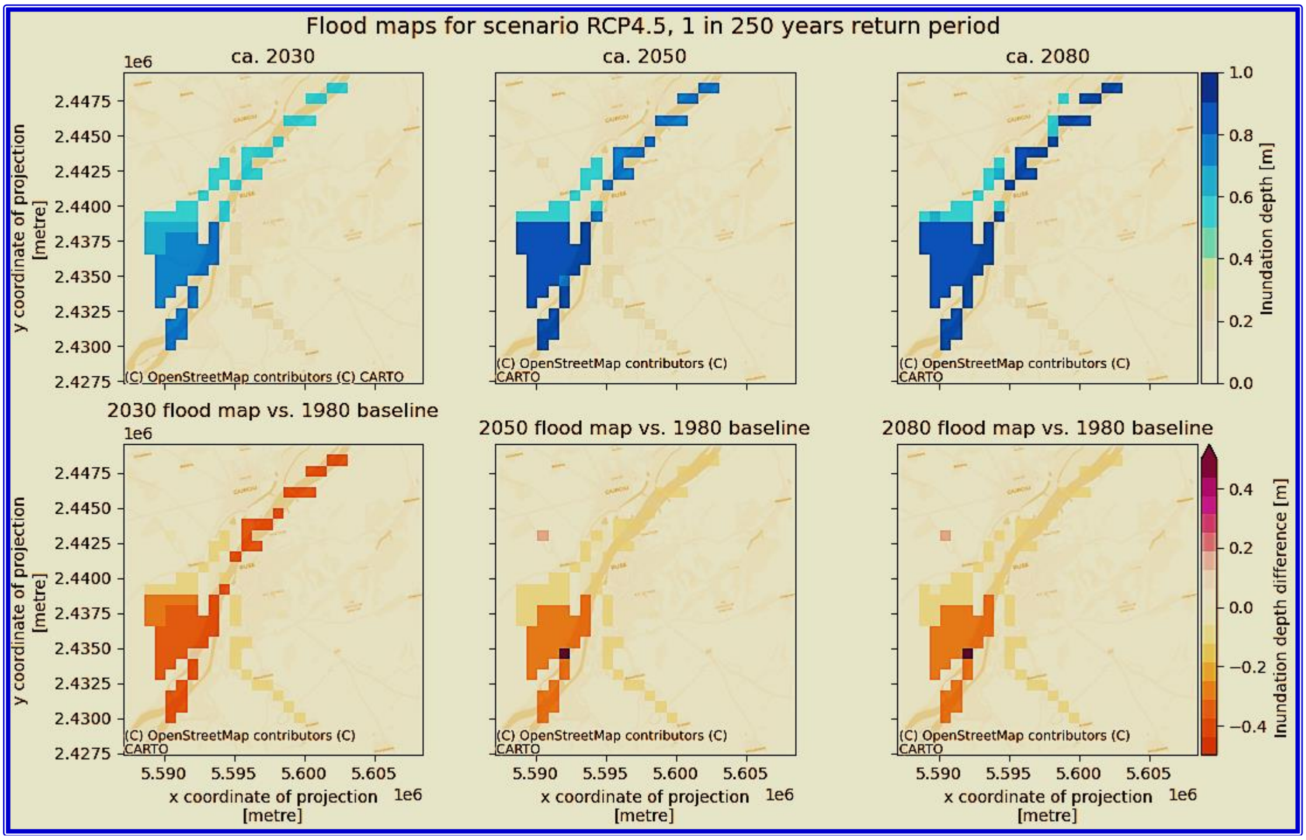

Figure 2-1 - Flood maps for scenario RCP4.5

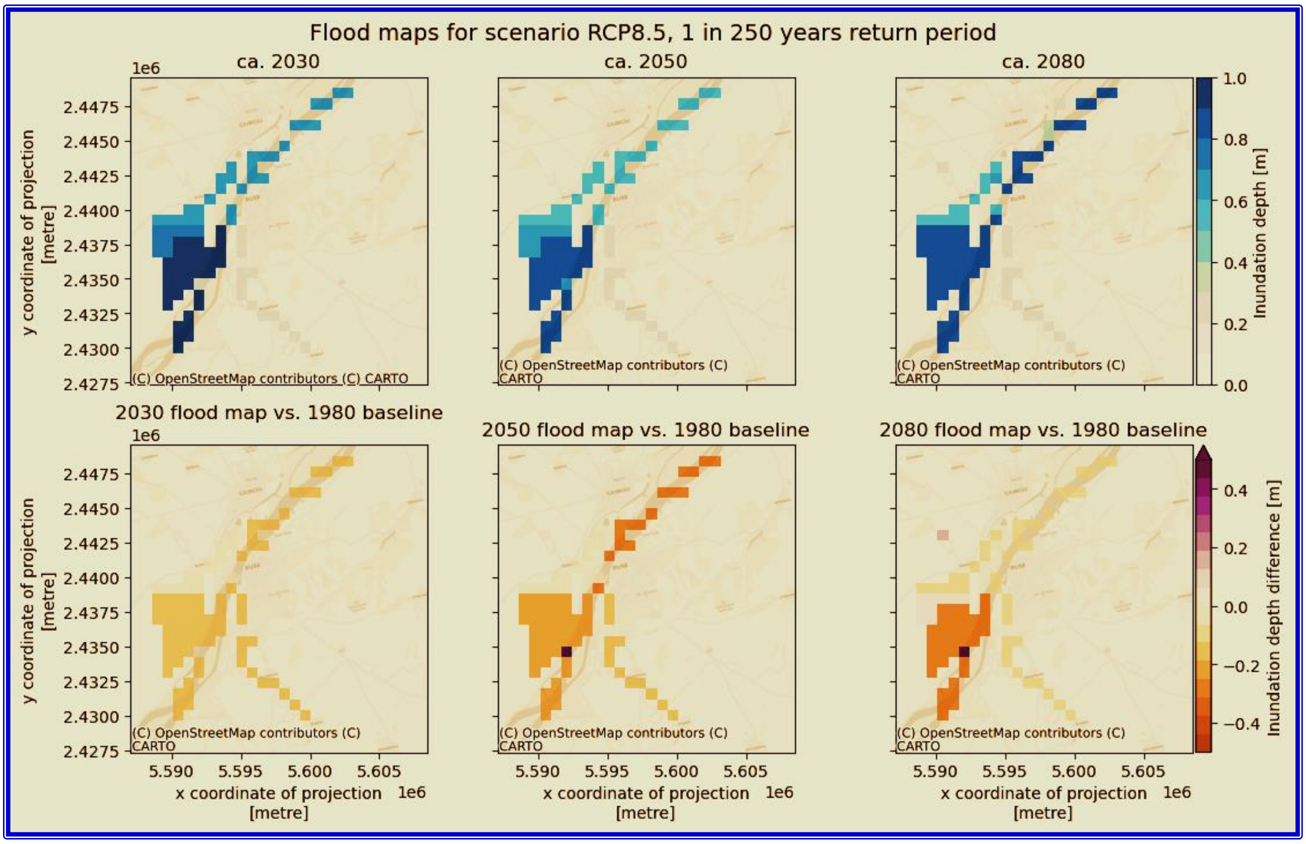

Figure 2-2 - Flood maps for scenario RCP8.5

The River Flood Hazard Assessment for Ruse Municipality is in alignment with the CLIMAAX River Flood workflow. The approach integrates key hydrological metrics—such as flood extent and depth—with return period-based modeling, enabling scenario comparison across varying levels of hazard (e.g., 10-, 50-, and 100-year floods). This structure allows for a nuanced understanding of both frequent and rare flood events, providing the foundation for long-term planning and risk communication.

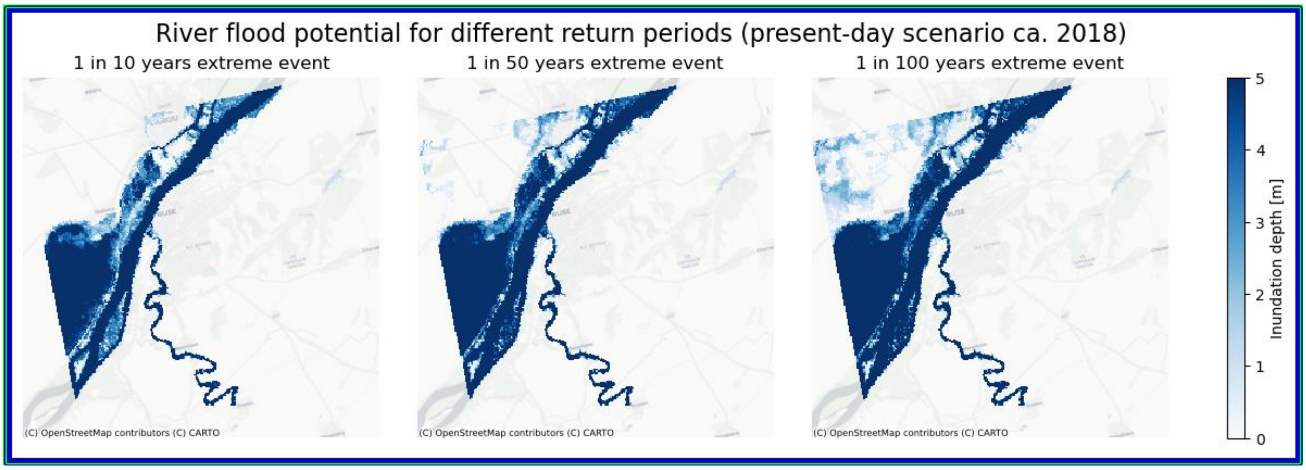

Figure 2-3 - River flood potential

By applying cutting and masking operations, the assessment successfully limits the focus area to Ruse Municipality, ensuring that all outputs are locally relevant and tailored to decision-making at the municipal level. The use of coordinate transformations, resampling, and interpolation further enhances the spatial accuracy of flood raster datasets. This preprocessing ensures consistency in scale and projection, reducing misalignment between hazard layers and underlying demographic or infrastructure data.

The workflow structure demonstrates readiness for multi-scenario comparison. Its modular coding logic supports the extension to different climate scenarios and flood return periods. Although the current implementation relies on historical or fixed return period data, the methodology can easily accommodate climate-adjusted inputs from EURO-CORDEX, LISFLOOD, or national PFRA projections. This positions the tool well for integration into future compound risk assessments or long-term climate adaptation planning.

In terms of data compatibility, the assessment relies on inputs and methods that are consistent with EU standards, particularly those promoted by the European Environment Agency (EEA) and Copernicus Emergency Management Services. This increases interoperability with broader European climate risk platforms and supports potential alignment with regional funding or reporting frameworks.

Despite these methodological strengths, several areas for improvement remain. Most notably, the final outputs lack clear visualizations of flood hazard layers. While flood rasters have been processed, they are not rendered as choropleth maps or overlaid on administrative boundaries. Such visuals are critical for communicating risk to non-technical stakeholders, including municipal planners, community leaders, and policymakers. Including even basic flood extent or depth maps would significantly enhance the accessibility and utility of the outputs.

Additionally, the current version of the assessment does not include narrative interpretation. There is no descriptive summary of which areas are most at risk, how flood intensity varies spatially across the municipality, or how critical infrastructure and communities may be impacted. Without this contextual layer, the technical outputs cannot be easily translated into actionable insights.

Despite these gaps, the assessment presents a strong technical foundation for local-scale river flood hazard analysis. Through the workflow, we successfully compared flood scenarios for different return periods, including an extreme event corresponding to a 1-in-250-year probability. This allowed us to assess the potential impacts of future climate extremes on Ruse's flood risk profile. Interestingly, the temporal comparison did not show a significant increase in flood depth. In fact, for certain modeled scenarios, slightly lower flood levels were observed relative to earlier periods. This suggests that in Ruse's case, local topography, hydrological behavior, and potential adaptive infrastructure may be playing a mitigating role—though this outcome warrants further exploration.

Overall, the hazard assessment is robust, data-driven, and compatible with broader climate risk frameworks. To maximize its impact, next steps should include integrating climate scenarios, and producing summary interpretations that bridge the gap between technical modeling and actionable policy recommendations. This will support the use of the tool in both strategic planning and operational decision-making for flood resilience.

