Deliverable Phase 1 – Climate risk assessment

Climate Risk Assessment for Resilient Svoge (CRARS)

Bulgaria, Svoge Municipality

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

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Document Information

Deliverable Title	Phase 1 – Climate risk assessment
Brief Description	This document constitutes a climate multi-risk assessment produced by the Municipality of Svoge by utilizing the CLIMAAX common methodological framework, whereby two workflows have been successfully applied for the municipality and the results have been analyzed to obtain more clarity of the climate risks' urgency and climate-dependent varying impact, including in light of the municipal capabilities so as to lay the foundation for policy and strategic planning for adaptation measures.
Project name	Climate Risk Assessment for Resilient Svoge (CRARS)
Country	Bulgaria
Region/Municipality	Svoge Municipality
Leading Institution	Svoge Municipality
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2.0	…	CLIMAAX's FSTP team	Review completed
5.0	…		Final version to be submitted

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Abbreviations and acronyms

Abbreviation / acronym	Description
AR6	Assessment Report 6 from the IPCC
BAS	Bulgaria Academy of Science
CDS	Copernicus Climate Data Store
CMMT	Core Municipal Management Team
CoP	Community of Practice
CRA	Climate Risk Assessment
CRARS	Climate Risk Assessment for Resilient Svoge
CRM	Climate Risk Management
DRMKC	Disaster Risk Management Knowledge Center
EEA	European Environmental Agency
EFFIS	European Forest Fire Information System
FWI	Fire Weather Index
IFP	Individual Follow-up Plan
IPCC	Intergovernmental Panel on Climate Change
NSI	National Statistical institute
NIMH	National Institute for Meteorology and Hydrology
NUTS	Nomenclature of Territorial Units for Statistics
RCP	Representative Concentration Pathways

Executive summary

The report "Deliverable Phase 1 – Climate risk assessment" (CRA) for the project "Climate Risk Assessment for Resilient Svoge (CRARS)" describes how the CLIMAAX climate risk assessment framework and toolbox have been successfully applied by the municipality of Svoge for two risk assessment workflows using European data – i.e. river floods and wildfire. The report is designed with the purpose to equip the municipality with initial insights into the two risks while at the same time to provide the foundation for refinement of the assessments by the incorporation of local data during the second phase of the CRARS project.

The report elaborates on the scoping for the CRA, as it delineates its objectives, context, participation, and risk ownership. The objectives of the CRA are to lay the science-based foundation for policy-making and strategic planning in Svoge municipality for the purposes of increasing climate resilience through well targeted climate change adaptation measures and management of the analyzed risks. The municipality is the main risk owner. Simultaneously, it does not have the resources to manage the risks and mitigate their impacts. Hence, the CRA is particularly significant to navigate the municipality in utilizing the available and potentially attracted resources in the most efficient and meaningful way.

The core part of the CRA is the analysis of the risks. Svoge has selected two risks on the basis of their perceived level of severity and urgency as defined by observational municipal knowledge but also confirmed by stakeholders. The selection of the workflows was guided by the need to find the tools of most utility for the municipality in respect to river floods and wildfire. The plotted results from the risk assessments indicate an increased level of severity for both risks. The river floods risk assessment indicated the damage hotspots that coincided with the areas with higher levels of inundation depth and clearly points to an inundation depth increase under the current climate, RCP4.5, and RCP8.5. The workflow made it possible for the municipality to see the link between hotspots of damages and land use type, which is important for the calculation of damages and for policy formulation and decision-making, especially for the special targeting and prioritization of adaptation, prevention, and response measures. The wildfire risk assessment workflow results show the special distribution of the wildfire danger and the related vulnerabilities in terms of protected territories, biodiversity irreplaceability, recovery cost, and population in WU interface. The increase in the severity of this risk includes both an increase in the length of the fire weather season and in the territory which falls under the heightened risk over time for both historical and RCP8.5 scenarios (under the mean model). The results show where the municipality is to focus its efforts and how it is to organize these in time so as to reach the maximum impact in prevention and adaptation.

The report also includes initial insights into monitoring and evaluation, along with an assessment of the project implementation progress. The municipality has found Phase 1 of the project to be highly valuable. Its results will constitute the basis for Phase 2 of the CRARS project by supporting dissemination efforts, further stakeholder engagement, and most importantly as the basis for local-data-based refinement of the CRA. Additionally, the implementation of workflows has provided a capacity-building opportunity for the municipality—one that is expected to deliver long-term benefits beyond the project's duration.

1 Introduction

1.1 Background

Svoge Municipality is located in the Southwestern Planning Region (NUTS2). It encompasses 38 urbanised areas with a total population of 18982 residents. The relief is mainly mountainous, with an average altitude of 851 and 900m, with most settlements located along river valleys. Svoge Municipality is a low capacity and administratively small municipality that is responsible for the third largest area of forests in the country. It has a total area of 868.61sq. km., which places it among the territorially large Bulgarian municipalities.

According to data from the State Forestry "Svoge", 60.9% of the municipal territory is occupied by forest areas. These areas are particularly prone to wildfires. In addition to economic sectors affected by the risk of wildfires, such as tourism and lumber production, these pose tremendous risk on the nature conservation as around half of the territory of the municipality consists of protected areas.

The municipality is rich in rivers and challenged by periodic river floods, including from the 3rd longest river in Bulgaria that runs through its entire territory. The municipality of Svoge has a temperate continental climate up to the altitude zones of 1500m., and above this altitude the climate acquires a mountainous character with increased annual precipitation and decreased average annual temperatures. The maximum precipitation happens in spring, and the minimum - in winter, with total annual precipitation of 700mm. Faced with the complexity of climate risks, Svoge is committed to a comprehensive climate adaptation approach. The municipality is a member of the EU Mission: Adaptation to Climate Change and has developed a municipal climate adaptation strategy as a starting point on it journey to climate resilience.

1.2 Main objectives of the project

The CRARS project aims to enable the municipality to develop a climate multi-risk assessment that will enable it to operationalise data for policy-making and for designing climate adaptation solutions for prevention. In particular, the more specific objectives of the project are the following: to develop a refined climate multi-risk assessment for the Municipality of Svoge; to use the assessment to feed into the municipal Climate Adaptation Strategy, which was completed in November 2024, to operationalize it with evidence-based scenarios and add/amend concrete measures based on the study, thereby improving policy-making and designing concrete climate change adaptation solutions; to improve citizen understanding and support for climate resilience measures; to use the assessment and the strategy to build a stronger case in favour of seeking national and EU funding for concrete adaptation measures; to use the assessment to contribute to regional and national efforts for coordination of prevention and response measures in the Svoge region with an emphasis on effective prevention measures and initiatives.

As one of the only 13 Bulgarian municipalities Charter signatories of the EU Mission Adaptation to Climate Change, the municipality is making efforts to reach progress in building climate resilience. We understand the importance of having a municipal climate adaptation strategy for coordinated, consistent, and coherent municipal efforts. Therefore, we took the decision to develop a municipal climate adaptation strategy with own resources. Such a document, however, would only be complete and offer pragmatic guidance for action when combined with a climate risk assessment. However, we did not have the funding and institutional expert knowledge to conduct such a study and therefore decided to apply for CLIMAAX. The CRA will feed into our Climate Adaptation Strategy, that was completed in November 2024, to operationalize it with evidence-based scenarios and add/amend concrete measures based on the study. The CLIMAAX-funded climate risk assessment for the municipality will allow us to improve policy-making and design concrete climate change adaptation solutions, will increase our own understanding and hence improve our efforts to raise citizen understanding and support for climate resilience measures, will help us build the case in favour of seeking funding for concrete measures. It will also enable us to contribute to regional and national efforts for coordination of prevention and response measures in the Svoge region. It will make it possible for us to develop effective prevention measures and initiatives.

1.3 Project team

The project is being implemented by two closely collaborating teams: the Core Municipal Management Team (CMMT), composed of three municipal employees appointed by the mayor, and a subcontracted team of external experts. These teams maintain continuous communication and operate according to the Work Plan outlined in the IFP. The CMMT is responsible for providing the external experts with relevant information and feedback from the municipal administration, ensuring at the same time that knowledge, know-how, and updates are regularly channeled back to the administration and that the administration fully benefits from the project as a learning opportunity. Additionally, the CMMT oversees the quality and timely delivery of activities and outputs by the subcontracted expert team in line with the Work Plan. The three CMMT members, all from the municipal department of EU projects, also facilitate information exchange and capacity building across various departments and sectoral units in respect to the CLIMAAX project and feeding local expert and observational knowledge into the deliverables. The external experts support the CMMT by executing assigned tasks and deliverables and supplying the expert and technical knowledge essential for the successful implementation of the CRARS project.

1.4 Outline of the document's structure

The core part of this document is the CRA for Svoge Municipality – Phase 1 (Section 2). This section follows the structure of the CLIMAAX framework. It begins with scoping information for the CRA process, covering the objectives, context, participation, and ownership. It then examines the risks by identifying the main hazards to be analyzed and reviewing the relevant data and knowledge. The document continues with an overview of the selected workflows and scenarios, presenting the risk analysis—including data review, hazard and risk assessments for each workflow, and preliminary key findings related to severity, urgency, and capacity. Preliminary reflections on monitoring and evaluation, along with relevant data, as well as an elaboration on the work plan for the remaining project phases are provided at the end of Section 2. Section 3 summarizes the main conclusions and key findings, while Section 4 offers a progress evaluation (including KPIs and milestones) and discusses how the progress achieved will support future phases of the project. Supporting documentation and references are listed at the end of the document in Sections 5 and 6, respectively.

2 Climate risk assessment – phase 1

2.1 Scoping

2.1.1 Objectives

The CRARS project aims to enable the municipality to develop a climate multi-risk assessment that will enable it to operationalise data for policy making and for designing climate adaptation solutions for prevention. The CRA is intended to deepen the municipality's comprehension of two critical and high-priority risks that exert substantial influence on its operations and long-term resilience. Its purpose is twofold: firstly, to elucidate the current landscape of climate-related challenges, thereby laying the groundwork for the strategic formulation of adaptation interventions aimed at mitigating present-day impacts and their associated severity. Secondly, the CRA seeks to project the anticipated evolution of these risks over time, equipping local authorities with the insight required to implement anticipatory, well-coordinated, and timely responses. Fundamentally, the assessment aspires to deliver a rigorous, data-driven analysis underpinned by a transparent and credible methodology, articulated in clear and accessible terms for policy-makers and political stakeholders. In doing so, it will provide a scientifically robust foundation to inform evidence-based policy development, guide the prioritization of technical adaptation strategies, and strengthen municipal capacities in prevention, emergency planning, and disaster response coordination.

The specific project objectives of the project are: develop a refined climate multi-risk assessment for the Municipality of Svoge; use the assessment to feed into the municipal Climate Adaptation Strategy, which was completed in November 2024, to operationalize it with evidence-based scenarios and add/amend concrete measures based on the study, thereby improving policy-making and designing concrete climate change adaptation solutions; improve citizen understanding and support for climate resilience measures; use the assessment and the strategy to build a stronger case in favor of seeking national and EU funding for concrete adaptation measures; use the assessment to contribute to regional and national efforts for coordination of prevention and response measures in the Svoge region with an emphasis on effective prevention measures and initiatives.

