Deliverable Phase 2 – Climate risk assessment

Climate Risk Assessment for Resilient Svoge (CRARS)

Bulgaria, Svoge Municipality

Version 1.0 | July 2025

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

Funded by the European Union

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

Document Information

Deliverable Title	Phase 2 – Climate risk assessment
Brief Description	This document constitutes a refined climate multi-risk assessment produced by the Municipality of Svoge by adding local knowledge and data to the initial CRA for Svoge based on the CLIMAAX common methodological framework, whereby two workflows have been successfully applied for the municipality and the results have been analyzed. This refined CRA has further helped the municipality 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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Deliverable submission date	29/06/2026
Final version delivery date	29/06/2026
Nature of the Deliverable	R – Report
Dissemination Level	PU - Public

Version	Date	Change editors	Changes
1.0	29/06/2026	Municipality of Svoge	Deliverable submitted
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
D1	Deliverable 1
DRMKC	Disaster Risk Management Knowledge Center
EEA	European Environmental Agency
EFFIS	European Forest Fire Information System
FEA	Forestry Executive Agency
FWI	Fire Weather Index
GDFSCP	General Directorate Fire Safety and Civil Protection
IFP	Individual Follow-up Plan
IPCC	Intergovernmental Panel on Climate Change
NSI	National Statistical institute
NPRFM	National Plan for River Flood Management
NIMH	National Institute for Meteorology and Hydrology
NIMH FWI	Fire Weather Index computed by the National Institute for Meteorology and Hydrology based on own collected data
NUTS	Nomenclature of Territorial Units for Statistics
RCP	Representative Concentration Pathways

Executive summary

This Phase 2 Deliverable prepared within the Climate Risk Assessment for Resilient Svoge (CRARS) project, presents the municipality's refined Climate Risk Assessment. Building upon the initial assessment developed during Phase 1 through the successful application of two CLIMAAX workflows based on European datasets - covering river floods and wildfire - the current report incorporates locally collected data to improve the precision, granularity, and practical relevance of the analysis. Following the CLIMAAX methodology, the refinement process focused on enriching the hazard, exposure, and vulnerability components of the assessment, thereby producing a more comprehensive, pragmatic, and policy-oriented understanding of climate risks.

The report begins by outlining the scope of the refined CRA, describing its objectives, methodological framework, stakeholder participation, and institutional ownership. Its overarching purpose is to provide a robust, evidence-based foundation for municipal decision-making by combining scientifically sound analytical methods with detailed local knowledge. In doing so, the assessment aims to support the preparation and implementation of climate adaptation and risk management policies, facilitate access to national and European funding opportunities, and strengthen coordination with regional institutions and stakeholders. As the authority primarily responsible for managing local climate risks, Svoge Municipality recognizes that proactive investment in adaptation represents both the most sustainable and the most cost-effective approach to reducing future impacts, making CRARS implementation a strategic priority.

The report subsequently presents the refined CRA. During Phase 2, the analytical work sought to validate the findings generated through the Phase 1 CLIMAAX workflows by comparing them with local knowledge, stakeholder experience, and additional datasets. It also aimed to enhance those findings by incorporating local data that would increase the spatial detail, contextual relevance, and practical applicability of the results. Overall, the workflow outputs developed during Phase 1 were strongly confirmed by stakeholders, who considered the European datasets appropriate for modelling local climatic conditions. At the same time, participants consistently emphasized the need to translate the outputs into information that could more directly support municipal policy. This objective was achieved by enriching the assessment with additional local data describing hazard characteristics, exposure, and vulnerability for the priority risks. For river flooding, the refinement incorporated information on riverbed conditions, flood protection infrastructure, land use, concentration of industry, and the location of socially important facilities serving the population. This additional data enabled a more precise identification of priority intervention areas and supported the prioritization of adaptation measures according to their urgency and expected effectiveness. For wildfires, the incorporation of local data ana expert analysis into the workflow outputs contributed to showing causality and clarifying how non-climatic factors contribute to the risk - this is important so as to minimize their impact, especially when it comes to human negligence or vegetation substitution planning by the forestry authorities.