2.3.1.2 Risk assessment

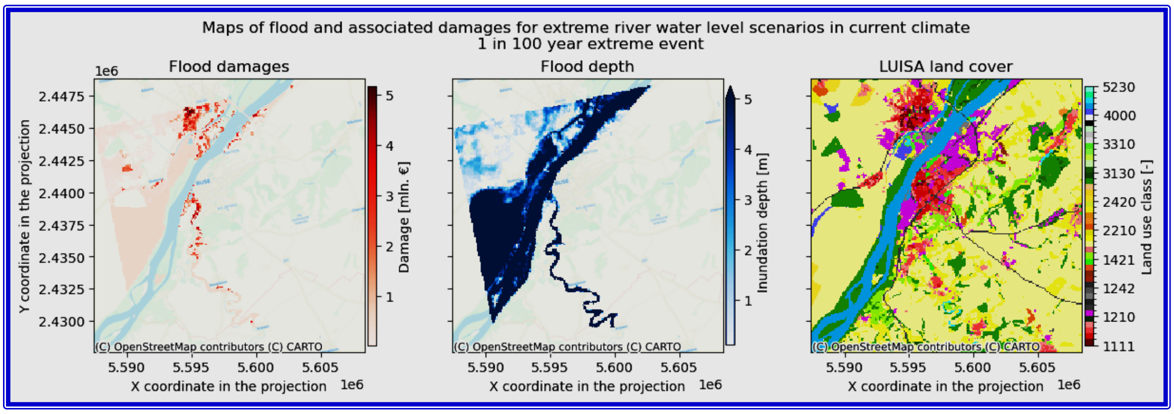

Figure 2-4 - Maps of flood damage

The flood risk assessment conducted under the CLIMAAX River Floods workflow reveals a spatially differentiated hazard profile across Ruse Municipality, shaped by geomorphological characteristics, land use patterns, and the hydrological behavior of the Danube River and its main tributary, the Rusenski Lom River. This dual-river system introduces distinct risk dynamics between the broader Danube corridor and the more localized but complex flood behavior of the Lom watershed.

The Danube River flood risk profile demonstrates a relatively moderate hazard level for Ruse Municipality. Compared to the opposite Romanian bank, where wide floodplains and lower topography increase flood severity, Ruse benefits from elevated terrain and a narrower riparian strip. While low-lying zones along the Danube exhibit some localized flood susceptibility, these areas are predominantly undeveloped or sparsely populated, minimizing exposure of residential, commercial, or critical infrastructure assets. Under standard return periods—such as 1-in-100-year flood events—the expected impacts on urban zones are limited, suggesting that, under current hydrological and infrastructural conditions, the Danube poses a moderate to low fluvial flood risk for Ruse city and its immediate surroundings.

In contrast, the Rusenski Lom River presents a significantly higher and more complex risk. This tributary's meandering course intersects multiple populated settlements, including parts of the Ruse urban area and adjacent villages. Hydrodynamic modeling and historical flood data indicate frequent overtopping risks, particularly during spring snowmelt and intense summer convective storms. These events contribute to rapid runoff accumulation and localized channel overflow. Affected areas include mixed-use zones with residential buildings, commercial assets, and linear infrastructure such as roads and utilities, elevating both the exposure and vulnerability indices. Given these conditions, the flood risk associated with the Rusenski Lom is classified as high, with potential for substantial socio-economic disruption, damage to property, and operational failure of local infrastructure if not proactively mitigated.

The key implications for risk management include differentiated strategies for each river system. For the Danube, maintaining and monitoring existing levees, preserving riparian ecological buffers, and updating flood risk maps remain central. For the Rusenski Lom, more urgent interventions are warranted. These include structural measures (e.g., retention basins, reinforced embankments), non-structural tools (e.g., updated zoning, early warning systems), and community-based preparedness and communication efforts.

Technically, the notebook used in this assessment demonstrates strong methodological design. It clearly distinguishes between hazard components (e.g., flood depth, extent), exposure layers (infrastructure, buildings, land cover), and vulnerability factors (population density, land-use type), resulting in a coherent and transparent multi-dimensional risk model. The input datasets—primarily raster-based flood depth layers—appear derived from credible sources, likely aligned with national PFRA outputs and Copernicus flood services. These were integrated using appropriate spatial techniques, ensuring consistency in projection and scale.

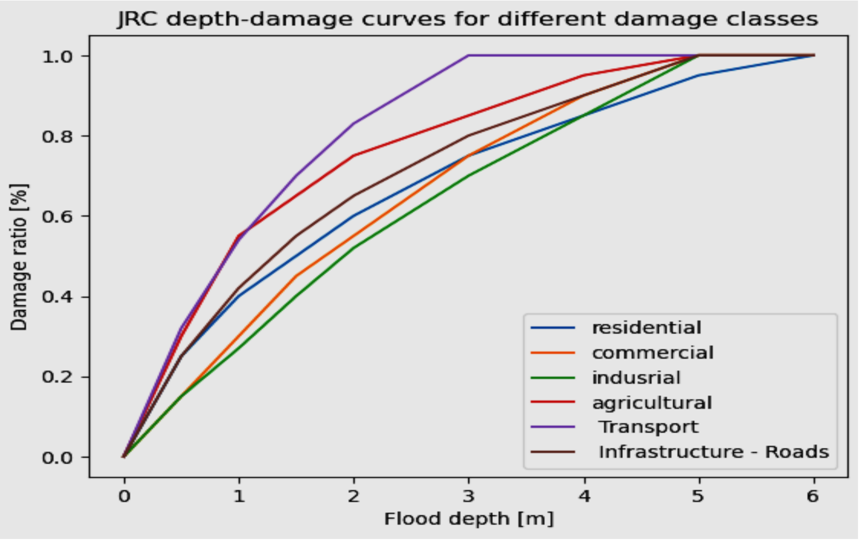

Figure 2-5 - Depth-damage curves by sector

Figure 2-5 presents standardized flood depth–damage curves from the Joint Research Centre (JRC) for different asset classes. Each curve illustrates the relationship between floodwater depth (in meters) and the expected damage ratio (as a percentage of total asset value). The transport and agricultural sectors show the steepest increase in damage at low inundation levels, reaching near-total loss at depths above 3–4 meters. Residential, commercial, and industrial assets exhibit a more gradual progression of damage. These curves are used in flood risk assessments to estimate economic losses under different flood scenarios and inform prioritization of resilience measures.

Scenario integration is addressed through varying return periods, which simulate different flood intensities. While explicit climate change projections (e.g., RCP-driven discharge estimates) are not yet included, the current structure is compatible with future integration of EURO-CORDEX or LISFLOOD-based projections, and can be extended to include SSPs for socio-economic layering. Code modularity is evident through reusable classification functions and logical separation of components, making the workflow transferable to other locations or hazard types.

Some preliminary choropleth mapping is evident in the workflow, but final rendered outputs are not yet complete. A visual summary—e.g., color-coded risk zones across the municipality—and a brief narrative interpretation of which areas face the highest exposure would significantly enhance communication and stakeholder engagement. Likewise, a tabular summary of impacted assets or risk scores by district would add practical value.

Further improvements include the addition of temporal elements and climate projections to align with long-term CRA objectives (e.g., horizon 2050 or 2100). Uncertainty analysis is also missing addressing sensitivity to return period selection, DEM accuracy, or land-use assumptions would increase the scientific robustness of the model and support its use in formal planning or EU policy alignment.

In conclusion, this risk assessment provides a reliable base for municipal adaptation planning, spatial risk zoning, and strategic communication with national and European stakeholders.

2.3.2 Heavy rainfall

Table 2-2 - Data overview Heavy rainfall

Hazard data	***Vulnerability data***	***Exposure data***	***Risk output***
Annual Maximum Daily Precipitation (AMDP) from EURO-CORDEX for RCP2.6, RCP4.5, RCP8.5 (2041–2070)	Population vulnerability: age (elderly/children), health sensitivity, socio-economic status	Urban land use areas with high impervious surface ratio (concrete, asphalt)	High-resolution spatial maps of rainfall-related pluvial flood risk
Historical daily rainfall and storm event data (1976–2005 baseline)	Informal or substandard housing in low-lying areas prone to surface runoff accumulation	Density of buildings, public infrastructure (schools, hospitals), and commercial assets in flood hotspots	Identification of flash-flood prone areas with high exposure and low coping capacity
Short-duration, high-intensity precipitation indices (e.g., Rx1day, Rx5day)	Lack of access to emergency response or drainage services	Transport corridors (roads, railways) crossing stormwater accumulation zones	Risk scores for infrastructure disruption under varying rainfall scenarios
Rainfall exceedance frequency maps (e.g., >50 mm/day, >70 mm/day)	Institutional vulnerability: lack of integrated stormwater planning, limited local adaptation budgets	Stormwater infrastructure mapped against projected runoff intensity zones	Asset and system-specific flood risk metrics (e.g., % of drainage capacity exceeded)
Seasonal rainfall trends (increase in summer storm frequency under RCP4.5)	Social awareness and preparedness: knowledge of early warnings, ability to respond	Population clusters within 100–200 m of known flood hotspots or drainage-challenged areas	Temporal risk profile showing seasonal peaks in flood potential for targeting early-warning and preparedness campaigns
Topography, land cover, slope, and runoff potential derived from DEM and soil data	Community resilience: access to insurance, disaster training, or municipal recovery funds	Urban expansion zones or peri-urban developments lacking updated drainage systems	Risk priority zones for adaptation investment (e.g., green infrastructure, stormwater retrofitting)

2.3.2.1 Hazard assessment

Ruse Municipality faces a growing risk from hydro-meteorological hazards, with heavy rainfall identified as one of the most significant and rapidly intensifying threats. This hazard assessment focuses on the evolution of extreme precipitation patterns, using the Annual Maximum Daily Precipitation (AMDP) as the key metric, analyzed under historical baselines and future climate scenarios (RCP2.6, RCP4.5, RCP8.5) for the 2041–2070 period.

The analysis employs climate model outputs from the EURO-CORDEX ensemble, centered on the grid point nearest to Ruse city (latitude 43.85, longitude 25.95) at a spatial resolution of ~12.5 km. These models generate daily precipitation time series that were used to compute AMDP values, assess trend evolution, identify seasonal shifts, and evaluate threshold exceedances across scenarios.

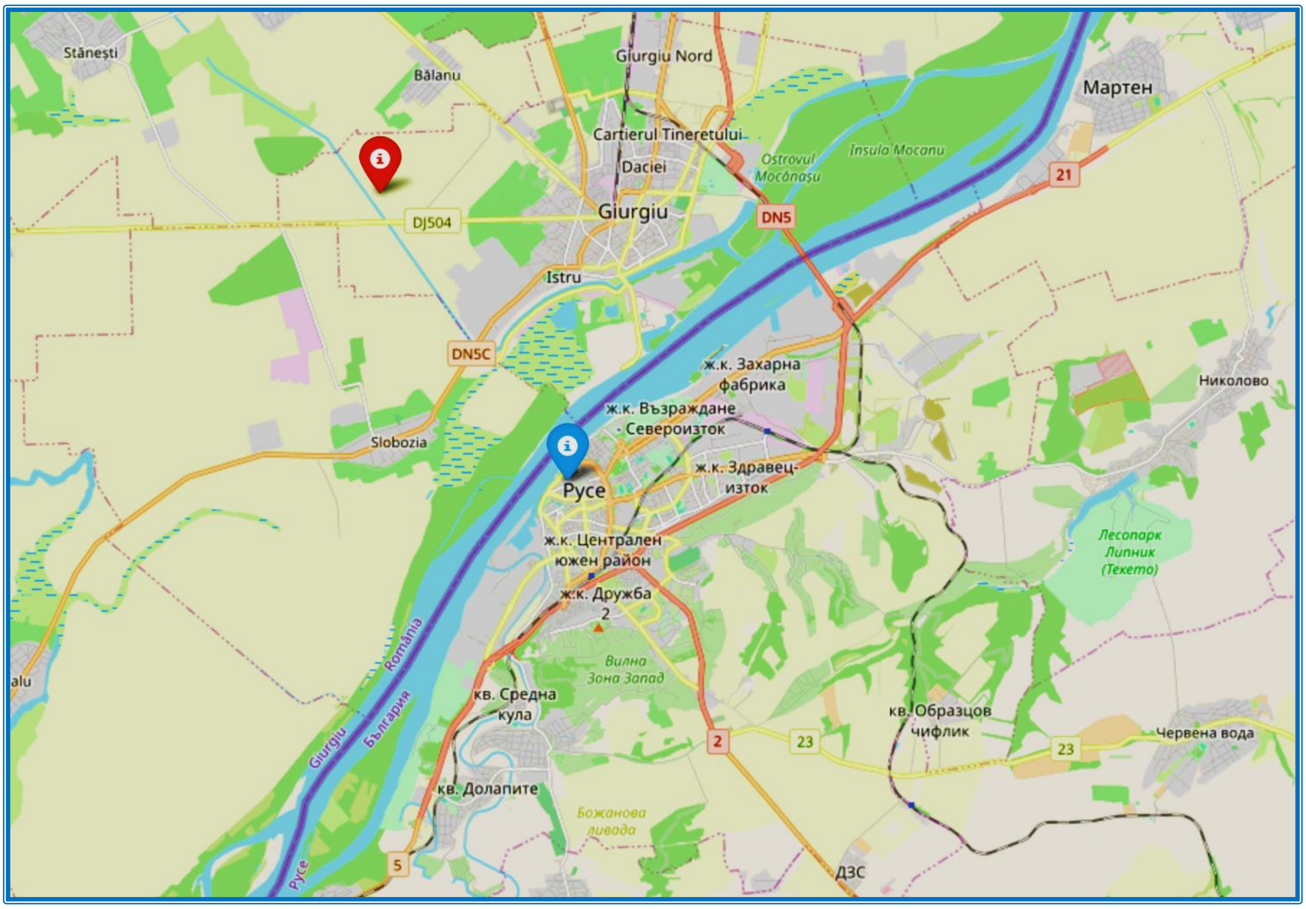

Figure 2-6 - Grid point Ruse

Climate models developed under initiatives such as CORDEX provide output data on a spatial grid rather than for individual settlements. Each grid cell—typically at a horizontal resolution of approximately 0.11 degrees (~12.5 km)—contains simulated values for key climate variables such as precipitation, temperature, and humidity. To ensure consistency with the spatial structure of the models, climate indicators for municipalities must be derived from the closest representative grid point rather than exact city coordinates.