The Climate Risk Assessment (CRA) will constitute a critical evidentiary foundation upon which the municipality's strategic planning documents will be anchored. It will substantiate and reinforce the rationale for the adoption of targeted adaptation strategies, thereby promoting a coherent and integrated policy framework aimed at strengthening local climate resilience. Moreover, the CRA will serve as a key advocacy tool, enabling the municipality to advance the case for proactive, preventive measures at both regional and national levels. By articulating the cost-efficiency and environmental benefits of prevention-based approaches, the CRA will also enhance the municipality's ability to secure financial support for adaptation initiatives, positioning prevention not only as a prudent investment but as a sustainable and forward-looking policy choice.

Prior to joining the CLIMAAX project, the Municipality of Svoge faced significant and prohibitive barriers to developing a Climate Risk Assessment (CRA). These included a lack of internal expertise and technical capacity, insufficient funding to engage external specialists, and the absence of a robust, standardized methodology that could ensure both scientific credibility and comparability with assessments conducted across other EU municipalities. Additionally, there was a pressing need for a methodological framework that balanced analytical rigor with policy-oriented applicability.

Participation in the CLIMAAX project has been transformative in this regard. It enabled the municipality to address the skills gap by facilitating access to expert support and, crucially, provided a reliable and methodologically sound framework to guide the assessment process. This methodology has proven especially valuable in resolving a persistent challenge: the effective use of European datasets and their intergration with local information – observational and quantitative. In the past, efforts to select, refine, and utilize available data—particularly at the local level—have been inconsistent and often fragmented. Svoge municipality, as most municipalities in Bulgaria is challenged by the lack of easy access to data and lack of accessibility of the data – i.e. how availabile and understandable the data is. The CLIMAAX workflows now offer a clear and structured approach for identifying and applying the most relevant data sources from the pan-European level on the one hand, and for collecting and honing local data on the other, enhancing the clarity and relevance of our analysis. Further refinement of local data and its integration in the two applied workflows will be a key focus in the project's second phase. A persisting challenge is the access to data in terms not only of availability but whether the data exists. The workflows in this respect are valuable for providing alternative ways to compensate for the sometimes lacking local data.

2.1.2 Context

In November 2024, the Municipality of Svoge formally adopted its Climate Adaptation Strategy, a comprehensive framework developed by an external expert team. This strategy leveraged a wide range of data from authoritative European and national sources, including the 2022 AR6 report by the IPCC, the DRMKC Risk Data Hub, the Copernicus Climate Change Service (C3S) Atlas, the Bulgarian National Institute of Hydrology and Meteorology (NIMH), the Bulgarian Academy of Sciences (BAS), and Climate Adapt. Serving as the cornerstone for local climate resilience efforts, this strategy will be further informed and refined through the Climate Risk Assessment (CRA) generated via the CLIMAAX methodology. The CRA will not only underpin the strategy's ongoing enhancement but will also facilitate the revision of other relevant municipal policy documents. Given the municipality's previous challenges in independently producing a CRA, participation in the CLIMAAX project represents a pivotal advancement by providing a rigorous, data-driven, and scientifically robust framework for a multi-hazard climate risk assessment.

Despite the national legislative framework assigning responsibility for disaster prevention and coordination to local governments, the municipality struggled to fulfill this mandate amid growing climate risks. Prior to the design of the adaptation strategy, the Municipality of Svoge primarily responded to climate change impacts and associated natural disasters in a reactive and ad hoc manner. Adaptation initiatives were largely event-driven rather than strategically planned, limiting their effectiveness and the ability to secure sustainable funding, as prevention efforts were not grounded in climate change projections. Confronted with the escalating severity and frequency of climate-related hazards and the pressing need for proactive intervention, Svoge took decisive steps by joining the EU Mission: Adaptation to Climate Change, independently developing a climate adaptation strategy, and securing participation in the CLIMAAX project. The CLIMAAX participation has been instrumental in bridging critical gaps in knowledge, financial resources, and methodological capacity necessary to undertake a comprehensive CRA.

Although Bulgaria has established a National Climate Change Adaptation Strategy (World Bank, 2019), which informed the development of Svoge's municipal strategy, the absence of mandatory and financially supported local CRAs significantly hampers the effective implementation of the national strategy. Because climate risks and corresponding mitigation measures manifest most tangibly at the local level, this structural gap leaves municipalities without adequate resources or mandates. Consequently, Svoge was compelled to pursue European Union initiatives to develop its own CRA, thereby creating a robust foundation for localized climate risk management and mitigation efforts. The CRA will serve as a critical instrument for the Municipality of Svoge to foster regional collaboration on adaptation and preventative strategies, while also strengthening its position to secure funding from national authorities. Leveraging the comprehensive CLIMAAX framework, the municipality is well-positioned to advance these strategic goals.

Several key economic sectors within the region—including timber production, tourism and light industrial enterprises — are acutely susceptible to climate-induced hazards, whether directly or indirectly. The municipality's Climate Adaptation Strategy (Svoge, 2024) already articulates a series of actions and interventions slated for the near and medium-term horizon. The forthcoming CRA will play an instrumental role in translating these strategic directives into actionable priorities by grounding them in rigorous scientific analysis. Moreover, it will enrich the strategy by identifying additional risks and vulnerabilities, potentially prompting the incorporation of supplementary adaptive measures and recommendations, thereby enhancing the municipality's resilience across multiple fronts.

2.1.3 Participation and risk ownership

Central to the formulation of the Svoge Climate Risk Assessment (CRA) is a robust and inclusive stakeholder engagement process. The project's initial phase focused on identifying key participants and launching an ongoing participatory framework as set forth in the work plan. This stakeholder group spans a wide spectrum: local residents, especially those from communities vulnerable to the two selected climate-related hazards; representatives from vital economic sectors such as tourism, retail, light manufacturing, and services; members of the media; and municipal officials specializing in disaster management and prevention. Moreover, regional bodies—including the governor's office, branches of the State Forestry Agency, River Basin Management Directorate, Civil Protection Service, Fire Department, and the Regional Environmental Inspectorate—are relevant for improving regional coordination. National government entities, notably the Ministries of Environment and Water, Regional Development and Public Works, and Agriculture, also form part of this collaborative network. Throughout the first phase, select stakeholders contributed valuable insights on climate risks, including through a consultation meeting bringing them together, as well as through ad hoc communication bilaterally, which played a pivotal role in validating and refining the selection of hazards and vulnerabilities under consideration. This early engagement prioritized groups with direct knowledge of local risks, such as vulnerable populations, municipal staff, and regional agency representatives. In the ensuing project stages, efforts will broaden to incorporate additional stakeholders including media outlets, national governmental bodies, and the wider community. To date, media outreach has included one engagement - a press release highlighting project progress and participation in the CLIMAAX Barcelona workshop.

Upon completion of the first two project phases, effective communication of results to citizens and stakeholders will be a priority. The municipality intends to organize a participatory co-design workshop aimed at raising public awareness and fostering community ownership of adaptation policies and measures. Concurrently, sharing these findings with regional and national authorities will enhance coordination across prevention and response activities, while also supporting efforts to secure necessary funding for climate adaptation initiatives.

The municipality holds unequivocal responsibility for managing climate risks, as codified in the Disaster Protection Act (National Gazette, 2016). This legislation assigns to the municipal administration, led by the mayor, the duty to craft and execute disaster action plans, including preventive and climate adaptation strategies. While civil protection during active disaster response benefits from existing guidance and consultation support primarily provided by the Ministry of Interior and its regional units, analogous support for anticipatory risk management and climate adaptation efforts is markedly deficient. When disasters such as river floods occur, the scale of response required often surpasses the capacity of municipal resources, necessitating assistance from higher-level authorities. This underscores the vital importance of proactive prevention, which preserves municipal resources and addresses persistent climate-related threats requiring continuous management. The CRA is poised to serve as an essential tool in identifying and prioritizing effective adaptation measures to prevent flooding events. Likewise, the irreversible damage posed by wildfires accentuates the need for well-timed and targeted preventative interventions, which the CRA will help to pinpoint.

2.2 Risk Exploration

2.2.1 Screen risks (selection of main hazards)

The Municipality of Svoge is highly vulnerable to climate change related risks - river floods, wildfire, extreme precipitation, drought, and flood related landslides. Recent experience and stakeholder feedback, as well as the observational knowledge of the municipal administration and the expertise of the relevant regional disaster response structures helped identify river floods and wildfire as the most prominent climatic hazards.

The rivers Iskar (the third longest river in Bulgaria) and Iskretska periodically flood the urbanised areas they pass through and cause substantial damages to private and public properties, road infrastructure, and the local businesses. According to the DRMKC -Risk Data Hub, the risk, exposure and vulnerability of the population from river flood is high with a score of more than 7.1 for all of the settlements in the municipality. In the past 10 years, local infrastructure is often flooded and destroyed, for instance the local stadium was under water in both June 2023 and June 2024. Floods are occasionally combined with sudden torrential rain that contributes to the force of the flood. Six settlements in Svoge municipality, including the city of Svoge, are even identified in the National Plan for Flood Risk Management under the category of settlements with high risk of floods.

Cassified as a “high risk region” in the Copernicus Wildfire Risk Viewer Map, Svoge is a municipality faced with the relentless challenge of wildfires. Large wildfires happen on an annual basis and damage substantial forest territories, raging for days. The municipality is among the three with largest forest areas in Bulgaria, at the same time being small in terms of administrative capacity. The average annual temperature has increased by 2.1 degrees from 1979 to 2023, which contributes to conditions conducive to wildfire, especially in the dry summer months, as well the decreasing average annual amount of rainfall from1046,3mm in1979 to 873mm in 2023. For instance in 2023 a wildfire burnt down 400 decares of shrubs and grass terrain and 50 decares of forest.

Because of the fast onset, frequency of occurance, and the severity of the impact, as well as the palpable potential for exacerbation of the situation, these two risks – river flooding and wildfire were chosen to be analysed in the CRA. Both affect the general population, the local economic and industrial sector, and infrastructure. The municipality has observational knowledge on these risks and is responsible for initiating and organizing response actions. However, lack of capacity entails full reliance on regional crisis response structures. The impact of river flooding and wildfire is economically costly and in a municipality such as Svoge where the purchasing power of the population is low, material and health consequneces have a high toll on the local population. Therefore, the municipality is putting a very strong emphasis on prevention – an aspect that has been disfunctional so far, with actions being taken more often than not after the occurance of river flooding and wildfires.

The municipality has predominantly observational knowledge of the selected risks, the relevant hazards and their impact. Other local and regional data has not been consistently used by the municipality in policy-making because of the difficulties with accessing it and the level of its complexity. Hence, the workflows also have the added value of providing us with an analytical process that once applied to our local conditions in respect to a particular risk we can reiterate again once more or better data is available. This will provide for continuity and coherence of policy-making, especially once, during the second phase, we manage to add a layer of local data.