The report includes reflections on project monitoring and evaluation, an overview of Phase 2 achieved progress, and a work plan for Phase 3. Svoge considers the second project phase to have delivered substantial added value, both in terms of quality of the refined CRA and institutional capacity developed. The refined CRA provides a solid foundation for the next phase of the project, during which its findings will inform updates to municipal strategic documents and enhance stakeholder engagement activities. Furthermore, the process of integrating local data into the workflows has significantly enhanced the municipality's know-how and practical understanding of the CLIMAAX analytical framework and this will enable its continued application in the future.

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 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 and its tributaries. 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 primary aim of Phase 2 of the CRARS project is the development of a refined and locally grounded multi-risk Climate Risk Assessment (CRA). Building upon the outputs generated through the CLIMAAX workflows, this phase integrates local data, expert knowledge, and local observations in order to produce a more comprehensive, context-specific, and operationally useful assessment. The overarching objective is to ensure that the final CRA provides municipal decision-makers with a robust evidence base for planning, prioritization, and climate adaptation actions. In addition, Phase 2 seeks to improve the precision, depth, and accessibility of the analysis so that its findings can be readily understood and applied by local authorities, practitioners, and stakeholders. Equally important is the ambition to strengthen local ownership of both the process and its outcomes by actively engaging institutional actors, civil society organizations, and community members throughout the assessment.

The analytical work undertaken during this phase has served as a platform for meaningful stakeholder participation and knowledge exchange. Feedback and insights gathered from local actors have contributed to refining the assessment and ensuring its relevance to local realities and priorities. This collaborative approach has also laid the groundwork for the subsequent phase of the project, during which the findings of the CRA will be used to update and further strengthen the Climate Change Adaptation Strategy of Svoge Municipality (adopted by Municipal Council decision in November 2024). At the same time, the assessment will be used to update other relevant municipal regulations within the municipal climate risk management framework, with particular emphasis on prevention, preparedness, and targeted support for groups that are disproportionately exposed or vulnerable to climate-related impacts.

The integration of locally sourced information during Phase 2 has not only validated the outputs generated through the CLIMAAX workflows but has also considerably enriched them. The resulting assessment offers a more nuanced understanding of local risks and vulnerabilities, making its findings more tangible and relevant for municipal planning processes. This additional level of detail increases the credibility and practical value of the assessment, strengthening its usefulness as an instrument for securing national and international funding, attracting investments, and advocating for the implementation of adaptation measures across the municipality.

Furthermore, the work carried out during this phase demonstrates the value of combining a scientifically robust methodological framework of European and global data with local knowledge and evidence. The CLIMAAX workflows provided the conceptual structure, analytical tools, and systematic approach necessary to guide data collection and interpretation, while local datasets and expertise supplied the specificity required for accurate validation and contextualization. Together, these elements have produced an assessment capable of supporting not only local decision-making but also broader regional discussions on climate resilience, disaster risk reduction, and long-term adaptation planning. By showcasing the outcomes of this integrated methodology, Svoge Municipality will be better positioned to advocate for a more coordinated regional approach to climate risk management and prevention.

The refined multi-risk assessment developed through Phase 2 will play a central role in shaping future municipal climate policies and actions. It will inform the revision and enhancement of the municipality's adaptation strategy and serve as a key reference for the preparation and implementation of associated municipal regulations and plans. In addition, the assessment will provide a strong evidentiary foundation for investment proposals, funding applications, and strategic planning initiatives aimed at increasing climate resilience. Its findings will support the selection and prioritization of adaptation measures by providing clear justification for policy choices and resource allocation decisions.

Beyond its strategic planning function, the assessment will contribute to the promotion of climate justice by helping the municipality identify and address the needs of population groups that face disproportionate climate-related risks. It will also support efforts to strengthen prevention-oriented approaches, demonstrating the long-term economic, social, and environmental benefits of investing in preparedness rather than relying solely on reactive measures. Finally, the assessment will be used to improve local and regional coordination in areas such as emergency preparedness, disaster response, and early warning systems.