For the purposes of this assessment, the central coordinates of Ruse Municipality were defined as latitude 43.85° N and longitude 25.95° E. Using these reference coordinates, the closest available grid point within the EURO-CORDEX model data was identified at latitude 43.8991° N and longitude 25.9053° E. The distance between the real city center and the model grid point is approximately 6.53 km, which falls well within the resolution range of the model and ensures high spatial relevance.

All climate data used in the heavy rainfall analysis—including Annual Maximum Daily Precipitation (AMDP), seasonal trends, and scenario-based projections—were extracted from this grid point. This point serves as the model-derived climate representation of Ruse Municipality and forms the basis for subsequent scenario evaluation and risk quantification.

- Historical Baseline (1976–2005)

During the historical reference period, the mean AMDP for Ruse Municipality was approximately 31.6 mm/day, with only 6.7% of years exceeding the critical hazard threshold of 50 mm/day. The variability was moderate, with most intense precipitation concentrated in spring and early summer. These values define the baseline for future comparisons, reflecting relatively low historical exposure to high-impact rainfall.

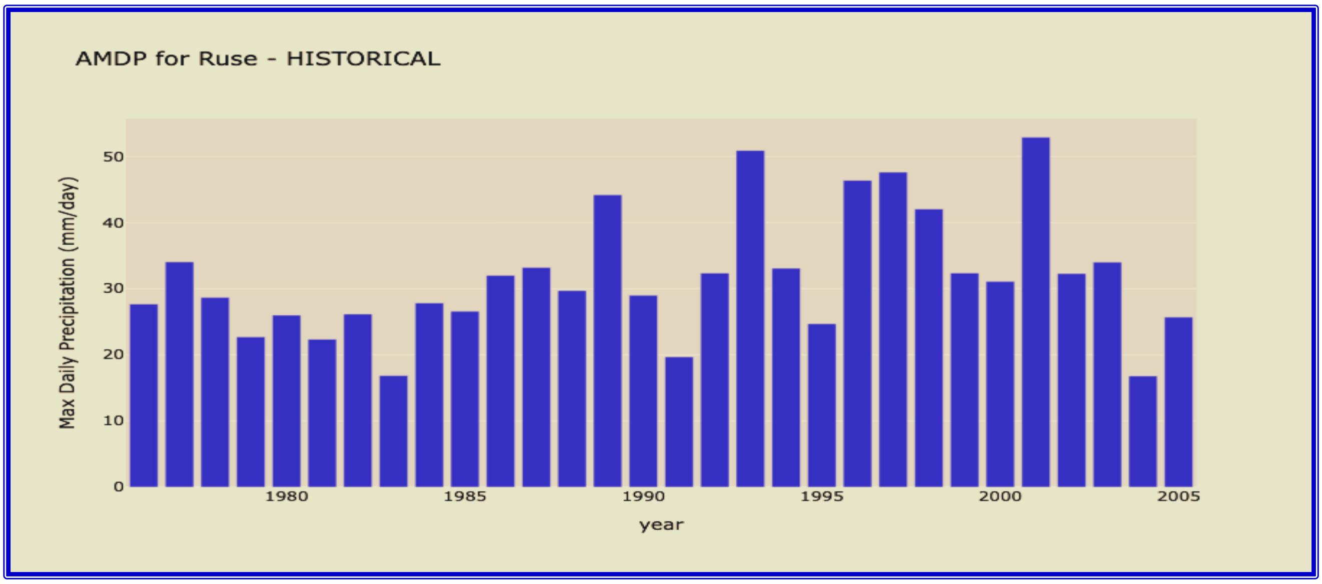

Figure 2-7 - AMDP for Ruse HISTORICAL

- RCP2.6 Scenario (2041–2070)

Although RCP2.6 represents a strong mitigation pathway, it still shows a substantial increase in hazard intensity. The mean AMDP rises to 41.1 mm/day, and 10% of years exceed 70 mm/day. The frequency of multi-day events above 50 mm/day also increases significantly. Interestingly, the long-term AMDP trend appears slightly negative (–0.29), indicating inter-annual variability rather than linear escalation. Spatial projections place Ruse in the upper half of high-risk zones, with neighboring municipalities such as Slivo Pole and Vetovo showing even higher AMDP values.

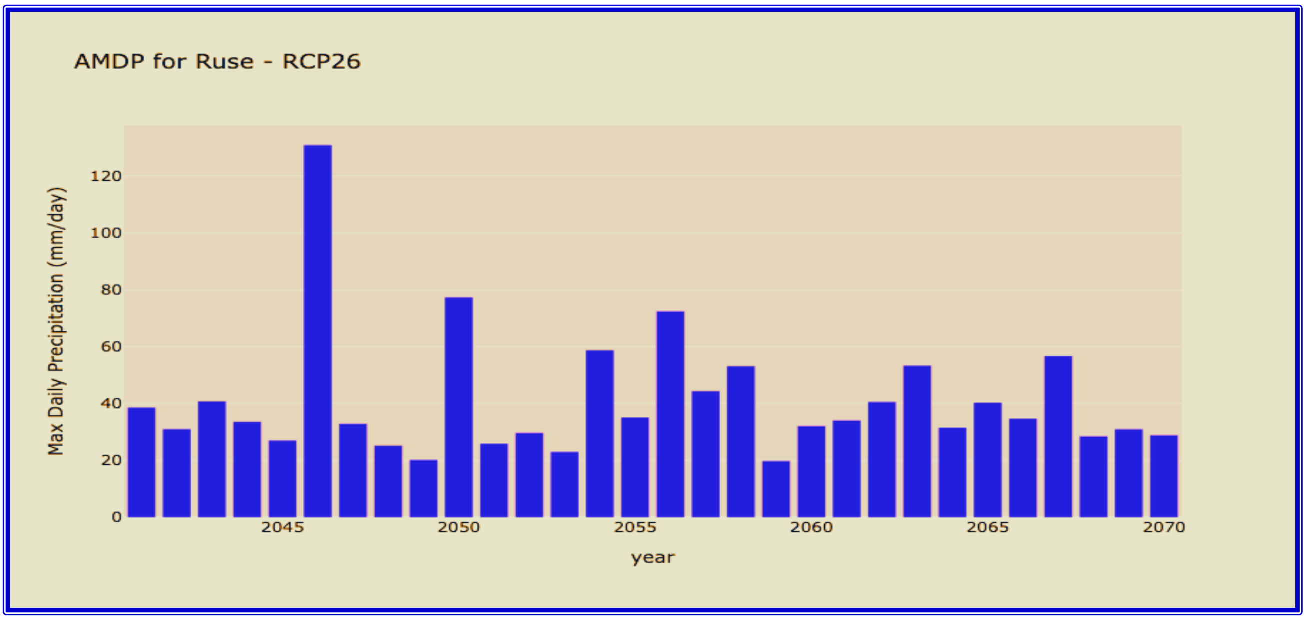

Figure 2-8 - AMDP for Ruse RCP2.6

- RCP4.5 Scenario (2041–2070)

Under this intermediate emissions pathway—often considered the most policy-relevant—the mean AMDP reaches 39.1 mm/day, with 20% of years exceeding 50 mm/day. Several years also project AMDP values above 70 mm/day, signaling an elevated threat of flash flooding. Seasonal distribution shifts noticeably toward summer, in line with increased convective storm activity. RCP4.5 simulations also record the highest seasonal precipitation in summer, marking a clear transition toward warm-season hazard dominance, which directly affects stormwater infrastructure and urban flood management.

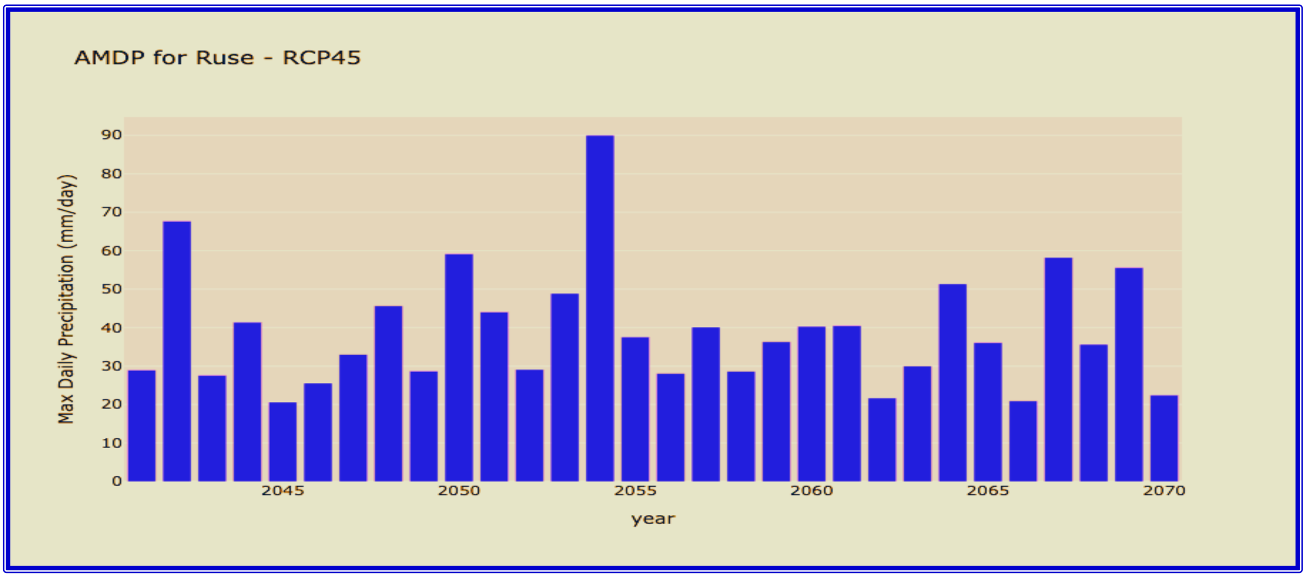

Figure 2-9 - AMDP for Ruse RCP4.5

- RCP8.5 Scenario (2041–2070)

Although not fully quantified in risk tables, visual plots indicate that RCP8.5 yields the highest peak AMDP values, with multiple instances above 90 mm/day. This scenario aligns with global high-emission projections, indicating nonlinear increases in precipitation intensity and greater event clustering. RCP8.5 is associated with the highest hazard unpredictability, posing major challenges for long-term infrastructure planning and emergency preparedness.