2.2.2 Workflow selection

2.2.2.1 Workflow #1: River Flooding

In response to the growing challenges posed by climate change, the municipality of Svoge selected the river floods workflow to assess the potential impacts of fluvial flooding associated with the Iskar river and its tributaries, in particular the Iskretska river. The primary objective is to identify areas most susceptible to economic loss, thereby establishing a robust analytical foundation for future adaptation strategies and guiding spatial development priorities—particularly in relation to investment planning and infrastructure resilience. Fluvial flooding, driven by periods of intense precipitation, has become increasingly evident in Svoge during the summer months. Utilizing European-scale flood hazard maps, the workflow enabled the identification of high-risk zones based on projected economic damages across varying flood return periods. The analysis highlighted specific riverine areas as particularly vulnerable, placing infrastructure, buildings, and local populations residing or working in these zones at elevated risk. Furthermore, since urbanized areas in Svoge municipality are localized predominantly around river bodies, it was important to identify what critical infrastructure and infrastructure of importance to the local economy (i.e. the tourism and light industry sectors) was or could become located within the areas of highest exposure. Thus, the workflow allowed the municipality to see the socio-economic implications of fluvial flood risks and their potential impacts to plan in prevention.

2.2.2.2 Workflow #2: Wildfire

According to the Protected Areas Act, the territory of Svoge municipality includes 11 protected areas. Of these, one natural park, two protected areas and 8 natural landmarks. About half of Svoge's territory is in protected areas or protected territories. At the same time, 60.9% of the municipal territory is occupied by forest areas. These two peculiarities of the municipality have two consequences: firstly, wildfires are an ongoing challenge exacerbated by climate change and the rising temperatures and these pose tremendous risks to local infrastructure and livelihoods as tourism and lumber production are among the most important economic sectors for the local economy; secondly, wildfires pose a risk to unique flora and fauna and the consequences could be detrimental to environmental protection and biodiversity. Wildfire as a fast onset and usually very hard to control occurrence, especially in mountainous regions, such as Svoge, is a climate risk that puts a lot of strain and stress on the local population. It is a climate related risk that also requires a lot of resources to counteract and recover from - particularly challenging for Svoge, which has to come to terms with budgetary restrictions and lower administrative capacity. Therefore, this workflow was selected by the municipality of Svoge to explore with priority, especially with the aim of planning for prevention and fast response to decrease or preempt the impacts as much as possible. The core objective is to identify the areas where fire danger is most intense and see what are the costs associated with wildfire occurrence.

2.2.3 Choose Scenario

Within the river flood assessment workflow, a twofold analytical approach has proven particularly valuable. First, evaluating present-day flood risk through various return periods enables a precise understanding of hazard exposure—specifically in terms of flood extent and inundation depth, as illustrated in the detailed flood mapping. Second, examining projected changes under future climate scenarios—namely RCP4.5 and RCP8.5—provides critical insight into how these risks may evolve over time when compared to the baseline conditions of 1980, as captured in the Aqueduct Floods dataset. This forward-looking dimension allows for a qualitative appraisal of how climate change may intensify or shift the dynamics of flood hazards under differing emissions trajectories. A comprehensive scenario must also account for the socio-economic dimensions of flood impacts. In Svoge Municipality, river flooding causes considerable damage to urbanized areas and generates negative impact on vulnerable sectors, such as tourism and lumber production, with the existing infrastructure largely unequipped to withstand severe flood events, the municipality lacking resouces to respond and recover, and the local population with a low purchsing power that makes recovery more difficult. Given these constraints—both financial and technical—reactive disaster response alone is neither sustainable, nor sufficient. Prevention emerges as the municipality's most strategic option. This requires a dual emphasis: the implementation of protective measures, particularly nature-based solutions, and the integration of flood risk considerations into long-term spatial planning. Together, these efforts form the backbone of a proactive, resilience-oriented approach that aligns with the municipality's limited capacity and urgent adaptation needs.

In the wildfire workflow for the hazard assessment three scenarios were considered – worst, mean, and best case scenario for the historical and the future climate data under the mean model. For the plotting of the WFI intensity maps across the region of Svoge, the seasonal FWI data considered relates to the timeframes 2046-2050 and 2051-2055, whereby the emissions scenario of 8.5 was selected as the most realistic and most perilous for the conditions in Svoge. To plot the change in the fire weather season length, for the historical data the longest available period was used, i.e. 1985-2005. The future maps were plotted by FWI data for the future and selecting the 8.5 RCP scenario for the years 2050-2060. The FWI threshold was set at 30 despite Svoge being a mountainous region predominantly because local observational knowledge points that wildfire frequency and intensity has increased recently.

2.3 Risk Analysis

2.3.1 Workflow #1: River Flooding

Table 2-1 Data overview workflow #1: Rivel flooding

Hazard data	*Vulnerability data*	*Exposure data*	*Risk output*
JRC high-resolution flood hazard maps in historical	*JRC damage curves for land use*	*JRC LUISA land use data (100 by 100 meter*	*Economic damage estimate, i.e. damage maps based on flood*

Hazard data	*Vulnerability data*	*Exposure data*	*Risk output*
climate for Europe		*resolution land use in 2018 in Europe)*	*maps and land use data - spatial mapping of locations that can be most affected economically*
Aqueduct Floods coarse-resolution flood maps - dataset of future river flood potential under climate change	*Vulnerability curves for flood damages with the LUISA land cover types*		

2.3.1.1 Hazard assessment

The river flood hazard assessment workflow employed in Svoge is designed to compute and visually represent flood extents under current climatic conditions for a range of return periods, while also projecting the influence of future climate scenarios—specifically RCP4.5 and RCP8.5—on the severity and spatial distribution of flood risks. This analytical process utilized high-resolution European datasets, which were geographically refined to focus specifically on the municipality's territory. While the methodology acknowledges several technical limitations associated with these datasets, a review of their practical implications for the Svoge context from observational local knowledge suggests that their influence on the overall findings is not significant.

Flood mapping under current climate conditions was conducted using the March 2024 (version 3) release of the Joint Research Centre's (JRC) high-resolution river flood maps, offering a spatial resolution of 3 arc-seconds (approximately 30–75 meters across Europe, depending on latitude). This dataset enabled the municipality to analyze and compare flood extents and inundation depths across varying return periods, thereby supporting a more granular understanding of present-day flood exposure. A known constraint of this dataset is its inclusion only of river basins exceeding 150 km²; however, in the case of Svoge, this is not a limiting factor, as the Iskar and Iskretsa rivers—both primary sources of flood events in the municipality—are covered.

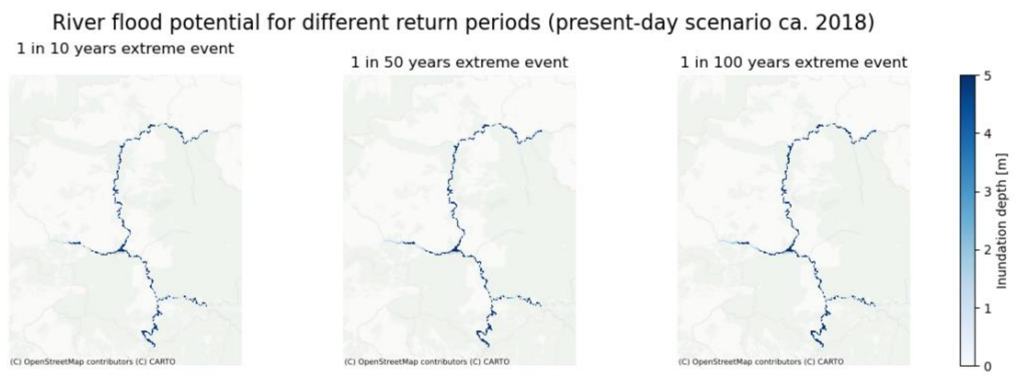


Figure 2-1 Flood inundation maps for the area of the Municipality of Svoge for extreme events with different return periods based on European high-resolution dataset

Another recognized limitation pertains to the dataset's flood modeling, which does not incorporate the presence of existing man-made protective infrastructure such as dams, levees, or dikes. Nonetheless, in Svoge's case, this constraint is again of limited relevance. The municipality currently lacks significant flood protection infrastructure, and the measures in place are not considered effective in mitigating flood risks at present. Hence, the exclusion of such features in the model does not substantially compromise the validity of the results for local planning and risk assessment.

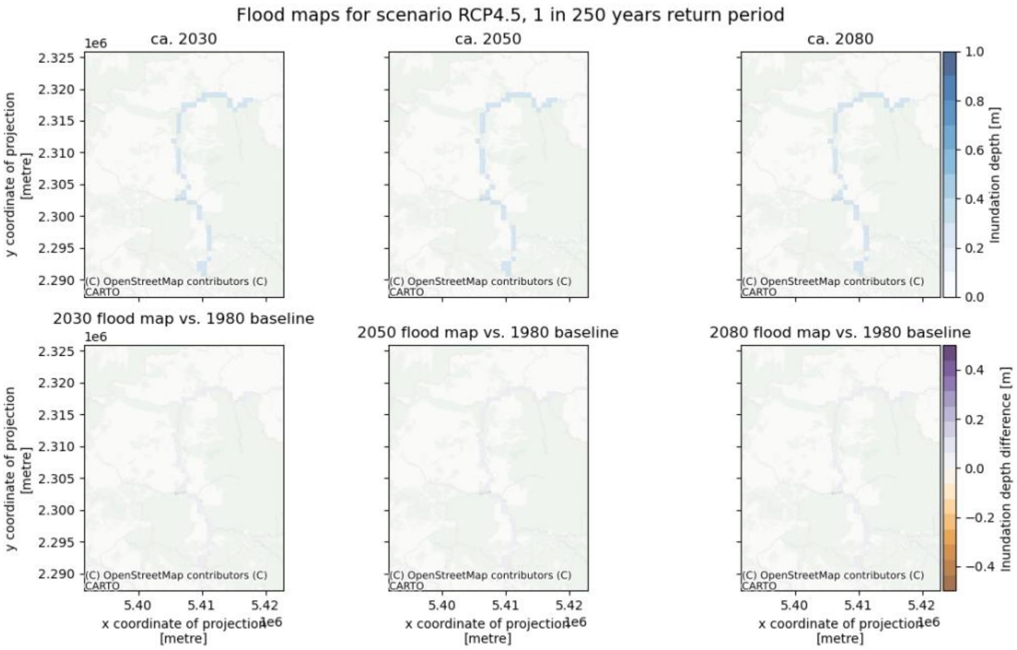


Figure 2-2 Flood maps for the municipality of Svoge for scenario RCP4.5, 1 in 250 years return period

A key advantage of this hazard assessment workflow lies in its ability to model the projected impacts of climate change on river flood behavior under two representative concentration pathways—RCP4.5 and RCP8.5. By analyzing how flood extent and inundation depth are expected to evolve under these scenarios, the municipality gains critical foresight into future risk dynamics. To this end, the workflow incorporates data from the Aqueduct Flood Hazard Maps, a dataset offering projections for extreme flood events based on baseline conditions around 1980, and future timeframes—specifically 2030, 2050, and 2080—under both emissions trajectories.