Svoge Municipality considers the outcomes of the refined CRA to be of substantial value not only for local governance but also for the wider region. To maximize its impact, the municipality intends to actively disseminate the results, lessons learned, methodological approaches, and practical experiences generated throughout the project. By sharing this knowledge through relevant regional networks, institutions, and cooperation mechanisms, the municipality aims to contribute to broader efforts to strengthen climate resilience, risk-informed planning, and adaptation practices across the region.

1.3 Project team

The project team consists of 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 while ensuring that knowledge, know-how, and updates are regularly transferred back to the administration so that it fully benefits from the project as a learning opportunity. The CMMT also oversees the quality and timely delivery of outputs in line with the Work Plan. The external experts support the CMMT by executing assigned tasks and deliverables and providing the expert and technical knowledge essential for the successful implementation of the CRARS project.

1.4 Outline of the document's structure

The principal focus of this report is the refined Climate Risk Assessment (CRA) for Svoge Municipality, developed as the Phase 2 deliverable of the CRARS project (Section 2) in accordance with the CLIMAAX methodology. The section opens with a description of the CRA scoping process, covering its aims, local context, stakeholder engagement, and governance arrangements. It proceeds with an assessment of climate risks based on the outputs generated through the CLIMAAX workflow, supplemented by additionally integrated locally sourced information to provide a more detailed understanding of hazards, vulnerabilities, and exposure factors. Building on these results, the report evaluates the significance and urgency of identified risks, examines existing adaptive capacity, and reflects on monitoring and evaluation outcomes. It also presents the planned activities for the next stage of project implementation. Section 3 summarizes the main findings and overarching conclusions, while Section 4 reviews project progress against key milestones and performance indicators and considers the implications of achieved results for future phases. Additional supporting materials and bibliographic references are included in Sections 5 and 6.

2 Climate risk assessment – phase 2

2.1 Scoping

2.1.1 Objectives

The objectives of the refined climate multi-risk assessment developed by the municipality within the CRARS projects are to operationalise data for policy making and for designing climate adaptation and prevention solutions. 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 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 adopted 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.

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 the analysis. 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 on the one hand. On the other, as Phase 2 has emphasized for us, sometimes local knowledge and data only becomes valuable when placed in the correct analytical framework, which the CLIMAAX methodology enabled us to do for the refinement and showed us how non-climatic factors can enhance the plots and projections.

2.1.2 Context

The Municipality of Svoge possesses a Climate Adaptation Strategy, a comprehensive framework developed by an external expert team and formally adopted in November 2024. 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

During Phase 2 of the project, efforts were broadened to incorporate additional stakeholders to involve the wider community. A meeting was organized to present the initial CRA from Deliverable 1 to seek reactions from stakeholders and the community at large. The discussion was structured along several topics. The first one was whether the CRA results seem plausible and realistic given local and personal knowledge and experience, both expert and non-expert. There were no concerns voiced with the data or the methodology, and the results were validated as credible. Although non-expert opinions would hold less bearing on the validation process, these we still important for the municipal team as a sign of local ownership of the document. The second was whether the results are understandable and what should be done to make them even more clear. There was a consensus that the analytical framework of hazard-vulnerability-exposure as risk components made the results understandable, which testifies to the importance of explaining this framework upfront to equip the community with the necessary analytical toolbox to view the results. Also, meeting participants acknowledged the fact that additional local data on aspects related to exposure and vulnerability would really make a difference for the results, i.e. make them directly applicable to support the adaptation planning activities. The third and final was related to policy implications – did stakeholders think that policy should be based on the CRA, would they support such an approach. Stakeholders were overwhelmingly in favour of using the CRA as the foundation for local adaptation policy and expressed eagerness to see the refined CRA with the added layer of local data and knowledge. Ad hoc bilateral and multilateral consultations and meetings with expert and non-expert stakeholders also fall within the same lines of responses to the three central topics formulated by the municipality to manage the engagement process during Phase 2.