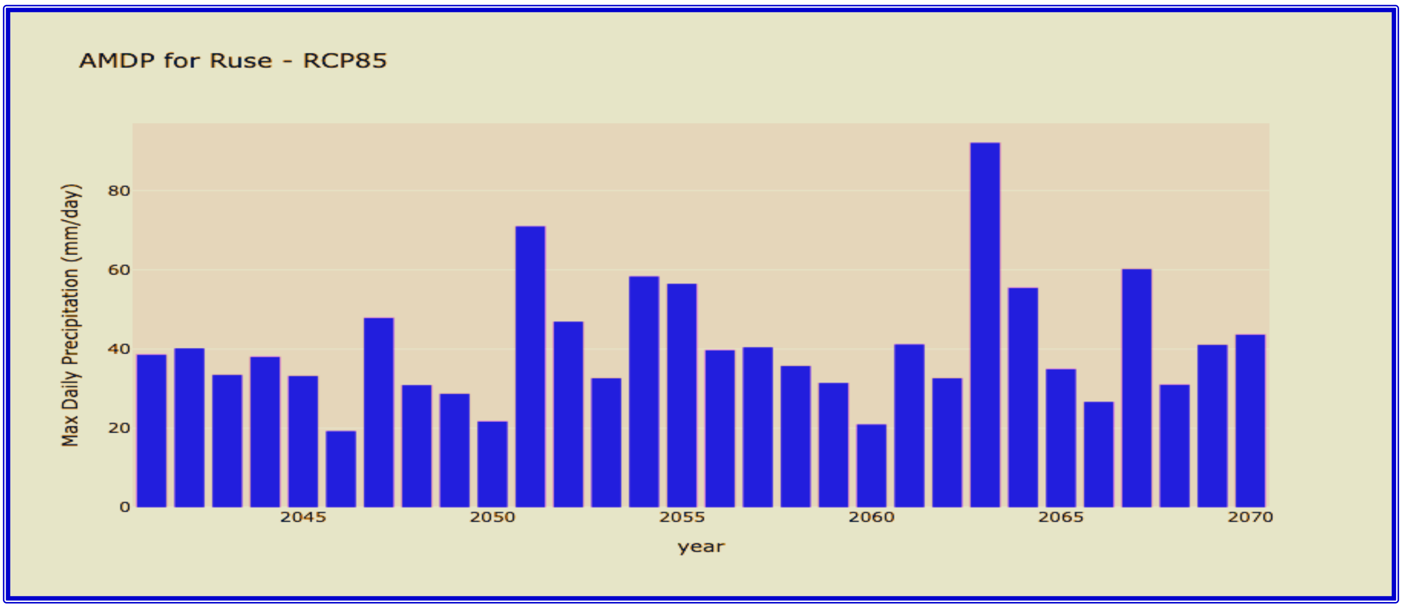

Figure 2-10 - AMDP for Ruse RCP8.5

Spatial and Seasonal Hazard Expansion

Gridded projections show that Ruse Municipality is expected to experience moderate to high increases in AMDP across all scenarios. Under RCP4.5, mean AMDP increases by over 45 mm/day compared to historical values—more than doubling the municipality's previous risk envelope. Surrounding municipalities, including Slivo Pole, Vetovo, and Tsenovo, are projected to exhibit even greater vulnerability due to their topography, land use, and proximity to floodplains.

Maps derived from scenario layers show a clear expansion of high-AMDP zones, particularly under RCP2.6 and RCP4.5. Darker risk zones (AMDP >80 mm/day) grow significantly in size, indicating a widening hazard footprint throughout the Ruse region. This shift calls for enhanced inter-municipal cooperation in water risk governance and infrastructure planning.

Scenario-based seasonal analysis shows that:

- RCP2.6 brings increased rainfall in winter and autumn, raising risks of cold-season pluvial floods.
- RCP4.5 introduces intense summer rainfall, increasing flash flood potential, urban runoff, and erosion.
- The seasonal variability index also rises under future conditions (from 3.62 historically to 4.32 under RCP2.6 and 3.98 under RCP4.5), indicating growing fluctuation between wet and dry periods and greater stress on urban water management systems.

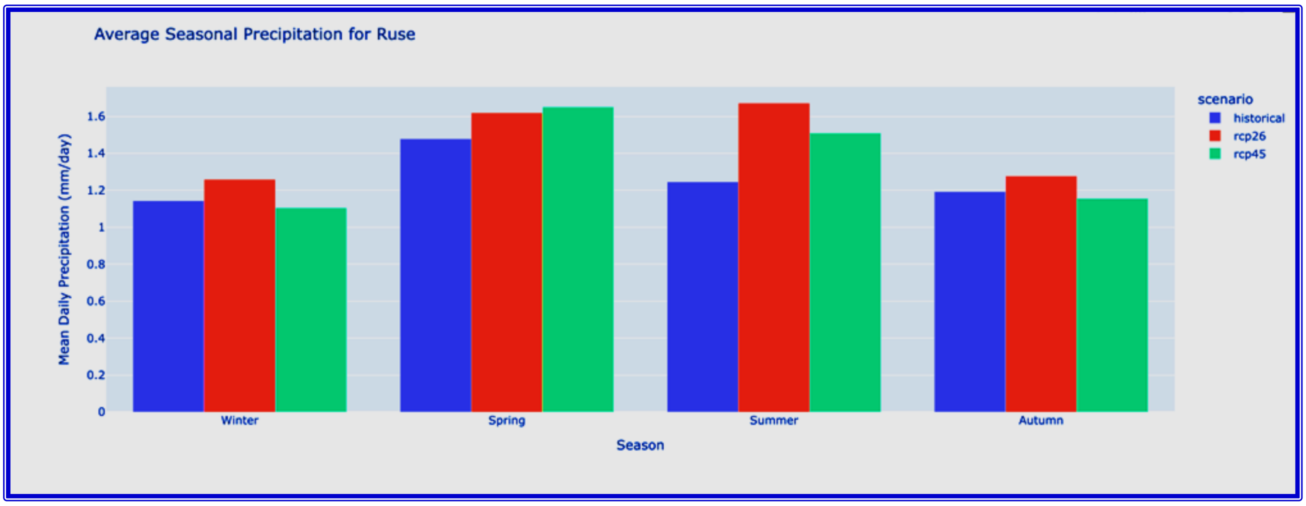

Figure 2-11 - Average seasonal precipitation

Across all modeled futures, Ruse Municipality is projected to face a marked increase in frequency, severity, and unpredictability of extreme rainfall events. The upward shift in AMDP values, combined with expanded spatial risk zones and seasonal intensification, reflects a transition from historically low hazard levels to a moderate-to-high rainfall hazard context by mid-century. These findings underscore the urgent need to strengthen stormwater infrastructure, update spatial planning tools, and integrate heavy rainfall scenarios into climate resilience strategies and emergency preparedness protocols.