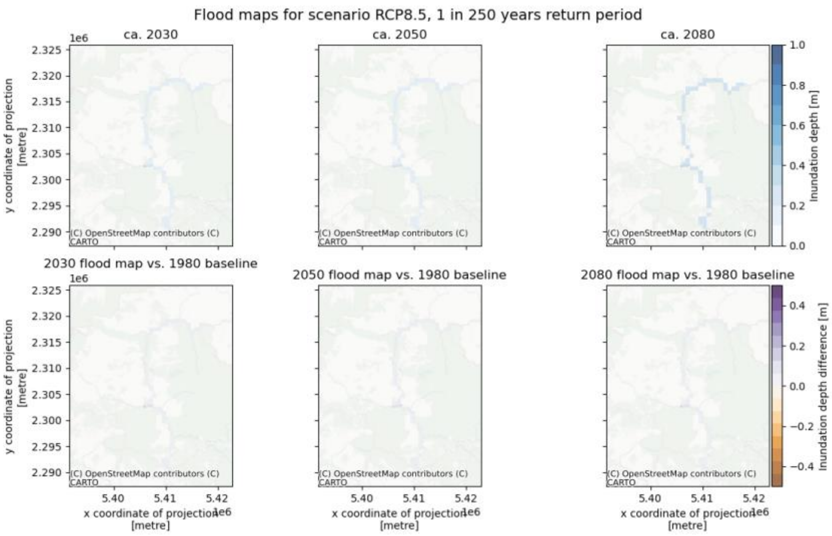


Figure 2-3 Flood maps for the municipality of Svoge for scenario RCP8.5, 1 in 250 years return period

Although the Aqueduct dataset operates at a relatively coarse spatial resolution (30 arc-seconds, or approximately 300 to 750 meters depending on latitude in Europe), it nonetheless provides valuable strategic insight. Its principal utility lies in identifying the general direction and magnitude of change in flood characteristics across different return periods. For the Municipality of Svoge, this analysis has been instrumental in determining whether river flooding is likely to intensify or diminish under each scenario and time horizon. Such foresight enables more informed adaptation planning and long-term resilience building, despite the spatial limitations of the dataset.

2.3.1.2 Risk assessment

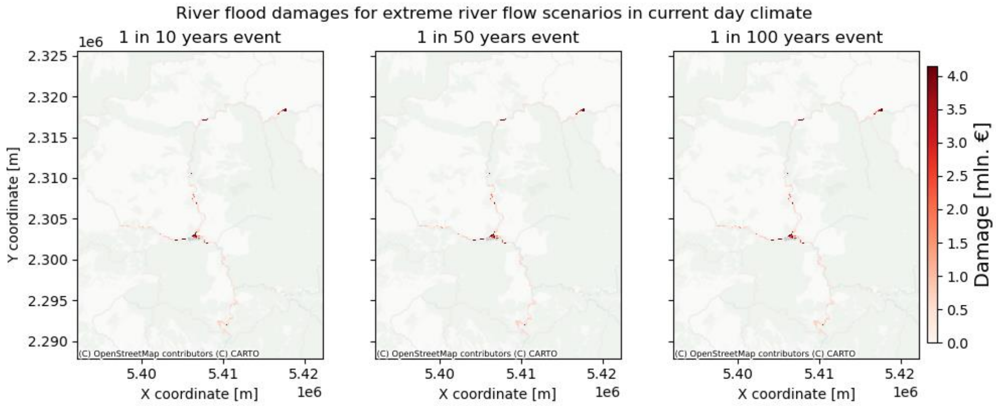


Figure 2-4 River flood damages for extreme river flow scenarios for the municipality of Svoge in current day climate

The river flood risk assessment workflow estimates potential economic losses by integrating flood hazard data with exposure and vulnerability analyses. Risk is calculated by overlaying flood maps for multiple return periods with land use and infrastructure data, applying economic damage functions to represent both exposure and vulnerability in monetary terms.

For the hazard component, two key datasets were utilized. Current climate flood maps were sourced from the Joint Research Centre (JRC), while projections for future climate conditions were derived from processed flood maps based on the Aqueduct Floods dataset. In both cases, data were geographically clipped to match the boundaries of the Municipality of Svoge. Exposure was established using land use data from the JRC Data Portal—specifically, 2018 land cover maps at a 100-meter resolution—also limited to the municipal area. This dataset formed the foundational exposure layer for the analysis.

To quantify potential damages, depth-damage functions provided by the JRC were applied. These functions correspond to various infrastructure damage categories and facilitated the integration of flood depth, land use, and infrastructure data to assess risk across different sectors. After harmonizing the spatial resolutions of all relevant datasets, economic values were assigned to each land use category. This was achieved through the application of LUISA (Land-Use-based Integrated Sustainability Assessment) damage curves, incorporating region-specific GDP per capita figures from the Bulgarian National Statistical Institute (2025), using 2023 as the reference year. The resulting vulnerability curves represent potential losses in euros per square meter for each LUISA land cover class.

Once all inputs were prepared, the DamageScanner tool was used to calculate potential economic damages. This model processes the resampled flood hazard data, municipal land use layers, damage curves by land use type, and a corresponding table of maximum allowable damages. The tool outputs estimated losses for all modeled return periods and climate scenarios. The spatial distribution of these projected damages was then visualized to identify high-risk zones within the municipality, as illustrated in Figures 2-4.

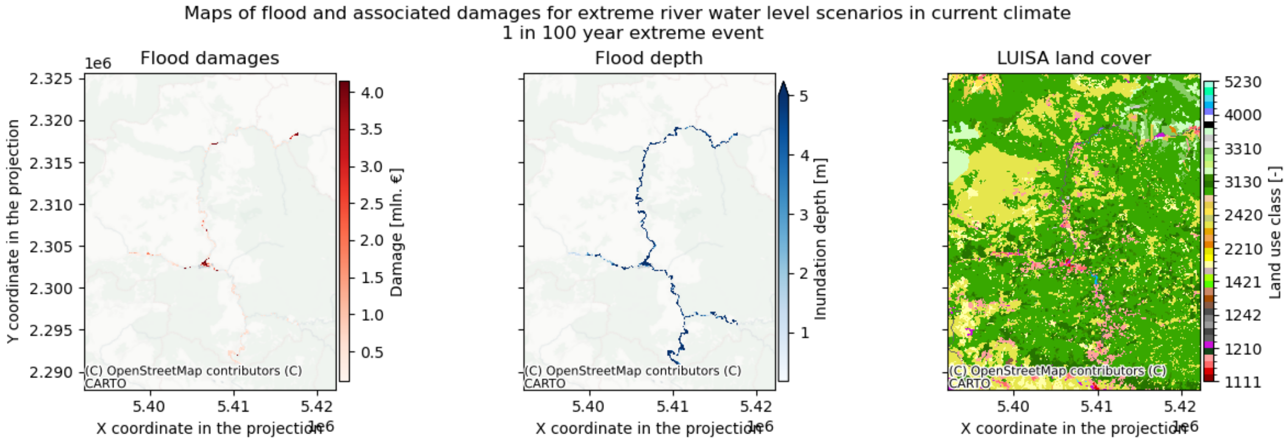


Figure 2-5 Maps of flood depth, associated damages, and land use for the municipality of Svoge for extreme river water level scenarios in current climate, 1 in 100 year extreme event

In this workflow, flood-related economic damage is estimated by integrating inundation depth data with depth-damage functions. For each grid cell, the model assesses the extent of flooding, the corresponding land use classification, the relevant damage curve, and region-specific economic parameters that approximate the financial value associated with each land use category. This composite methodology enables a spatially detailed estimation of potential losses. To better understand the spatial variability of damage, Figure 2-5 presents a comparative visualization of flood extent, economic damages, and land use patterns for a flood event with a 1-in-100-year return period. This layered representation offers insight into how depth of inundation translates into economic risk and highlights which areas of the municipality are most vulnerable to financially significant impacts.

The analysis reveals a strong correlation between zones of deeper inundation and higher estimated damages. These high-risk zones often coincide with areas of concentrated urbanized areas—demonstrating that both physical flood depth and land use context are critical determinants of risk exposure. The visualizations presented in Figure 2-5 enabled the identification of key hotspots where significant economic losses from river flooding are most likely to occur under the modeled return period. These maps also illustrate the specific land use categories associated with the projected damages, offering insight into which types of assets are most at risk.

A detailed interpretation of the findings derived from the river flood hazard and risk assessments for Svoge municipality is provided in Section 2.4.

2.3.2 Workflow #2: Wildfire

Table 2-2: Data overview workflow #2: Wildfire FWI

Hazard data	*Vulnerability data*	*Exposure data*	*Risk output*
Fire Weather Index from the Copernicus Climate Data Store (CDS) –	*CDS datasets for the following vulnerability indicators: population in WU interface, protected land areas, ecosystem irreplaceability index,*	*Seasonal FWI data from CDS and Burnable vegetation data from EFFIS.*	*Map of fire risk – displaying areas with the highest wildfire risk against the climatic danger as represented by the FWI.*

Hazard data	Vulnerability data	Exposure data	Risk output
EURO-CORDEX data.	*population density, restoration cost index.*		

2.3.2.1 Hazard assessment

The FWI Wildfire Hazard workflow was used to generate insights into the variation of the length of the fire season and a spatial visualization of the intensity of the FWI. The hazard workflow was applied for the entire region of Sofia wherein Svoge municipality is located as this was the administrative division available through bounding box. This however does not pose any considerable challenges to the analysis as the delineation of Svoge can clearly be distinguished and the various areas within the municipality are sufficiently visible due to its large territory and central location within the region.

Map of administrative division of Bulgaria with Sofia region shown in darker gray and Svoge in yellow.