This deepening of the engagement process was only possible as a result of the strong foundation laid in Phase 1. The project's initial phase focused on identifying key participants and launching an ongoing participatory framework as set forth in the work plan. The 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 stakeholder constellation. 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. This first stage of the engagement process has proven to work well for the subsequent steps taken in Phase 2 as described in the previous paragraph.

Upon completion of the first two project phases, effective communication of results to citizens and stakeholders will be a priority once more during Phase 3. This time, the municipality will 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.

In respect to the organization of risk ownership, 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.

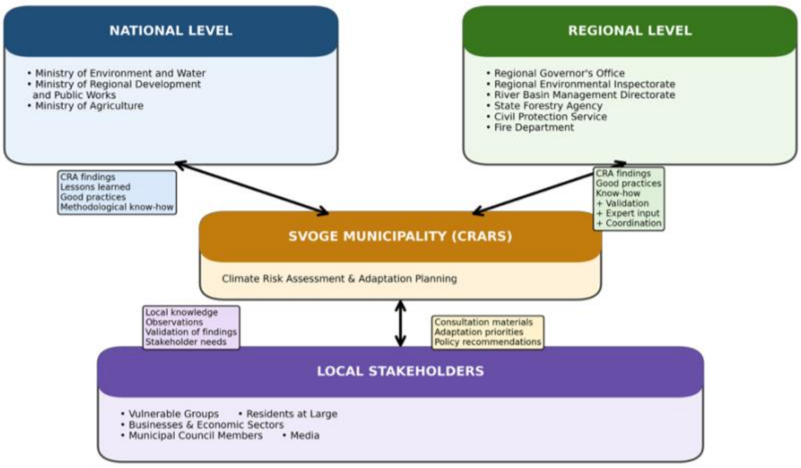


Figure 2-1 Stakeholder communication and information flow for the CRARS project

2.1.4 Application of principles

The CRARS project has placed strong emphasis on inclusiveness, participation, and equitable representation throughout its implementation, ensuring that principles of social justice are embedded within both the assessment process and the resulting policy documents. Continuous engagement with stakeholders has been a central feature of the project, recognizing that the quality and relevance of a climate risk assessment depend not only on technical analysis but also on the knowledge, experience, and perspectives of local actors. In contexts where locally available climatic and environmental datasets remain limited, stakeholder contributions play a particularly important role in validating findings, identifying locally significant vulnerabilities, and strengthening ownership of both the process and its outcomes. The climate risks prioritized through the assessment reflect not only environmental hazards but also the social dimensions of vulnerability and exposure, acknowledging that climate impacts are often experienced unevenly across different population groups and geographic areas. The project has therefore sought to ensure that potentially vulnerable and disproportionately affected segments of the local community are adequately represented throughout the scoping, analysis, and validation stages. Through a structured multi-stakeholder approach, the CRARS project has fostered dialogue, built consensus around findings, and contributed to the development of more just and resilient foundation for adaptation measures.

The analytical robustness and overall quality of the assessment have been ensured through the systematic application of the CLIMAAX climate risk assessment methodology and analytical approach. The project team has remained committed to maintaining a strong scientific foundation while simultaneously ensuring that the assessment produces practical and policy-relevant outputs that can support municipal planning and decision-making processes. Throughout the implementation of CRARS, significant efforts have been invested in strengthening local ownership of both the analytical process and the resulting knowledge products. Particular attention has been given to integrating local data, expert knowledge, stakeholder perspectives, and observational evidence into the assessment framework. This has enabled a more detailed and context-specific understanding of climate risks while increasing the transparency, credibility, and practical relevance of the analysis for local institutions, decision-makers, and community stakeholders.