2.3.2.2 Risk assessment

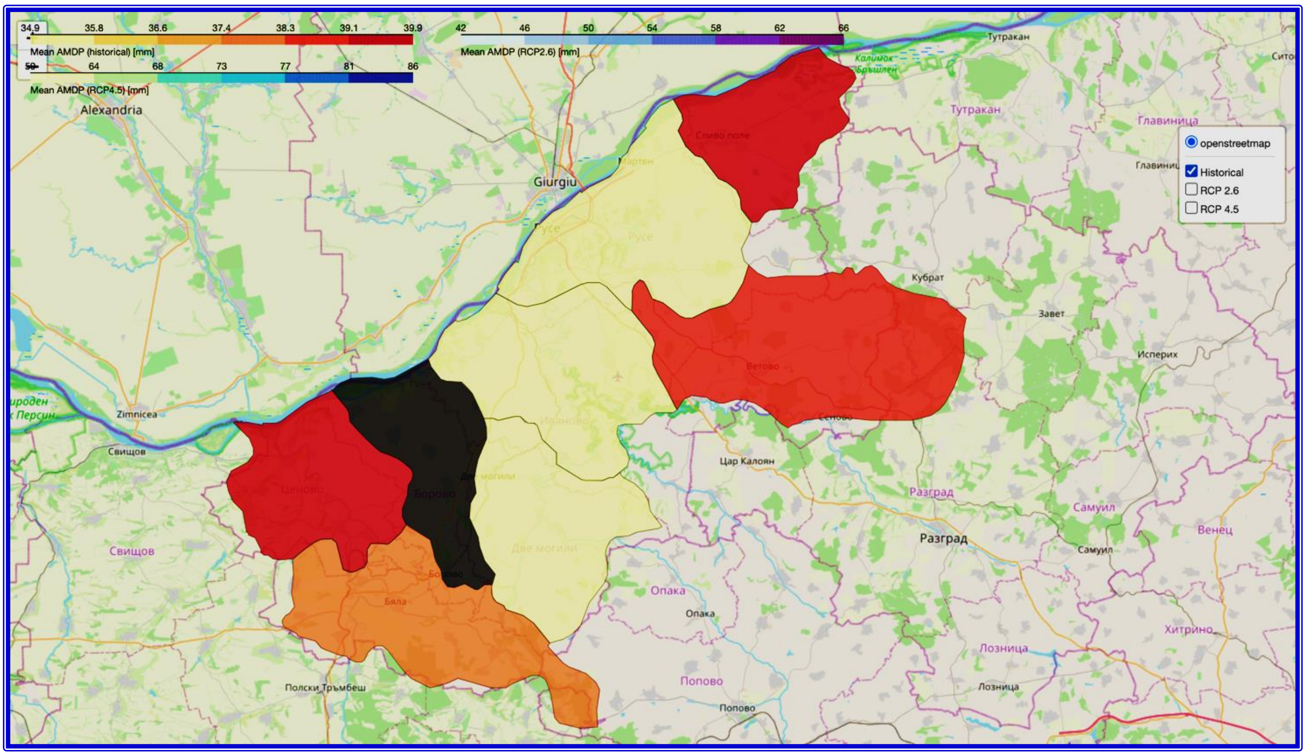

Figure 2-12 - AMDP HISTORICAL

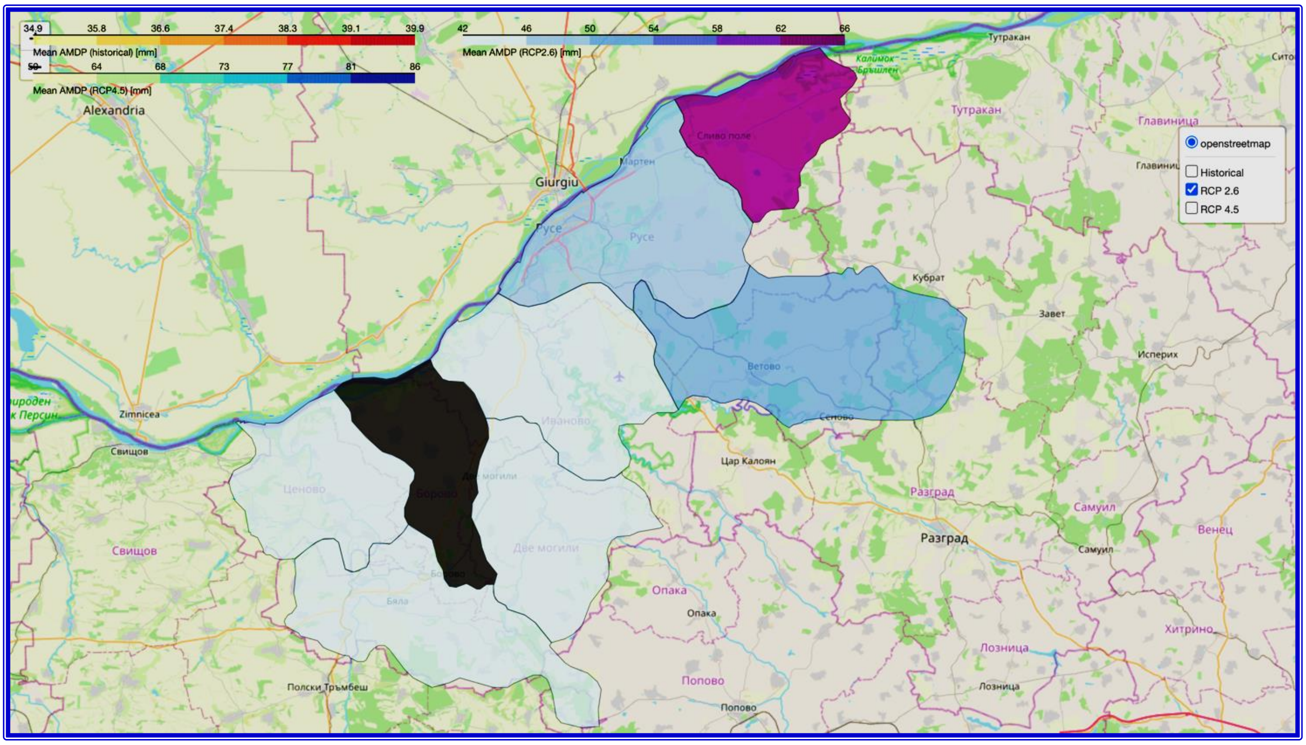

Figure 2-13 - AMDP RCP2.6

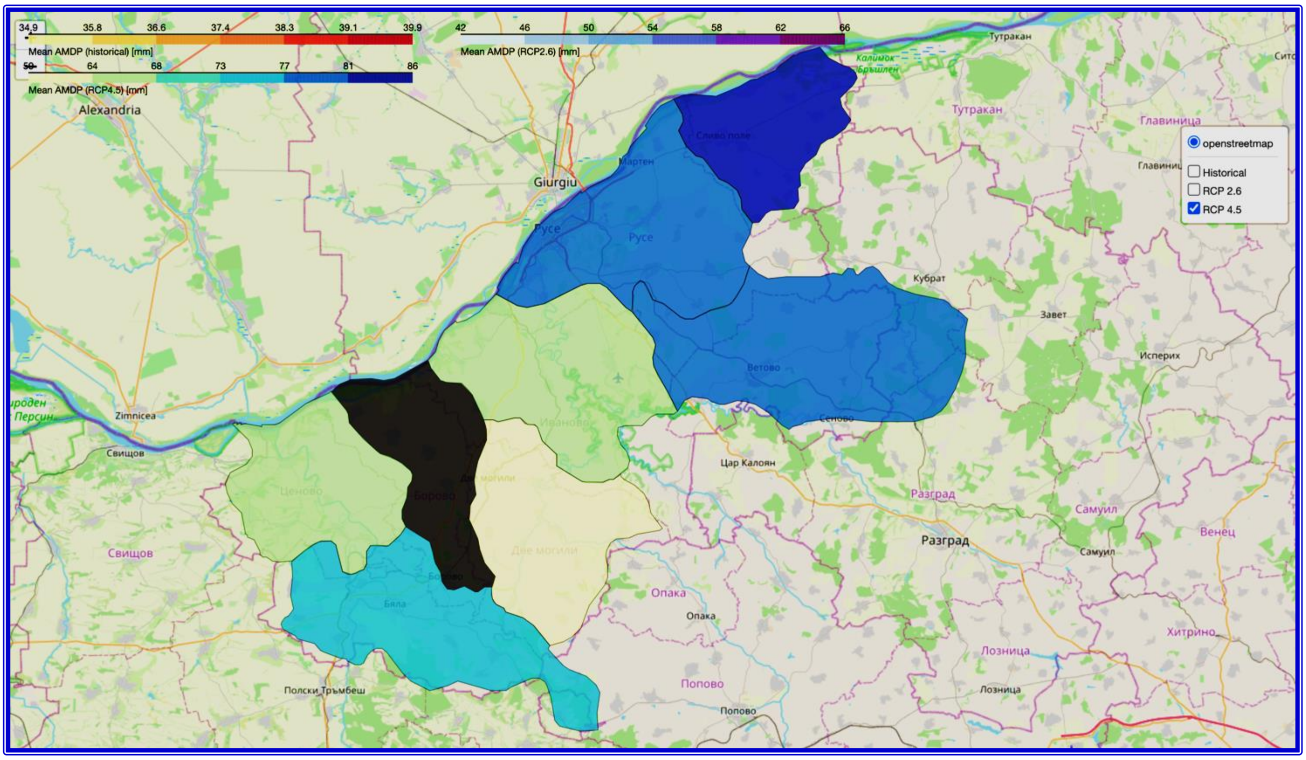

Figure 2-14 - AMDP RCP4.5

Building upon the hazard assessment, the risk evaluation for Ruse Municipality integrates exposure, vulnerability, and the probability of heavy rainfall impacts on human settlements, infrastructure systems, and natural environments. The analysis focuses particularly on the implications of rising Annual Maximum Daily Precipitation (AMDP) values under future climate scenarios, and how these changing precipitation patterns interact with the municipality's spatial structure, socio-economic conditions, and infrastructural resilience.

The maps, showed on Figures 2-12, 2-13 and 2-14 compares the Mean Annual Maximum Daily Precipitation (AMDP) across municipalities in the Ruse region under three climate scenarios:

◦ Historical (1976-2005): Represents the baseline climate conditions. Municipalities with higher AMDP already face stronger storm events and localized flooding risks.

◦ RCP 2.6 (2041-2070): A low-emissions scenario aiming to limit global warming to below 2°C. Some municipalities show increases in AMDP, hinting that risk does not fully disappear under mitigation.

◦ RCP 4.5 (2041-2070): A medium-emissions scenario. Several municipalities experience noticeable increases in AMDP, expanding the potential flood risk zone.

Ruse is a regional urban and industrial hub situated along the Danube River, with a population exceeding 150,000. It concentrates significant infrastructure, economic assets, and population density—conditions that inherently elevate exposure to hydrometeorological hazards. The flood risk posed by extreme rainfall events is amplified due to several interrelated factors.

First, the municipality's dense urbanization results in large impervious surface areas, limiting natural infiltration and substantially increasing surface runoff during high-intensity rainfall events. The presence of aging drainage infrastructure, much of which was not designed for extreme precipitation, exacerbates localized flooding, particularly in older residential districts and industrial zones.

Second, Ruse is hydrologically connected to two major river systems—the Danube and the Rusenski Lom. This geographical position increases the likelihood of compound events, where riverine overflow from upstream flood pulses coincides with localized pluvial flooding. Such interactions can intensify urban flood impacts and extend inundation periods beyond typical flash flood durations.

Third, critical infrastructure—including power substations, major rail and highway corridors, hospitals, and water treatment facilities—are located in or near low-lying and poorly drained areas. These assets are particularly vulnerable to operational failure during high rainfall events, potentially disrupting essential services at both municipal and regional scales.

Fourth, surrounding municipalities—Slivo Pole, Vetovo, Tsenovo—are projected to face similarly high AMDP values. These areas, often interconnected through shared transport networks and utility infrastructure, create a broader regional exposure footprint. Simultaneous flooding across jurisdictions poses coordination challenges for emergency response and adaptive planning.

Beyond physical exposure, Ruse faces significant socio-economic and institutional vulnerabilities that shape the overall risk profile. Among the most critical are:

Aging water management infrastructure: Legacy systems in older urban districts lack the capacity to handle current rainfall intensities, let alone projected future extremes. Overflow, backflow, and network congestion are common during peak storm events.

Social vulnerability: Low-income populations, informal housing areas, and elderly residents are disproportionately affected by flood events. These groups often reside in areas with poor drainage, limited insurance coverage, and reduced capacity to respond or recover from climate-induced disruptions.

Institutional constraints: The municipality lacks a dedicated climate adaptation budget and has limited access to technical resources for high-resolution climate modeling or risk mapping. This gap limits proactive planning and delays investment in long-term resilience infrastructure.

Land-use and zoning pressures: Urban expansion into flood-prone and erosion-sensitive areas has increased in recent years, particularly on the peri-urban fringe. Without updated spatial planning regulations and green infrastructure integration, vulnerability to surface water flooding will continue to rise.

Risk Dynamics by Scenario: The risk evaluation incorporates combined climate-hazard scoring based on frequency, seasonal variability, and intensity of AMDP exceedances across modeled futures:

- RCP2.6, while representing a strong mitigation trajectory, still yields 10% of years with AMDP >70 mm/day, the highest among the scenarios. Seasonal variability is also most pronounced here, indicating a persistently high baseline risk.
- RCP4.5 projects slightly lower exceedance rates but more concentrated summer rainfall, aligning with convective storm intensification. In combination with existing vulnerabilities, this scenario presents a high likelihood of localized flash flood events.

Historical observations had a much lower frequency of high-intensity rainfall events (only 6.7% of years exceeding 50 mm/day), underscoring the dramatic escalation of risk anticipated under future climate trajectories.

The calculated risk scores (~0.22–0.23) for both RCP2.6 and RCP4.5 reflect consistently elevated risk levels, regardless of emissions pathway, driven by Ruse’s persistent exposure and sensitivity.

For the purposes of this analysis, a critical threshold of 50 mm of daily rainfall has been applied to identify the risk of extreme precipitation. The selection of this value is based on empirical observations of flooding caused by localized intense rainfall events in the city of Ruse, as well as on an assessment of the functional capacity of the existing drainage infrastructure, which is not designed to handle volumes exceeding this amount within a 24-hour period. Additionally, the threshold of 50

mm/day is consistent with the guidelines provided in the CLIMAAX methodological framework and is also used in other municipal assessments within the project.
According to the National Institute of Meteorology and Hydrology (NIMH), the average monthly rainfall for May in Ruse is approximately 55 mm. A single-day precipitation event reaching 50 mm therefore represents an entire month's rainfall within 24 hours, an intensity that far exceeds the absorption and drainage capacity of most urban infrastructure.
Historical records confirm that rainfall exceeding 50 mm/day has consistently resulted in flooding and disruption:

- On 22–23 October 2019, Ruse experienced 60 mm of rain in one day, causing flooded underpasses, streets, and buildings. The local emergency services received over 140 calls to 112, indicating widespread impact and public distress.
- On 26 July 2023, Vetovo, a municipality within the Ruse region, recorded 75 mm in 24 hours, again resulting in significant urban flooding, according to national media coverage (bTV).
- A severe storm in June 1989 led to flash flooding and six casualties in Ruse.
- The most extreme historical case occurred on 18 June 1941, when up to 170 mm of rain fell in a single day.

These cases underscore the disproportionate impacts that occur once daily precipitation exceeds 50 mm. They support the use of this threshold as a trigger point for early warnings, drainage system evaluation, and emergency planning.
Additionally, climate scenarios from the EURO-CORDEX model for the period 2041–2070 indicate a clear increase in the frequency of days exceeding this threshold. Under the RCP4.5 scenario, between 15% and 20% of the years in the reference period are projected to include at least one day with rainfall exceeding 50 mm, representing a significant increase compared to the historical period, during which this share is below 7%. Furthermore, in approximately 8–10% of the years, an even higher threshold of 70 mm/day is expected to be exceeded, posing a risk of acute surface flooding and infrastructure failure in vulnerable areas.
In the absence of a complete hazard-impact database, this threshold aligns with the recommendations in the CLIMAAX Handbook, which suggest that local thresholds for heavy rainfall should be based on observed impacts, infrastructure design standards, and expert judgement where empirical data is limited.
Furthermore, Eastern European drainage infrastructure standards typically assume a design limit of 30–50 mm/day. Therefore, urban neighborhoods with high building density and a large proportion of impervious surfaces—such as Druzhba, Zdravets, and parts of the industrial zone—
re particularly at risk. These areas face an elevated likelihood of rainwater accumulation in the street network, flooding of underground structures, and overload of the sewer system.

Finally, the threshold is consistent with the priorities outlined in Ruse Municipality's Disaster Risk Reduction Programme (2021–2025), which emphasizes the need for impact-based triggers in risk management and climate adaptation.

Spatial Risk Insights

Spatial analyses based on AMDP hazard maps reveal that Ruse lies within a mid-to-high risk corridor extending through the northern part of the province. Under RCP4.5, Ruse shifts from moderate to high flood risk classification, particularly in districts with poor drainage or concentration of critical infrastructure. Surrounding municipalities exhibit comparable or higher risk levels, suggesting the need for cross-jurisdictional planning and investment coordination.

These insights highlight the importance of site-specific resilience strategies, especially in neighborhoods characterized by topographic depressions, stormwater bottlenecks, and vulnerable populations.

Potential Impacts:

If not proactively addressed, the projected increase in heavy rainfall events may result in:

- Urban flooding of streets, underpasses, basements, and civic buildings
- Disruption of transport networks, including road closures and rail delays
- Stormwater overflow and contamination of water bodies and public spaces
- Business interruption and economic loss, especially for small and medium-sized enterprises
- Public health risks, including exposure to waterborne diseases, mold, and psychological stress
- Conclusion

The intersection of rising rainfall intensity with Ruse's infrastructural and socio-economic vulnerabilities defines a climate risk trajectory that is both urgent and complex. Even under low-emission pathways, the frequency and severity of high-impact precipitation events are expected to triple or quadruple compared to the past. With dense urban systems, limited adaptive infrastructure, and exposed assets, the overall risk level is moderate to high, requiring immediate integration of resilience strategies.