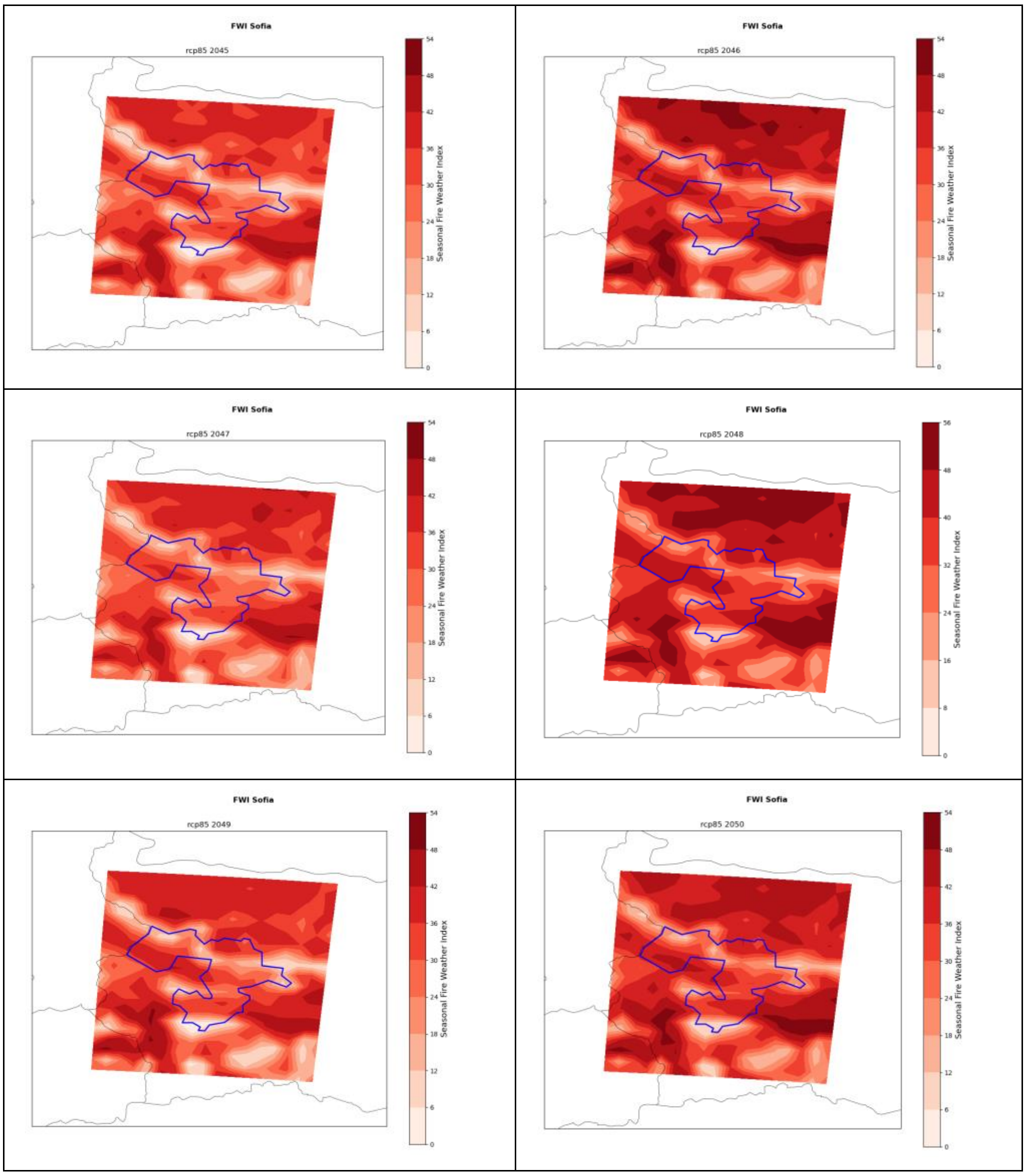
Geographical map of Svoge municipality showing the terrain.

General development plan of Svoge municipality approved in June 2023

Figure 2-6: Maps showing the delineation of Svoge municipality within Sofia region, the geographical area of Svoge, and the general development plan of the municipality.

The workflow used the CDS Fire Weather Index EURO-CORDEX data, whereby the seasonal FWI shows the mean fire weather index over the months June-September. The data for the studied region was extracted from the CDS datasets and plotted for FWI intensity, while the FWI results were analyzed through the lens of the fire danger categorization of the European Fire Information System (EFFIS). The seasonal FWI data considered relates to the timeframes 2046-2050 and 2051-2055, whereby the emissions scenario of 8.5 was selected as the most realistic and most perilous for the conditions in Svoge. To ensure the utmost robustness of the obtained results, the multi-model ensemble mean was used as the sources for the projection. In terms of projections severity the mean case was selected. This resulted in a map identifying the areas in Svoge municipality with the most favorable conditions for the development of wildfires based on the availability of fuel and climatic factors.

To generate the variation projection in fire season length, daily FWI data was downloaded and cut from CDS for the studied region. FWI data for the historic period for all global climate models available is utilized as the baseline to calculate future variations. For the sake of robustness of results the longest available period was used, i.e. 1985-2005. The multi-model ensemble mean as the source of the projection is selected as this gives the highest robustness of results. Using FWI data for the future and selecting the 8.5 RCP scenario for the years 2045-2054, future projections of fire season length are plotted. The FWI threshold was set at 30 despite Svoge municipality being a prevailingly mountainous region based on the assumption that severity and frequency of fires is quite advanced already. For each selected year, the duration of the fire weather season is determined by counting the number of days when the Fire Weather Index (FWI) exceeds a specified threshold – 30 in the case of Svoge - these are referred to as fire weather days. This calculation is performed for both historical records and future climate projections in order to assess anticipated changes in the length of the fire-prone season over time. Ultimately, the workflow generated a fire weather season length map for the municipality, whereby the fire weather season length in the historical and future periods is plotted for every point in the municipal territory. Maps are generated for the worst, mean, and best case scenarios for the historical and future data. The historical and future maps provide the basis for analyzing how the fire weather season length will evolve with climate change, including a potential range across the three scenarios, giving a mean but also indications of the most positive and negative conditions that might occur in Svoge. This gives a prospective into the variability of magnitude that is fundamental for prevention measures and adaptation efforts.



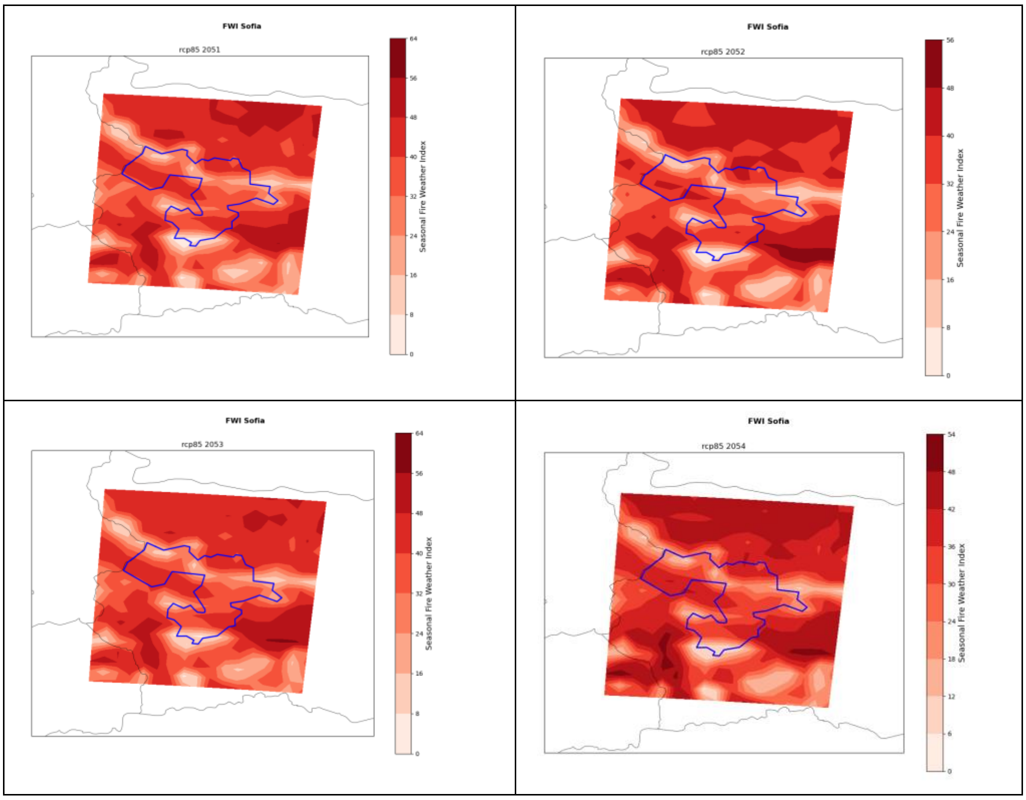


Figure 2-7 : Fire Index Intensity Maps for Svoge municipality within the region of Sofia for RCP 8.5 for the 10 year period of 2045-2054.

The hazard workflow produced insights into the changes in the FWI intensity for the future period of 10 years between 2045-2054, whereby it is visible that the index will increase for RCP 8.5 and that the areas with the most intensive FWI are the forest areas in the South Western areas of the municipality.

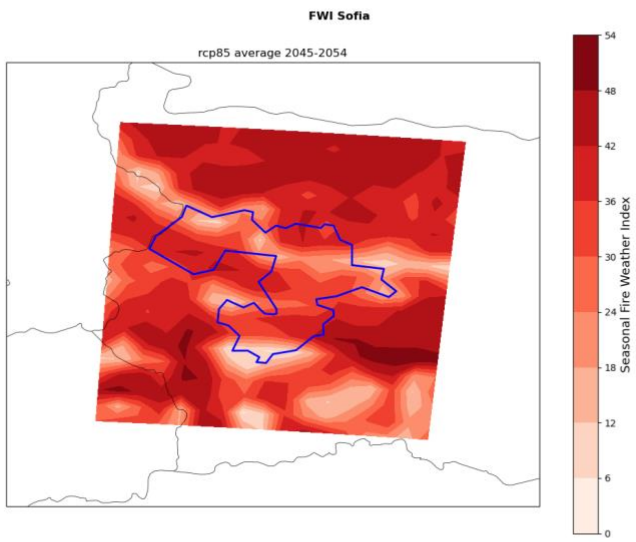


Figure 2-8: Average Seasonal FWI intensity for the period 2045-2054 for Svoge municipality within the region of Sofia.

For the fire season length, the analysis benefits from juxtaposing the two plots for the historical and future data to see not only how the fire season length will vary but also to see at which locations it is likely to be longest across the various scenarios. The mean and worst case scenarios are of interest mostly, and scrutinizing the maps, it becomes clear that the season length for the worst case scenarios both historical and RCP 8.5 data is within the range of 120-150 days for the South West forest regions in the municipality while for the mean scenario it falls in categories above 60 days. This gives us the cumulative estimate that season length will vary between 60 to 150 days in these forest seasons.