This assessment underscores the relevance of applying the CLIMAAX risk framework to guide:

- Urban drainage upgrades and rainwater harvesting
- Nature-based solutions, such as retention wetlands and permeable surfaces
- Early warning and flood forecasting systems
- Dynamic zoning and land-use regulations responsive to hazard projections

These interventions will be key to strengthening the city's capacity to cope with climate-driven rainfall extremes, protect vulnerable communities, and ensure long-term urban resilience.

2.3.3 Wildfire (FWI)

Table 2-3 - Data overview workflow Wildfire

Hazard data	***Vulnerability data***	***Exposure data***	***Risk output***
Fire Weather Index (FWI) values from Copernicus Climate Data Store (historical and projected)	Limited fire preparedness in rural/peri-urban settlements	Residential and agricultural zones near forested or unmanaged vegetation areas	Wildfire risk zones categorized by FWI thresholds and exposure proximity
Number of high-FWI days (e.g., FWI > 30) across climate scenarios (RCP2.6, 4.5, 8.5)	Elderly or low-income populations with reduced evacuation or response capacity	Forest-adjacent communities (e.g., Basarbovo, Obraztsov Chiflik)	High-risk settlement buffers where wildfire hazard intersects with vulnerable populations
Seasonal fire danger trends (spring to autumn fire season length)	Municipal gaps in early warning systems, fuel management, and emergency response coordination	Cultural and natural heritage sites located in or near flammable vegetation	Spatial prioritization of prevention zones (fuel breaks, outreach areas, and critical infrastructure at risk)
Vegetation and land cover data (ESA-CCI, CORINE) indicating burnable biomass distribution	Absence of local fire risk awareness, drills, or communication strategies	Critical infrastructure (electricity lines, roads, water systems) traversing high-biomass fire-prone zones	Fire vulnerability overlay identifying infrastructure in high ignition/spread potential zones
Topography, wind exposure, and slope data affecting fire spread dynamics	Lack of firebreaks, unmanaged land, and forest degradation increasing ignition potential	Recreational zones and tourism facilities in nature parks or dry forest edge zones	Composite wildfire risk maps combining FWI, fuel load, and exposure for land-use and emergency planning

Hazard data	Vulnerability data	Exposure data	Risk output
Climate projections for temperature, precipitation, and drought indices (supporting seasonal fire risk rise)	Limited firefighting access in remote or rugged terrain	Transportation corridors and evacuation routes intersecting fire-prone areas	Risk classification matrix supporting planning of evacuation routes, response zones, and long-term mitigation infrastructure

2.3.3.1 Hazard assessment

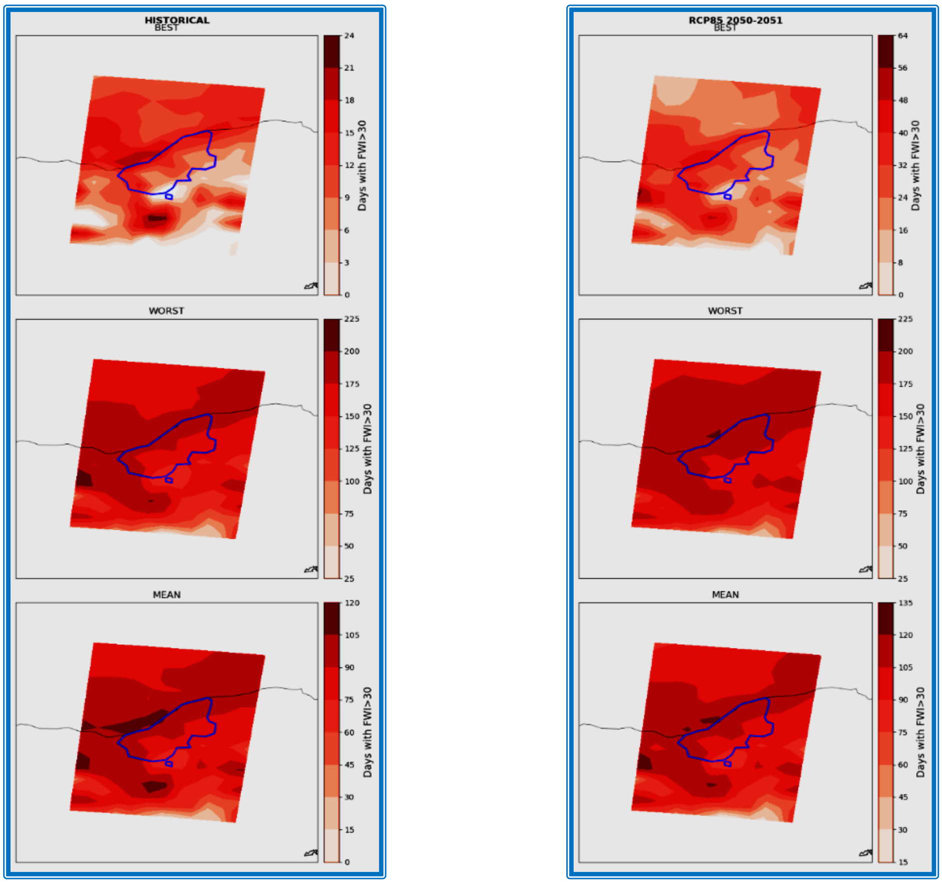

Figure 2-15 - Days with FWI >30

The approach incorporates scenario-based hazard assessment using climate projections and geospatial tools to evaluate current and future fire danger trends. The assessment strictly follows the workflow guidelines outlined in the CLIMAAX Handbook, using FWI as the core hazard indicator. The methodology leverages climate data from the Copernicus Climate Data Store, ensuring compliance with EU data standards and supporting long-term risk planning. The structure of the analysis allows direct integration with other CRA components, including socio-economic overlays and cross-sectoral impacts.

A range of high-emission scenario projections was used to simulate the evolution of wildfire hazard under stress-testing conditions, suitable for resilience planning through 2050 and beyond. These scenarios allow for comparative analysis between historical fire seasons and projected future periods under different levels of climate forcing. Though labeled as “best,” “mean,” and “worst” cases, the scenarios are implicitly drawn from ensemble climate models and reflect distinct trajectories of emissions, adaptation, and exposure.

Despite limitations in HTML rendering, the maps clearly distinguish high-risk fire zones using indexed color schemes and overlaid administrative boundaries. The results reveal distinct clusters of elevated FWI values, particularly in areas characterized by forest vegetation, low agricultural activity, and proximity to riparian corridors—such as those near the Rusenski Lom Nature Park.

Temporal trends are also well captured. The assessment tracks changes in the number of days with FWI above 30, a common threshold for high fire danger. These values are compared across historical and future periods, revealing a clear upward trajectory in fire-prone conditions, both in terms of duration and spatial coverage.

In the best-case scenario (suggesting moderate adaptation within a high-emission world), the number of high-FWI days nearly doubles in several parts of the region. These areas are typically forested zones with biomass buildup and limited active land management, increasing their vulnerability to ignition and fire spread.

In the worst-case scenario, while the total count of high-FWI days remains stable, the geographic extent of high-risk zones increases considerably. This spatial expansion poses serious challenges to ecosystem resilience, biodiversity conservation, and fire response logistics in rural and peri-urban landscapes.

The mean scenario also demonstrates a consistent rise in high-FWI frequency, especially in topographically complex zones or locations with historically poor fire response access. These results indicate a widening of the fire hazard footprint across the municipality, necessitating a recalibration of emergency response and land-use policy.

However, additional interpretation of results would improve impact communication. Currently, the figures identify fire danger levels, but narrative analysis of exposure and socio-ecological vulnerability—such as fuel types, population density, or land accessibility—is limited. Expanding this interpretation would clarify how biophysical hazard overlaps with settlements, infrastructure, and environmental assets.

The assessment would benefit from:

- explicit scenario labeling, referencing the emission pathways (e.g., RCP8.5, SSP3) and assumptions used.
- Socio-economic overlays, to move from hazard mapping to full risk analysis by integrating exposure layers such as population density, infrastructure proximity, and land use.
- Uncertainty and limitations section, addressing model resolution, data assumptions, and the exclusion of human ignition factors (e.g., tourism, agriculture, arson), which are essential in fire-prone zones.

This wildfire risk assessment provides strong evidence of intensifying fire hazard conditions in Ruse Municipality, particularly in forested, low-density, and interface areas. The increasing duration and extent of high-FWI days across all modeled scenarios indicate that wildfire risk—historically viewed as secondary in the region—is becoming a primary concern for land-use planning and emergency preparedness.

The findings support the urgent need for:

- Early-warning systems and remote fire monitoring
- Landscape-scale fuel management and firebreak planning
- Integration of fire risk into spatial development frameworks
- Public education campaigns and civil protection readiness

By embedding these insights into local adaptation strategies and CRA reporting, Ruse Municipality can more effectively address the escalating challenge of wildfire risk in a changing climate.

2.3.3.2. Risk assessment

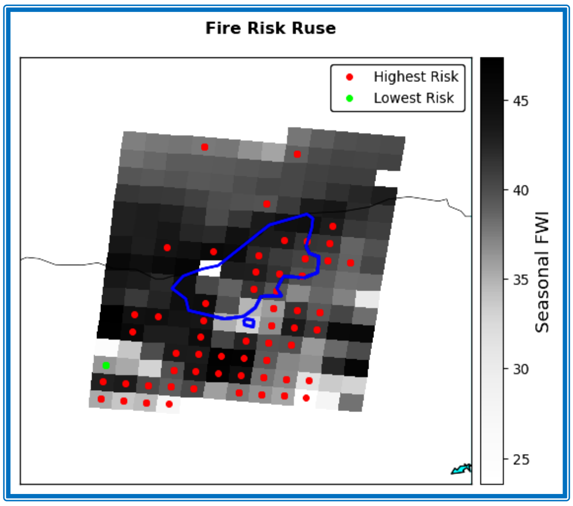

Figure 2-16 - Fire risk Ruse

The wildfire risk assessment conducted for Ruse Municipality provides a clear framework for evaluating fire risk as a function of both biophysical hazard (Fire Weather Index, burnable area) and socio-environmental vulnerability, offering a scalable model for local adaptation and risk reduction planning.

The workflow distinguishes between fire danger—captured through daily FWI values and the extent of burnable vegetation—and vulnerability, which integrates human, economic, and ecological sensitivities. This separation enables the construction of a composite wildfire risk index, allowing for targeted interventions based on different risk dimensions. Such structuring reflects European good practice for climate risk assessments and supports future integration into national and EU reporting mechanisms.

Another valuable feature of the workflow is its customizability and transparency. The ability to set user-defined FWI thresholds ensures local relevance, as fire danger in Ruse's mixed landscape of forests, agricultural lands, and peri-urban zones may differ from that in Mediterranean or mountainous contexts. The use of Pareto analysis to combine vulnerability indicators adds methodological sophistication, enabling multi-criteria weighting without losing transparency or replicability.

The assessment also demonstrates strong data management and preprocessing. Climate raster inputs (FWI from Copernicus), land cover data (ESA-CCI), and burnable area classifications (EFFIS) are correctly reprojected and spatially aligned, addressing one of the most common weaknesses in regional CRAs. Spatial harmonization allows accurate overlay analysis and increases confidence in the final outputs. The code structure is modular and clean, with well-defined functions (e.g., cut_to_region, extract_EFFIS) and informative logging. These technical choices improve reproducibility and reduce user error, which is crucial when transferring the tool to other municipalities.

While the technical foundation is robust the discussion around vulnerability dimensions could be expanded. Although the indicators are referenced conceptually (e.g., human, economic, environmental), they are not fully operationalized. Including concrete examples—such as population density layers, proximity to critical infrastructure, and the distribution of ecosystem services—would not only improve analytical depth but also enable better targeting of fire resilience interventions.

Another limitation is the lack of multi-scenario analysis. While RCP2.6 is referenced, the implications of other climate scenarios (e.g., RCP4.5, RCP8.5) are not explored. This omission reduces the assessment's usefulness for long-term adaptation planning. Integrating scenario-based projections of fire weather trends would allow users to evaluate fire risk trajectories under various emission pathways, helping to define thresholds for adaptive action.

Additionally, uncertainty quantification and sensitivity testing are not currently included. This is a technically complex but essential next step, especially for decision-support tools aimed at resource allocation or risk communication. For example, how sensitive is the final risk index to changes in FWI thresholds, or to land cover shifts due to deforestation or afforestation? Even a qualitative discussion of these uncertainties would improve model transparency and align the tool with CLIMAAX's emphasis on adaptive, evidence-based decision-making.

Despite these limitations, the analysis reveals valuable insights into spatial patterns of wildfire risk within Ruse Municipality. The output visualizations, though basic, show clusters of high-risk areas—marked by red indicators—corresponding to zones that combine elevated fire weather potential with ecological and socio-economic vulnerabilities.

A particularly noteworthy finding is the observation that areas located farther from water bodies tend to have a higher fire risk profile, even in instances where FWI values are not at their peak. This highlights that wildfire risk is not driven solely by meteorological conditions (temperature, humidity, wind), but also by land-use patterns, vegetation characteristics, and human influences—including abandoned agricultural land, lack of fuel management, and insufficient firebreak infrastructure.

These findings suggest that biophysical fire danger must be contextualized with anthropogenic factors to fully understand and mitigate wildfire risk. Rural-urban interface (WUI) zones and forest-edge communities lacking formal fire preparedness or response systems are especially vulnerable and should be prioritized in future planning.

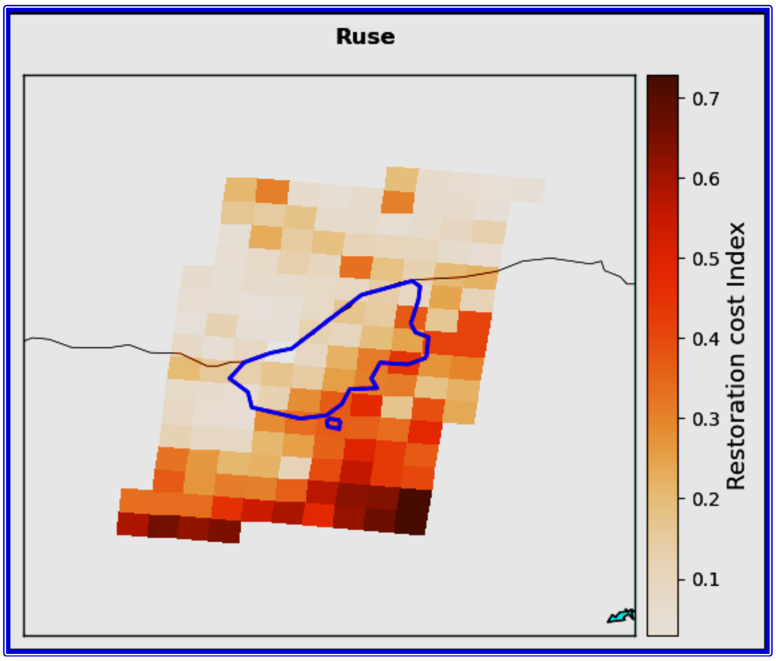

Figure 2-17 - Restoration cost index

The map, showed on Figure 2-17, illustrates the Restoration Cost Index for Ruse Municipality and surrounding areas in the context of wildfire risk. The index represents the estimated difficulty and cost of ecological and infrastructural restoration following wildfire events, based on land cover, topography, and vegetation type. Darker areas indicate zones where post-fire restoration is expected to be more complex and resource-intensive, particularly in the southern and southeastern parts of the region. The blue outline marks the administrative boundary of Ruse Municipality. This spatial insight supports prioritization of wildfire mitigation, emergency planning, and post-event recovery strategies.

Conclusion

The wildfire risk assessment for Ruse Municipality represents a technically robust and adaptable model for local-level climate risk analysis. By combining climate hazard indicators with spatially resolved vulnerability layers, the assessment supports integrated fire management and adaptation strategies.

Ultimately, this assessment highlights the growing importance of wildfire resilience in Ruse Municipality, particularly as climate change drives longer fire seasons and expands the geographic footprint of fire-prone areas. Integrating these insights into land-use planning, emergency services, and ecological management will be essential to protecting both people and landscapes in the decades ahead.

2.4 Preliminary Key Risk Assessment Findings

2.4.1 Severity

The climate risk assessment for Ruse Municipality identifies three interlinked and priority hazards: river flooding, heavy rainfall and pluvial flooding, and wildfires, particularly in peri-urban and natural zones. Each hazard was analyzed using CLIMAAX workflows, incorporating historical data, spatial hazard modeling, and socio-economic exposure layers to evaluate current and future risk.

River floods present a differentiated profile. While the Danube poses a moderate localized risk due to Ruse's higher elevation compared to the opposite Romanian bank, the Rusenski Lom River carries a much higher flood threat. Its meandering course intersects vulnerable settlements and infrastructure, and flood modeling under 1-in-100 and 1-in-250-year return periods highlights high-exposure zones, especially in peri-urban and low-lying areas.

Heavy rainfall emerges as a high-severity hazard, with a notable increase in Annual Maximum Daily Precipitation (AMDP) under all projected scenarios (RCP2.6, 4.5, and 8.5). Values exceeding 70–90 mm/day in future periods indicate rising risks of flash flooding and stormwater system overload, particularly in areas with dense urbanization and outdated drainage networks.

Wildfire risk is also rising, with a projected increase in days with FWI > 30, especially under high-emission scenarios. Risk hotspots include peri-urban zones such as Basarbovo and Obraztsov Chiflik, where unmanaged vegetation, limited firefighting access, and increased human activity converge.

The major risks identified include: (1) flash floods and infrastructure disruption due to intense rainfall; (2) structural and socio-economic damage from Rusenski Lom overflows; and (3) wildfires threatening rural settlements and forested zones. In terms of severity: river floods pose moderate to high localized risk, heavy rainfall is of high severity and increasing unpredictability, while wildfires present a moderate but intensifying threat with seasonal escalation.

2.4.2 Urgency

The timing and urgency of the major climate risks in Ruse Municipality vary by hazard type but collectively demand immediate and coordinated action. River floods occur primarily in spring and early summer, driven by snowmelt and convective storms. While the hazard follows a predictable seasonal pattern, its urgency is medium-term; however, proactive planning measures such as land-use regulation and zoning reforms—particularly along the Rusenski Lom—should begin without delay to mitigate escalating exposure.

In contrast, heavy rainfall represents a sudden-onset hazard with year-round potential, peaking during summer months. The rising trend in Annual Maximum Daily Precipitation (AMDP) and the municipality's limited drainage capacity elevate the urgency to high and immediate. Real-time early warning systems, stormwater infrastructure upgrades, and public risk communication are essential short-term priorities.

Wildfires, while linked to slow-onset climatic trends such as drought and heatwaves, can erupt rapidly and with high intensity. The urgency here is medium, with the most critical window spanning spring through autumn. Preparedness efforts—particularly fuel load management, monitoring systems, and awareness campaigns—must be in place ahead of the peak fire season.

Overall, the onset typology ranges from slow and seasonal (river floods), to sudden and high-impact (pluvial floods and wildfires), reinforcing the need for both immediate response capabilities and long-term structural adaptation.

2.4.3 Capacity

Existing climate risk management in Ruse Municipality is marked by limited resources and fragmented implementation across sectors. Financially, there is no dedicated municipal budget for climate adaptation, with reliance on EU co-funding mechanisms such as Interreg, LIFE, and the Green Deal. This dependence, combined with constrained local budgets, restricts large-scale investments in protective infrastructure. Social awareness of climate risks remains low, and while basic emergency protocols are in place, broader community engagement in adaptation planning is minimal.

On the human resource side, municipal and civil protection staff possess general technical expertise, but there are notable capacity gaps in climate modeling, data interpretation, and geospatial risk analysis. Physical infrastructure includes partial flood defenses along the Danube and segments of the Rusenski Lom, but stormwater systems are outdated, and fire prevention infrastructure is sparse, particularly in peri-urban areas. Natural infrastructure, such as Rusenski Lom Nature Park, offers limited buffering capacity but is degraded by land-use pressures and lacks integration into hazard mitigation efforts.

Despite these constraints, several opportunities emerge. The CRA process strengthens eligibility for EU funds aimed at resilience and green infrastructure. Improved risk communication and participatory planning can build public trust and empower vulnerable populations. Capacity-building through the CLIMAAX Toolbox can foster institutional knowledge. Upgrading urban systems with nature-based solutions will improve both resilience and public health, while aligning climate adaptation with biodiversity goals enhances long-term ecosystem and economic sustainability.

2.5 Preliminary Monitoring and Evaluation

The first phase clarified key climate risks—river flooding, heavy rainfall, and wildfires—and highlighted vulnerable zones and infrastructure gaps. Main challenges involved limited high-resolution data, outdated infrastructure maps, and capacity gaps in multi-hazard modeling. While some new data was integrated, further resources, localized projections, and technical training are needed to deepen understanding and improve risk-informed planning.

In the next phase of the project, in parallel with collecting and supplementing the input information with higher resolution data, it is planned to develop a second set of workflows for the climate risk specific to the municipality of Ruse - heat waves, droughts and snow. This will ensure the generation of a full set of accurately highlighted workflows for the municipality climate risks.

Further wide dissemination of the climate questionnaire (Supporting document No 5.3.4.1/ 5.3.4.2) developed at this stage among stakeholders is also foreseen. The questionnaire aims to gather information on the climate attitudes of different stakeholder groups - business, different vulnerable groups of population, civil society organizations, public authorities - each with different contributions to the climate issue. In addition, the survey will contribute to broadening the respondents' knowledge and understanding of climate change.

There are several meteorological stations within the scope of the National Meteorological Network available on the territory of the Ruse municipality. They provide long-term observational data, including the oldest meteorological station in Bulgaria, which started its work in 1866. Some of the stations are located in various highly urbanized parts of the city. There is excellent potential for further creation of a first-class base of ground-observational climate data for the Ruse municipality. However, despite its public ownership, these data are located in the archives of the National Institute of Hydrology and Meteorology, and this poses the challenge for the CLIMAAX team of the Ruse municipality to have unhindered and free access to these data.

To achieve high local specificity in the assessment of climate risk in the Ruse Municipality, it is necessary to further collect high-resolution data on the parameters of the economic sectors presented here. These parameters concern the territorial scope of the sectors, their production and manufacturing infrastructure, their personnel, their management, and the ability to cope with climate challenges. In this regard, in many cases it may be necessary to collect data directly from the enterprises themselves. This would complicate and prolong the collection process, but at the same time it would provide the most comprehensive and objective information possible, which probably cannot be found in national and regional databases.

The demographic module is very important for determining climate risk in the municipality. It is necessary to accurately identify all climatically-vulnerable groups in Ruse - adolescents and adults, the chronically ill, the socially poor, the disabled, addicts, etc. The problem is that for some of the marginalised groups it is difficult to find objective data on their numbers and whereabouts. Highlighting this issue can be a serious challenge for the project team.

A large part of the territory of the Ruse municipality is covered by Natura 2000 (Supporting document No 5.2.4.6). The municipality includes 5 protected areas and 1 protected territory. They are habitats of numerous and extremely valuable plant and animal species. The project team should approach this with caution and provide highly specialized databases on the specific climate sensitivity of the many different species. For this purpose, it is advisable to seek the cooperation and assistance of some of the non-governmental organizations in the municipality and the region.

The work on the first phase of the CLIMAAX project has enriched the existing knowledge with valuable details and specifics on the methodology for climate risk assessment in relation to the different climate hazards occurring in European region. It became clear that the rich knowledge resource in continental resolution are a solid basis for further downscaling to the level of local climates. High-resolution local data can be successfully used for this purpose, but for a certain part of them access is hampered by some local institutions, and for another part data are highly specialized, and/or fragmented, insufficiently reliable, or completely missing.

3 Conclusions Phase 1- Climate risk assessment

The completion of the first phase of the Climate Risk Assessment (CRA) for Ruse Municipality represents a significant milestone in the region's journey toward climate resilience. Through the structured application of the CLIMAAX methodology, this phase has provided a critical baseline understanding of the key climate-related hazards facing the municipality, the areas and sectors most at risk, and the institutional capacities available to address these challenges. The findings underscore the importance of shifting from a reactive to a proactive approach in managing climate risks, particularly in light of the increasing frequency, severity, and complexity of the threats identified.

Ruse Municipality, due to its geographical location, socio-economic profile, and infrastructural composition, faces a diverse set of climate hazards. The most prominent among these are fluvial flooding, particularly from the Rusenski Lom River; pluvial flooding due to extreme rainfall events; and wildfires in peri-urban and rural areas. Each of these hazards presents a unique risk profile, but they also interact in complex and sometimes compounding ways. The assessment has shown that traditional hazard management strategies—focused on isolated events or single-sector vulnerabilities—are no longer sufficient in the face of dynamic and interconnected climate risks. Instead, a systemic, integrated, and forward-looking approach to adaptation planning is required.