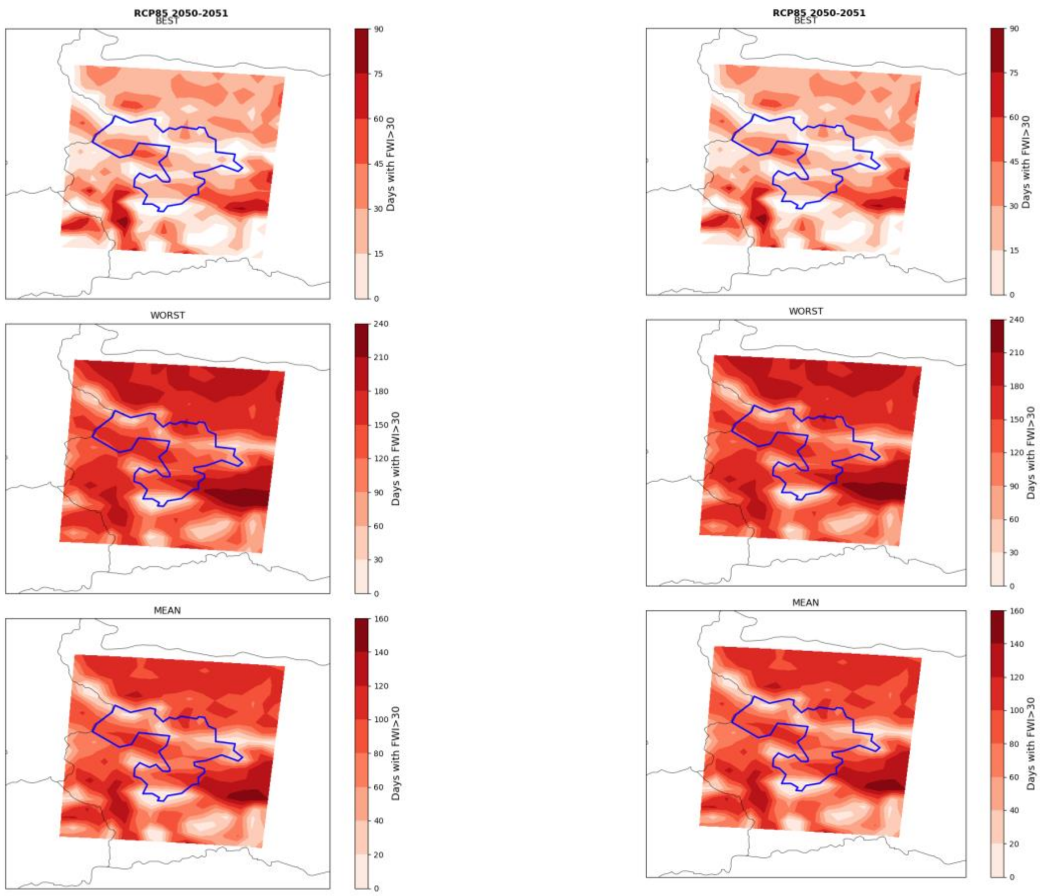


Figure 2-9: Juxtaposition of the maps for the two plots with historical and future data for RCP8.5 for the period 2050-2052 with FWI>30.

2.3.2.2 Risk assessment

This workflow uses a definition of wildfire risk as established by the European Forest Fire Information System (EFFIS), which defines it as the interplay between wildfire danger and vulnerability. To begin with, wildfire danger is determined by combining two key factors: climatic conditions—represented in this context by the seasonal Fire Weather Index (FWI)—and the presence of combustible vegetation, which reflects fuel availability. These two elements are individually normalized and then averaged to generate a spatially distributed fire danger index. This danger index is then integrated with various indicators of vulnerability to derive a comprehensive risk index. The selected vulnerability indicators reflect the potential impact of wildfires on human populations, economic assets, and ecological systems. To finalize the risk assessment, a Pareto analysis is conducted. This method identifies the areas within the region that exhibit the highest cumulative risk levels based on the chosen indicators.

There are two limitations identified for the methodology of this workflow. The first one which is that it only provides information on wildfire development risk related to weather conditions is actually of benefit to the study of Svoge as thus it puts the focus only on climate change related occurances and isolates the istances of fire due to human activity – intentional or unintentional – both of which are possible in the municipality. Additionally, the fact that the workflow does not take into account the past occurrence of wildfires (burnt area indicator as a component of the fire danger definition is taken out) as an indicator of fire danger is also a plus as it would have been difficult to identify which of these occurrence are the result of climatic conditions and fuel availability and not a result of human activity. The second workflow limitation which is that the workflow does not provide information about fire evolution after ignition does not substantially impact the usefulness of the plots for Svoge as the municipality finds it most valuable to know the most likely areas of ignition, which suffices to plan for adaptation measures in prevention.

The studied area is defined as Sofia region again as with the hazard workflow due to the administrative division and the availability of bounding box maps for the workflow. Here, this does not create difficulties for the analysis and provides a sufficient level of detail due to the large territory of Svoge municipality and the possibulity to clearly identify areas by layering and juxtaposing maps. The fire danger definition is composed of two components - the seasonal FWI representing the climatic favorablity for fire development (weather and fuel moisture) and fuel availability as presented by the EFFIS burnable area dataset. The selected FWI threshold to define a fire weather day is within the high fire danger category according to the pan-European conditions and set at 30 – based on Svoge being a mountainous area, the FWI intensity and observational knowledge. Seasonal FWI EURO-CORDEX data from CDS is used for the RCP scenario 8.5. To isolate land without burnable material, the FWI data is filtered and the ESA-CCI Land Cover dataset from CDS is used to cut out these areas. Combining these two danger components the workflow generates a wildfire danger index with a zoom of 0.5 degrees as Svoge is located in the central part of the Sofia region and this provides sufficient coverage. The plots show that the highest risk, i.e. Fire Danger Index, is for the South West forest areas of the municipality where most burnable vegitation is availiable and the FWI index is higher.

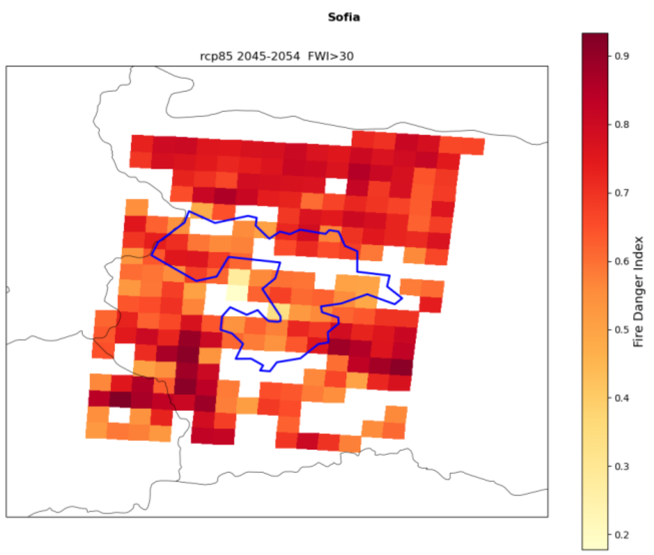


Figure 2-10: Fire Danger Index map for RCP8.5 2045-2054 with FWI>30 for Svoge municipality within the region of Sofia.

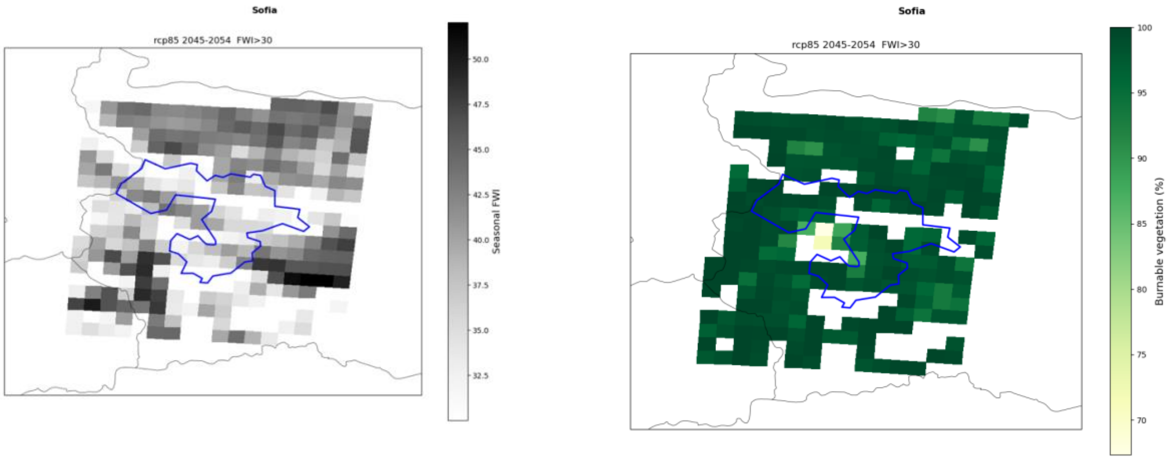


Figure 2-11: Maps illustrating the components of the fire danger index, i.e. seasonal FWI and availability of burnable vegetation for RCP 8.5 for the period 2045-2054 with FWI>30.

The vulnerability component of the workflow includes data on the idicators of population from the Wildland Urban Interface, protected areas fraction, ecosystem irreplacability, population density, and restoration cost. A Pareto analysis is used to combine the vulnerability indicators with the danger components of the risk workflow and produce a Pareto front, i.e. pixels with the highest risk profile given that all factors under consideration in the analysis have an equal contribution to wildfire risk. Since Svoge in the forest areas of interest is not a densely populated region, the population density vulnerability variable is excluded. The workflow thus produces a map indicating the areas with the highest wildfire risk with a spacial resolution of 11x11km, whereby a risk dot indicates the center of a 11X11km radius where the highest risk is found with all red dots sharing an equally high risk profile. This map provides information on where the wildfire risk is highest and lays the foundation for planning adaptation measures in prevention.

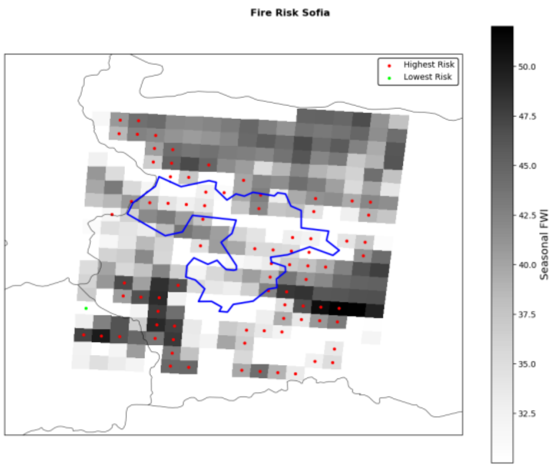


Figure 2-12: Fire risk map for Svoge municipality within the region of Sofia.

The three maps below in Figure 2-13 show the most impactful indicators for Svoge from the vulnerability component, namely the availability of protected areas, irreplacability of ecosystems, and the cost of restoration.

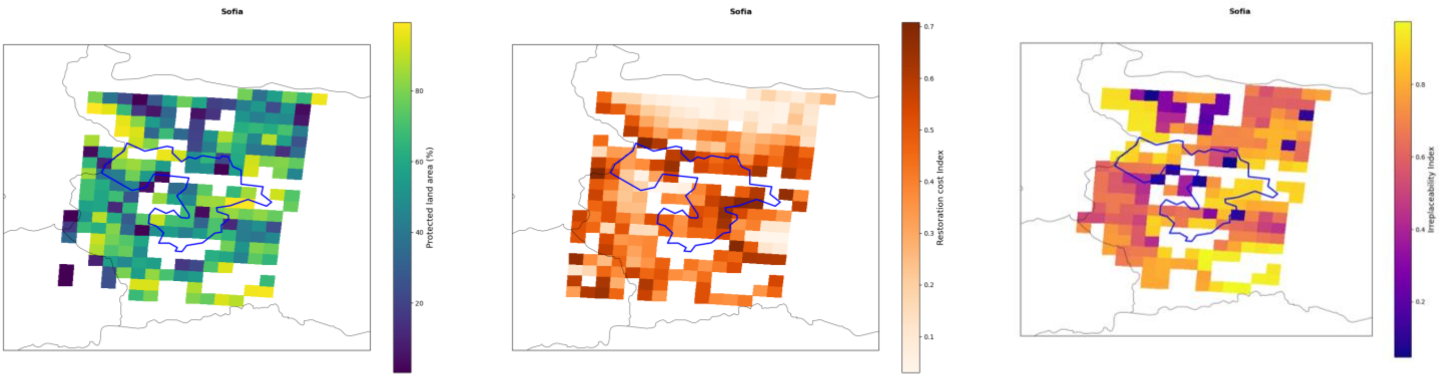


Figure 2-13: Maps showing three indicators from the vulnerability componene as follows from left to rght: protected land area, restoration cost index, and ecosystem irreplacability index.