One of the most important outcomes of this phase is the identification of areas of high exposure and vulnerability. These include densely populated urban neighborhoods with inadequate stormwater infrastructure, floodplain settlements along the Rusenski Lom, and peri-urban zones with accumulated biomass and unmanaged vegetation. Vulnerable populations, such as the elderly, low-income households, and residents in informal housing, are particularly exposed. The assessment has demonstrated that without significant adaptation measures, these communities will continue to bear the brunt of climate-related impacts—ranging from property damage and service disruptions to health risks and economic losses.

Equally critical is the recognition of institutional limitations and opportunities. The CRA process has highlighted that while Ruse possesses some elements of a risk management framework—such as basic emergency response systems and a foundation of technical expertise—there are substantial gaps in long-term strategic planning, inter-institutional coordination, and climate-specific capacity building. The lack of a dedicated municipal budget for climate adaptation, limited integration of risk data into spatial planning, and underutilization of natural infrastructure further constrain resilience efforts. Nevertheless, the municipality's participation in the CLIMAAX project opens important avenues for progress. Through this framework, Ruse now has access to harmonized methodologies, decision-support tools, training resources, and potential EU-level funding that can significantly enhance its adaptive capacity.

The data-driven and participatory nature of the assessment is also a noteworthy achievement. The integration of local knowledge, stakeholder input, and scientific modeling has not only improved the quality and relevance of the results but has also strengthened stakeholder engagement and cross-sectoral collaboration. This is essential for building social capital and public trust, both of which are critical ingredients for successful adaptation.

Looking forward, the conclusion of Phase 1 serves as both an analytical and strategic foundation for the subsequent phases of the CLIMAAX process. The risk assessment findings will inform the design of targeted adaptation measures, the development of a robust monitoring and evaluation framework, and the institutionalization of climate risk considerations in municipal governance. The insights generated will be directly applicable to the revision of urban development plans, zoning ordinances, emergency preparedness protocols, and investment strategies in critical infrastructure and ecosystem services.

The municipality's ability to reduce its climate risk will depend on several key actions in the near term. These include enhancing the technical capacity of municipal staff, establishing a sustainable funding mechanism for adaptation, improving access to high-resolution climate and vulnerability data, and fostering a culture of risk-informed decision-making across all levels of local governance. Furthermore, the development of multi-hazard early warning systems, the mainstreaming of nature-based solutions, and the strengthening of partnerships with regional and national institutions will be essential components of a successful adaptation pathway.

In summary, Phase 1 of the Climate Risk Assessment for Ruse Municipality provides compelling evidence of the urgent need for climate action and the value of structured, participatory, and evidence-based planning processes. It affirms that while the challenges are considerable, the municipality has the opportunity—and now the analytical foundation—to build a resilient future. Through continued engagement in the CLIMAAX process and the strategic implementation of the recommendations arising from this assessment, Ruse can become a leading example of municipal climate resilience in Bulgaria and the broader Danube region.

4 Progress evaluation and contribution to future phases

This deliverable represents a critical foundation for the broader climate risk assessment (CRA) and resilience planning process in Ruse Municipality under the CLIMAAX framework. Developed through an iterative and evidence-based approach, it synthesizes the outcomes of Phase 1 activities and translates them into actionable knowledge that directly shapes the scope, methodology, and focus of the project's next phases. The integration of multiple hazard types—river floods, heavy rainfall, and wildfires—within a structured, multi-hazard risk framework has enabled a baseline understanding of both the biophysical threats and the socio-economic vulnerabilities that define the region's climate risk landscape.

The deliverable demonstrates the systematic application of the CLIMAAX workflows and tools to the local context of Ruse. By incorporating high-resolution hazard modeling, climate scenario analysis (RCP2.6, RCP4.5, RCP8.5), and exposure-vulnerability mapping, the outputs establish a data-informed narrative of risk evolution through to 2050 and beyond. Each of the assessed hazards was evaluated in terms of its frequency, severity, spatial extent, and interaction with critical systems—namely infrastructure, population centers, natural assets, and land-use configurations. These findings do not stand in isolation but rather form the analytical core upon which the design and implementation of targeted resilience measures in subsequent phases will be based.

From a process standpoint, the first-phase deliverable serves multiple strategic functions. It validates the selection of priority hazards and justifies the chosen methodological pathways, ensuring that the CRA aligns with both CLIMAAX standards and EU-level adaptation goals. It also operationalizes the concept of risk through the identification of hotspot zones, vulnerable populations, and system-level weaknesses, providing a geographic and functional template for pilot interventions, cost-benefit assessments, and scenario testing in future workstreams. The inclusion of hazard-specific metrics, such as Annual Maximum Daily Precipitation (AMDP) for pluvial flooding, Fire Weather Index (FWI) for wildfire potential, and return period flood modeling for fluvial risks, provides quantitative anchors that can be expanded in technical depth in the project's modeling and planning components moving forward.

Importantly, the deliverable also identifies the institutional, technical, and resource-related barriers that need to be addressed in the next phases. These include limitations in data granularity, lack of integrated modeling capacities, low community awareness, and the absence of dedicated financial instruments for climate adaptation at the municipal level. A key contribution of this first-phase work is the articulation of these constraints not as standalone challenges but as entry points for capacity-building, stakeholder engagement, and cross-sectoral policy alignment. These insights will guide the design of practical training modules, knowledge exchange activities, and participatory planning sessions in Phases 2 and 3.

The transition from hazard assessment to actionable planning requires a shift from analytical insight to strategic prioritization. In this regard, the current deliverable enables that shift by producing clear, spatially explicit, and thematically disaggregated risk profiles that can now be used to identify priority actions. For example, the identification of flood-prone zones along the Rusenski Lom River with overlapping infrastructure exposure can be used to inform flood protection retrofits, green infrastructure integration, or even managed retreat policies. Similarly, the wildfire risk clusters in peri-urban forest interfaces support the future deployment of fuel management programs, firebreak installations, and early-warning systems. In the context of heavy rainfall, the identified weaknesses in stormwater infrastructure directly inform the planning of nature-based solutions, such as permeable pavements or rain gardens, to reduce surface runoff and urban flooding risks.

The outputs also contribute to regional and national policy alignment. The risk maps, scenario analyses, and vulnerability assessments developed in Phase 1 are directly compatible with Bulgaria's National Climate Adaptation Strategy and the EU Mission on Climate Adaptation. These materials will support Ruse Municipality's ability to contribute to national reporting obligations, access targeted EU funds (e.g., Horizon Europe, Just Transition Mechanism), and design monitoring frameworks aligned with the EU Green Deal objectives. Furthermore, they lay the groundwork for integrating climate resilience into the Municipal Development Plan and associated sectoral strategies related to transport, health, water, energy, and biodiversity.

In terms of continuity and workflow integration, the deliverable also helps define the functional design of tools and models to be applied in later phases. The Python-based notebooks developed in this phase—focused on flood hazard modeling, AMDP trend analysis, and wildfire risk mapping—can now be expanded to include socio-economic scenario layering (e.g., SSPs), cost-efficiency modeling for interventions, and impact assessments of policy measures under different governance conditions. The modularity of these tools allows for scalability across administrative levels and thematic domains, enhancing their utility in Phase 2's scenario simulation and in Phase 3's policy co-design efforts.

Stakeholder engagement, though preliminary in Phase 1, is also guided by this deliverable. The identification of high-exposure communities, infrastructure clusters, and environmental hotspots provides a geographic and thematic basis for targeted stakeholder consultations. The next phases will build on this by facilitating participatory risk prioritization workshops, co-development of adaptation pathways, and institutional dialogue between municipal, regional, and national actors. The data and narratives developed in Phase 1 will serve as the common language through which stakeholders can interact, negotiate trade-offs, and explore adaptation synergies.

In conclusion, this deliverable is not merely a summary of findings but a strategic bridge that connects analytical rigor with implementation relevance. It establishes a shared evidence base, confirms the validity of the chosen hazard focus, reveals system-level vulnerabilities, and highlights the institutional readiness and capacity gaps to be addressed in the coming phases. By translating complex climate data into actionable insights and spatialized risk narratives, the deliverable paves the way for Ruse Municipality to transition from risk identification to resilient transformation—anchored in science, guided by local priorities, and aligned with European resilience objectives.

Table 4-1 - Overview key performance indicators

Key performance indicators	***Progress***
1 climate multirisk assessment report published	Planned by the end of month 21
1 multi-risk climate assessment report	Deliverable 1 - Completed and submitted
50 000 residents, key local and regional authorities and stakeholders reached through awareness campaigns	In progress – initial media outreach and survey distribution started
1 awareness-raising campaign conducted	In planning
2 local workshops, one final conference and meetings conducted for decision-makers and stakeholders	Workshop 1 - conducted; Kick off meeting with stakeholders - conducted; Workshop 2 and final conference - scheduled
2 international workshops for sharing of experience and best practices	Barcelona – planned; Brussels – to be attended
Municipal strategic documents regarding risk reduction, disaster and accidents management being revised	Planned by the end of month 21

Table 4-2 - Overview millstones

Milestones	***Progress***
M1: Completion of Framework review and recommendations (Activity 1.1)	Completed
M2: Successful Kick-off meeting and press conference (Activities 1.2 & 1.3)	Completed
M3: Workshop on CLIMAAX framework application (Activity 1.4)	Completed
M4: Completion of CLIMAAX framework application report (Activity 1.5)	Completed
M5: Completion of Data Collection and Research for Multi-Risk Assessment (Activity 2.1 & 2.2)	In progress
M6: Stakeholder workshop on multi-risk assessment (Activity 2.3)	Planned by the end of month 15
M7: Attend the CLIMAAX workshop held in Barcelona	Scheduled
M8: Submission of Multi-Risk Assessment Report (Activity 2.4)	Planned by the end of month 16
M9: Review and analysis of municipal strategic documents on climate risk, environmental and disaster management (Activity 3.1)	Upcoming
M10: Draft amendments to strategic documents regarding risk reduction, disaster and accidents management (Activity 3.2)	Upcoming
M11: Attend the CLIMAAX workshop held in Brussels	Upcoming
M12: Final Conference and Presentation of Project Results (Activity 3.3)	Scheduled for July 2026

5 Supporting documentation

5.1. Main Report: Phase 1-Climate risk assessment

(Deliverable Phase 1 - Ruse Municipality - v.final 2 .pdf)

5.2. Visual Outputs (infographics, maps, charts) and Datasets collected (Excel or CSV)

5.2.1. River Floods workflow
- 5.2.1.1. River floods hazard assessment (.zip) – including .ipynb file, infographics, maps, charts and CSV files, extracted by Jupyter lab
- 5.2.1.2. River floods risk assessment (.zip) – including .ipynb file, infographics, maps, charts and CSV files, extracted by Jupyter lab

5.2.2. Heavy rainfall workflow – including .ipynb file, infographics, maps, charts and CSV files, additional data, extracted by Jupyter lab

5.2.3. Wildfire workflow
- 5.2.3.1. Wildfire hazard assessment (.zip) – including .ipynb file, infographics, maps, charts and CSV files, extracted by Jupyter lab;
- 5.2.3.2. Wildfire risk assessment (.zip) – including .ipynb file, infographics, maps, charts and CSV files, extracted by Jupyter lab

5.2.4. Files (html) for fast file access

5.2.5. Other climatic extremes
- 5.2.5.1. Map of floodplains during fluvial floods in Bulgaria
- 5.2.5.2. Map of mean annual number of days with extreme precipitation in Bulgaria
- 5.2.5.3. Map of Agricultural lands affected by drought in Bulgaria
- 5.2.5.4. Map of hot days in Bulgaria
- 5.2.5.5. Map of the average number of deaths caused by extreme heat in Bulgaria
- 5.2.5.6. Map of Natura 2000 coverage on the territory of Ruse municipality

5.3. Communication Outputs (Press release, media)

5.3.1. Kick-off meeting
- 5.3.1.1. Presentation-kick off meeting
- 5.3.1.2. Screenshot-kick-off meeting

5.3.2. Media press conference
- 5.3.2.1. Presentation-media press conference
- 5.3.2.2. Screenshot- press conference
- 5.3.2.3. List of links to media publications

5.3.3. Workshop
- 5.3.3.1. Presentation-workshop
- 5.3.3.2. Screenshot-workshop

5.3.4. Questionnaire
- 5.3.4.1. Questionnaire form in Bulgarian (sample)
- 5.3.4.2. Questionnaire form in English (sample)

5.3.5. Photos

5.4. Analysis report of the legal, financial and administrative framework at national and local level in relation to climate change adaptation

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