A detailed interpretation of the findings derived from the wildfire flood hazard and risk assessments for Svoge municipality is provided in Section 2.4.

2.4 Preliminary Key Risk Assessment Findings

2.4.1 Severity

Both analyzed risks – river floods and wildfire will become of increased severity. The results from the assessment are interpreted below, including insight both from the risk and hazard workflows.

The river floods hazard assessment results show an increase in severity under the historic, the RCP4.5, and the RCP 8.5 climate scenarios. For the present day data climate scenario, the flood potential for the different return periods (10, 50, and 100) comes with a heightened inundation depth and a slight extension of the inundation area to the tributary Iskretsa. This spatial change can actually be ignored for planning purposes as it is miniscule and the inundation depth emerges of utmost importance. When analyzing the change in flood hazard potential under the RCP4.5 climate scenario with a 250 return period, the hazard workflow points that the inundation depth will increase but again the affected areas are not likely to change comparing against not only the baseline year but also across the 2030, 2050, and 2080 plot. In respect to the RCP8.5 climate scenario the conclusion in respect to affected areas remains the same – these are not likely to change but this scenario reveals that there could be a compounding hazard at play: a lower inundation depth for the years 2030 and 2050 and an increased inundation for 2080 compared to the baseline year could point to the possible impact of droughts as another climatic hazard under this scenario. The notably greater inundation depths observed in the 2080 projections, as opposed to those for 2030 and 2050, highlight the escalating interplay between flood and drought risks associated with the RCP 8.5 scenario.

The river flood risk assessment under the present day climate for return periods of 10, 50, and 100 years reveals a clear trend of increasing damage severity. These higher-impact zones visually align with areas of greater inundation indicated in the flood hazard maps under present climate conditions, particularly along the Iskar and Iskretsa rivers. According to the workflow-derived flood damage maps, this heightened severity disproportionately affects several key settlements — including Svoge, Gara Lakatnik, Tserovo, Gara Bov, and Redina. Among them, Svoge and its surrounding areas stand out as the most severely impacted in terms of financial loss, with damages reaching into the millions of euros. These areas also face the deepest inundation, making them top priorities for targeted protection, prevention, and climate adaptation strategies. Moreover, the overlap between zones of high inundation depth (from hazard data) and elevated economic loss (from risk analysis) intersects with critical infrastructure — such as rail, water supply, and energy networks — that has proven vulnerable and costly to repair following past extreme events. This convergence of risks also poses serious threats to the tourism industry.

The wildfire hazard assessment shows a distinctive increase in the territory with days with FWI above 30, as well as an increase in the length of the fire weather season. This trend is valid both under the historic and the RCP8.5 scenario. In both scenarios under the mean model most endangered are the South Western and Central forest parts. Almost half the territory of the municipality is with this risk profile. Under the mean and worst case scenarios of the historic data and in the RCP8.5 data, the territory with FWI above 30 includes more territory to the North. The RCP8.5 scenario is with intenser severity in both spacial coverage and number of days with FWI over 30 – where the majority of the territory falls in the category of 120-150 days, whereas under the historic data the same falls in the category of 90-120 days. The trends in the unfolding geographical coverage and intensity of the hazard is confirmed also by the seasonal FWI index for RCP8.5 average for 2045-2054. These intensification of the severity of the hazard that is uneqivocally confirmed with the worflow is a clear indication that the municipality needs to step up its actions in adaptation and prevention.

The wildfire risk assessment workflow is particularly useful for the municipal adaptation and prevention efforts as it shows which areas are with the highest risk. Looking at the interplay of exposure and vulnerability, these plots help prioritise efforts and strategise both spacially and temporarily. The Central and Western forest parts that are under heightened risk have urban areas close to their outskirts which is an important factor to take into consideration. Almost half of the territory of the municipality, experiences a considerable Fire Danger Index of appoximately 0.6. The irreplacability index for biodiversity is 0.8 for the considerable part of the territory under risk according to the risk assessment workflow results. From the forest areas under highest risk in the Western and Central part around 60% are protected area, whereas when it comes to the Northern areas – the direction in which also the hazard plots showed a tendency for the climatic hazard to extend geographically in the future - this percentage rises to 80%. For the areas identified with the highest risk by the risk workflow, the restoration cost varies between the considerable 0.6 and 0.7 values. On the one hand this analysis shows where Svoge is to focus its efforts, on the other since land of particularly important biodiversity is concerned, this analysis will be used by the municipality to advocate for national funds and assistance in preservation and adaptation efforts and the Ministry of Environment and Water will be the natural first point of contact for these efforts and an advocacy ally to secure the necessary resources. The large area covered by this intensifying risk is also an indication of the need to act as soon as possible due to the large scale potential of the risk.

2.4.2 Urgency

River flooding already poses a significant risk in the municipality of Svoge, a risk that is expected to intensify under both current climatic conditions and future projections, including the RCP4.5 and RCP 8.5 scenarios. This escalating risk necessitates swift and proactive measures by the municipality to mitigate potential damages. The damage assessment maps developed as part of the risk analysis are crucial in this regard—they not only identify the areas most vulnerable to flooding but also quantify the expected impacts. This information is essential for prioritizing investments in protective infrastructure and implementing targeted adaptation strategies. The nature of river flooding, being triggered by extreme and often unpredictable precipitation events, adds an additional layer of urgency. As a sudden-onset hazard, it leaves little room for reactive measures, making preventive action even more critical.

Similarly, wildfire risk stems from sudden and often unpredictable events, demanding an immediate and decisive response from local authorities when such incidents occur. In regions where wildfire risk is higher—especially those encompassing protected natural areas—the potential for high restoration costs underscores the need for short-term adaptation actions. These initial efforts should be designed with flexibility, allowing for gradual scaling over the next 10 to 15 years, particularly as wildfire frequency is expected to rise both under the historic and future RCP8.5 scenarios. Adaptation planning must also account for the specialized expertise required, along with the financial and temporal investment needed. Since these actions often involve complex considerations around biodiversity and ecosystem preservation, implementation can be both time-consuming and costly. As such, initiating mitigation strategies as early as possible is not only advisable but essential.

2.4.3 Capacity

The municipality of Svoge currently faces significant limitations in addressing the risk of river flooding. Preventive efforts to date have been largely reactive and fragmented, lacking the structure and scope needed for effective long-term risk mitigation. Although the municipality has developed a “Program for Reduction of Disaster Risk” (Svoge Municipality, 2025), actual disaster response to river floods often exceeds the municipality's capacity, requiring intervention from regional authorities and activation of the regional disaster response framework. Similarly, post-flood recovery efforts cannot be sustained through local funding alone and typically depend on support from national sources. These constraints underscore the urgent need to strengthen disaster prevention, improve climate adaptation planning, and build institutional capacity for flood risk management. By focusing on this risk in the Climate Risk Assessment (CRA), the municipality is laying essential groundwork—not only to enhance local resilience but also to improve eligibility for future national funding, attract EU financial support, and potentially encourage private sector investment in risk-reduction measures.

Regarding the wildfire risk, no specific preventive measures have been established so far. The municipality does issue alerts for forecasted extreme heat conditions—events known to increase wildfire risk—but has yet to implement concrete actions aimed at reducing the frequency or severity of such incidents. However, the CRA process has significantly improved the municipality's understanding of wildfire danger and vulnerability and has provided critical insights into impacted areas. This new knowledge will support more targeted adaptation planning, making it easier to develop practical measures and secure funding from both national and EU sources. The CRA also offers a clearer basis for prioritizing actions and allocating resources effectively, thereby improving the municipality’s readiness to address wildfire risk going forward.

2.5 Preliminary Monitoring and Evaluation

During the initial phase of the project, we engaged extensively with the CLIMAAX methodology, establishing the requisite technical infrastructure locally to enable the practical application of the selected workflows. This phase facilitated the testing and deployment of two key workflows, allowing for a comprehensive understanding of their operational complexities, inherent value, and potential limitations. Such engagement enabled a nuanced interpretation of the results, taking into account the influence of any methodological constraints on outcome reliability. Furthermore, this groundwork laid the essential foundation for the second phase that will focus on the collection and integration of locally relevant data to refine the CRA.

Challenges encountered primarily arose during workflow testing, manifesting as technical errors; however, these were promptly resolved with minimal disruption to progress. The majority of technical challenges were related to the time required for downloading some of the data. Stakeholder consultation played a pivotal role in validating hazard prioritization, confirming that the municipality's selection of the two risks corresponded with their severity and urgency for adaptation interventions. Engagement efforts at this juncture concentrated on local and regional actors, whose contextual expertise was invaluable for informing the hazard selection process underpinning Deliverable 1. Stakeholders contributed a pragmatic layer of observational knowledge and experience with impact management. A challenge in resepect to stakeholder engagement was the inclination of relevant stakeholders to doubt the added value their observational knowledge and experience could have for the CRA development and express hesitation to participate – this was addressed with raising stakeholder awareness about the practical objectives of the CRA that makes local knowledge, alongside local data, important for analysing hazards and risks and customizing workflows. Looking ahead to phases two and three, the municipality intends to broaden its stakeholder engagement to encompass a wider array of participants, emphasizing dissemination of CRA findings to the more general public and the media to enhance awareness of the project added value and how it will feed into the policy-making processes at the municipal level.

Reflecting on the initial phase, we have attained a robust comprehension of the climate risks through the standardized CLIMAAX framework. While acknowledging some methodological limitations, these are not anticipated to significantly alter the overall findings in our context. Nevertheless, we anticipate that refining the workflows with localized data will enhance risk characterization and provide additional critical insights. Prompted by the CLIMAAX experience so far, the municipality plans to look into possibilities for developing own datasets or formalised entries of observational data so as to generate a pool of readily available information that can be used in future reiterations of the workflows, once new data or research become available to analyse the selected risks in new light. In relation to this, the municipality is also contemplating on adding computational hardware to service the processes related to these plans and the more data-driven approach it would like to take to climate change adaptation policy in the future. In-house skills and competences that are currently being developed through the CLIMAAX experience need to be maintained and replicated to ensure durability and sustainability of the data and science-driven approach to policy-making. The municipality is also looking into possibilities to acquire a more comprehensive understanting of climate change impact on different local systems and has applied for the Pathways to Resilience (P2R) program to this end to compliment and build upon our efforts under the CLIMAAX program. This ambition to become part of P2R, however, is only a fact thanks to the CLIMAAX know-how and the experience accummulated in exploring climate risks.

2.6 Work plan

The Workplan for the remaining two phases of the project includes 6 core actions. Under the second phase the following three actions will be undertaken: 1/. the external expert team and the CMMT organize a meeting with residents and other stakeholders to present the climate multi-risk assessment and collect input for refinement; 2/. The external expert team reviews relevant local data to plug into the risk assessment and submits a report with the selected data to the CMMT for approval; 3/. Upon CMMT approval, the external expert team plugs the data into the risk analysis and produces a refined climate multi-risk assessment. Under the third phase the actions planned as the following: 1/. The external expert team and the CMMT hold a co-design meeting with residents and other stakeholders to present the refined study and collect feedback for changes to municipal policies; 2/. The external expert team reviews the Municipal Climate Change Adaptation Strategy and recommends amendments based on the refined assessment, with an emphasis on concrete adaptation measures. It also identifies other municipal regulations relevant to these measures and proposes amends to make them more efficient in supporting the municipal climate adaptation strategy and policy; 3/. The CMMT reviews proposed changes and passes them to the leadership for adoption. These actions had been planned during the IFP development and the team believes that it will be possible to fulfil all six actions as planned in a timely and effective manner.

Under the second phase it will be of particular interest to see to what extent the analysis will be altered through the addition of local data. Bearing in mind how difficult it is for the municipality to access local data, if the second phase shows no dramatic improvement, the municipality will continue to reiterate the workflows with pan-European data to keep abreast with significant future changes. This will be easier logistically. Alternatively, if the opposite proves true, the municipality will establish a set of particular data that it would like to collect, get continuous access to, and keep on hand for future references. This is particularly important to also improve the reliability, coherence, and consistency of the data over time – an aspect that will become increasingly important with the advancement of climate change impacts.

With the experience of phase 1 and the acquired familiarity with the workflows and their logic, the CMMT is comtemplating the addition of a thrid workflow that is related to the two currently analysed and could have compounding impacts and the drought workflow would be the choice of most utility.

3 Conclusions Phase 1- Climate risk assessment

The assessment of climate-related hazards and risks has yielded essential insights for managing the two primary risks selected by the municipality—river flooding and wildfire. One of the key challenges encountered was the limited availability of data below the NUTS2 administrative level. However, running the workflows for the territory of the Sofia region offered valuable input applicable to the municipality of Svoge, due in part to its large geographical area and position. To enhance the precision of the risk analysis, Phase 2 of the project will focus on integrating additional local data.

The municipality of Svoge experienced significant benefits from its participation in CLIMAAX in Phase 1 of its project. With financial support from CLIMAAX, the municipality was able to hire external experts, which was instrumental in carrying out the assessment. Svoge becoming aware of previous CRA efforts in other regions, alongside additional information on tools like P2R and resources for future funding of adaptation actions, added depth to the process. In this regard, the CLIMAAX Community of Practice (CoP) webinars proved to be a particularly informative resource. One of the central difficulties faced during Phase 1 was the municipality's low level of technical readiness for conducting risk assessments, along with a lack of internal expertise in CRA methodologies. Phase 1 was therefore crucial in establishing both the necessary technological infrastructure and procedural knowledge for conducting assessments using the CLIMAAX approach. The ability to repeat and update this process after the project ends adds significant value—especially considering that neither Svoge, nor most Bulgarian municipalities, have prior CRA experience. In this context, the technical assistance provided through CLIMAAX was highly useful.

One unresolved challenge that will be addressed in the upcoming phase is the lack of accessible, high-quality local data. The project team plans to concentrate on gathering and refining such data during Phase 2. Often, this information is either unavailable, difficult to obtain, or not formatted in a way that supports policy decision-making—frequently because it is developed for scientific rather than governance purposes.

The involvement of local stakeholders during Phase 1 proved essential. Community-based and non-expert knowledge contributed to defining the context of the assessment and ensured that the CRA remained aligned with the priorities, expectations, and needs of the local population.

A notable outcome of the scoping phase was the prioritization of river floods and wildfire as the focus of the CRA. This decision was based largely on observational knowledge and local perceptions of urgency. Both risks are projected to worsen under various climate change scenarios and require immediate risk management actions from the municipality. The wildfire threat is particularly urgent, as the current level of risk exceeds what the municipality can reasonably manage, especially given its limited disaster response capabilities and the absence of preventive measures. River flooding is similarly pressing, with a short timeframe for action and a direct impact on core urban areas, posing serious disruptions to residents' daily lives. Considering the scale of resources and planning required for effective adaptation to both hazards, the municipality aims to begin work on each as soon as possible. In addition, both risks are linked to cascading and compound effects that can spill over into other sectors and affect multiple systems. With this in mind, the municipality plans to remain engaged in European-level initiatives focused on multi-risk assessments. One such initiative is the P2R project, which Svoge applied to during its second call for proposals in August 2025.

4 Progress evaluation and contribution to future phases

This initial CRA for Svoge municipality was developed as the first project deliverable through the application of two workflows. In the upcoming second phase, this assessment will be further refined by integrating reliable local data to improve both its detail and accuracy. This local data will be incorporated into the same workflows to generate a more granular and robust version of the CRA for the second deliverable.

Since the methodology utilized in Phase 1 will continue to guide the CRA work in Phase 2, the tools, insights, and outputs generated so far will remain foundational to all upcoming tasks. Phase 3 will build directly on the work of the first two phases, focusing on updating the municipality's climate adaptation strategy. It will also include review of other relevant policy documents and proposals for their update to reflect the CRA results and conclusions.

This initial CRA will also serve as the foundation for stakeholder engagement and dissemination activities planned for Phases 2 and 3. The municipality intends to expand outreach efforts to a broader range of stakeholders and local residents after Phase 2 is underway, using the results from the first deliverable to both inform and engage. These communication efforts are designed with a dual purpose: first, to raise awareness of the identified risks and the CRA findings, and second, to gather feedback that can inform the refinement and validation of the assessment. In contrast, stakeholder engagement during Phase 1 was more limited in scope and aimed primarily at gathering local insights and experiential knowledge to shape the initial assessment. Stakeholder engagement in Phase 3 will build both on Deliverable 1 and Deliverable 2 to facilitate policy co-creation focused on making CRA insights actionable and continuing to build local ownership of adaptation measures based on the CRA and the amendded municipal Strategy for Adaptation to Climate Change.

Table 4-1 Overview key performance indicators

Key performance indicators	*Progress*
2 workflows (river floods and wildfire) successfully applied on Deliverable 1;	Completed.
2 workflows (river floods and wildfire) successfully applied on Deliverable 2;	To be implemented in phase 2
3 communication actions targeting stakeholders, of which: • one consultation meeting with residents and other stakeholders for input to feed into the process for Deliverable 1; • one meeting with residents and other stakeholders to present the climate multi-risk assessment and collect input for refinement to feed into the process for Deliverable 2; • one co-design meeting with residents and other stakeholders to present the refined assessment and collect feedback for changes to municipal policies in relation to Deliverable 3.	One consultation meeting was conducted, as well as additional ad hoc consultations with various relevant stakeholders, where their input was needed. The remaining two meetings will be held respectively during phase 2 and 3.
at least 5 stakeholders relevant to municipal and regional climate resilience engaged through project activities (residents, local and	Ongoing KPI for the entire project.

Key performance indicators	*Progress*
regional media, business, regional authorities, national authorities, nongovernmental organizations/associations) (KPI applies throughout the project);	For deliverable 1 predominantly local stakeholders with observational knowledge and experience were engaged.
at least 3 press releases to local/regional media on project progress and/or results/impact (KPI applies throughout the project).	Ongoing KPI for the entire project. 1 press release was published and sent out to the media on the participation of the municipal team at the CLIMAAX Barcelona Workshop in June 2025 (included on in the supporting materials on Zenodo).
2 letters to regional/national policy-makers (KPI applies throughout the project).	To be completed in phases 2 and 3.

Table 4-2 Overview milestones

Milestones	*Progress*
M1: Core Municipal Management Team (CMMT) designated by the mayor (Phase 1).	Completed.
M2: Subcontracting support selected and contract signed (Phase 1).	Completed.
M3: Consultation meeting with residents and other stakeholders for input on climate risks is held (Phase 1).	Completed on 17 July 2025.
M4: Workflow 1 tested (Phase 1).	Completed.
M5: Workflow 1 applied (Phase 1).	Completed.
M6: Workflow 2 tested (Phase 1).	Completed.
M7: Workflow 2 applied (Phase 1).	Completed.
M8: The climate multi-risk assessment is produced and submitted to the CLIMAAX Coordinator as Deliverable 1 (Phase 1).	Completed.
M9: The CLIMAAX workshop in Barcelona attended by municipal official(s) (Phase1).	Completed on 10 June 2025.
M10: A meeting with residents and other stakeholders to present the climate multi-risk assessment and collect input for refinement is held (Phase 2).	To be completed in Phase 2.
M11: A report with reviewed and selected local data to plug into the risk assessment is submitted by the external expert team to the CMMT for approval (Phase 2).	To be completed in Phase 2.
M12: Workflows are refined with local data (Phase 2).	To be completed in Phase 2.

Milestones	*Progress*
M13: The refined climate multi-risk assessment is produced and submitted to the CLIMAAX Coordinator as Deliverable 2 (Phase 2).	To be completed in Phase 2.
M14: A co-design meeting with residents and other stakeholders to present the refined study and collect feedback for changes to municipal policies is held (Phase 3).	To be completed in Phase 3.
M15: The Municipal Climate Change Adaptation Strategy is reviewed by the external expert team, which recommends amendments based on the refined assessment, with an emphasis on concrete adaptation measures. Other municipal regulations relevant to these measures are also identified and amendments to make them more efficient in supporting the municipal climate adaptation strategy and policy are proposed (Phase 3).	To be completed in Phase 3.
M16: Proposed amendments to the municipal Climate Change Adaptation Strategy and any other relevant municipal regulations/policies are passed by the CMMT to the municipal leadership for adoption (Phase 3).	To be completed in Phase 3.
M17: the CLIMAAX workshop in Brussels attended by municipal official(s) (Phase 3).	To be completed in Phase 3.

5 Supporting documentation

- Main report in PDF (submitted on the CLIMAAX Deliverable Platform).
- Zip file with workflow notebooks for hazard and risk and plotting results for Workflow 1: River floods (submitted on Zenodo, DOI: 10.5281/zenodo.17092827)
- Zip file with workflow notebooks for hazard and risk and plotting results for Workflow 2: Wildfire (submitted on Zenodo, DOI: 10.5281/zenodo.17092827).
- Press release on the municipal team's participation in the Barcelona workshop in June 2025 (submitted on Zenodo, DOI: 10.5281/zenodo.17092827).

6 References

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