A precautionary and evidence-sensitive approach has been adopted in relation to data collection and interpretation. The project recognizes that local climatic conditions and risk patterns may not be sufficiently well reflected in regional data based on measurements outside the municipal territory due to the mountainous terrain. For this reason, priority has been given wherever possible to locally sourced information, observations, historical records, and expert knowledge that can improve the precision of the assessment and provide greater clarity regarding local patterns of vulnerability, exposure, and risk. This approach has strengthened the relatability of the findings by ensuring that the assessment is firmly grounded in the specific environmental, social, and economic conditions of the municipality. By combining scientific methodologies with locally validated evidence, the CRARS project has produced a more nuanced and actionable understanding of climate risks that can effectively support future resilience-building measures, adaptation planning, and risk-informed governance.

2.1.5 Stakeholder engagement

Stakeholder engagement has formed a central component of the CRARS project and has been carried out through a combination of public consultations, targeted expert discussions, and bilateral and multilateral meetings with relevant institutional and community representatives. The engagement process was designed to ensure that the climate risk assessment was informed not only by scientific and technical evidence but also by local knowledge, lived experience, and the perspectives of those most exposed and vulnerable to climate-related risks.

The main stakeholder engagement activities included a public consultation meeting involving priority groups and members of the wider public, as well as a series of ad hoc bilateral and multilateral meetings with municipal and regional experts, representatives of public institutions, and representatives of groups disproportionately affected by the analysed climate risks. These communications were organized throughout the refinement process of Phase 2 to gather information, validate findings, discuss results, and ensure that the assessment adequately reflected local conditions and priorities.

Project goals, methodologies, and expected outcomes were communicated through presentations, facilitated discussions, and targeted consultations. Participants were informed about the objectives of the CRARS project, the analytical framework used for the climate risk assessment, and the intended application of the assessment results in future municipal planning, climate adaptation measures, disaster risk management, and resilience-building activities. Particular attention was devoted to explaining the purpose of stakeholder contributions and the ways in which local knowledge would complement technical analyses and available datasets to refine the initial CRA.

Participants actively contributed information regarding observed climate impacts, local vulnerabilities, exposure patterns, and existing coping capacities within the municipality. Municipal and regional experts provided sector-specific insights related to infrastructure, environmental management, emergency response, public services, and local development planning. Representatives of disproportionately affected groups highlighted challenges faced by vulnerable populations and contributed valuable perspectives on the social dimensions of climate risk. Members of the public also shared observations and experiences regarding recent climate-related events and their impacts on local communities and livelihoods.

The feedback received during the consultation and meetings played an important role in refining the assessment. Stakeholder contributions were used to validate analytical findings, supplement available data, identify locally significant risk drivers, and improve the overall accuracy and relevance of the climate risk assessment. The information gathered also helped prioritize risks, strengthen the understanding of vulnerability and exposure factors, and ensure that the final outputs were grounded in local realities. The outcomes of the engagement process will continue to inform the subsequent third project phase, aimed at the development of adaptation measures, resilience-building actions, and creating an enabling policy framework for future municipal planning processes.

Several challenges were encountered during the engagement process. As is often the case in local climate adaptation initiatives, stakeholders had varying levels of familiarity with climate risk assessment concepts and methodologies, requiring additional effort to ensure a common understanding of project objectives and terminology. In addition, the limited availability of detailed local climatic data increased the importance of stakeholder knowledge and validation. These challenges were addressed through targeted communication, flexible consultation formats, and continuous dialogue with stakeholders throughout Phase 2.

Overall, the engagement process successfully strengthened the quality, legitimacy, and local ownership of the CRARS refined CRA. It ensured that the project reflected both scientific evidence and community perspectives while building a stronger foundation for future climate adaptation and resilience-building efforts within the municipality.

2.2 Risk Exploration

2.2.2 Screen risks (selection of main hazards)

During the second phase of the CRARS project, Svoge Municipality retained the two priority climate risks identified and selected for the CRA during the initial assessment process in Phase 1- wild fires and river flooding. Building upon the methodological foundation provided by the CLIMAAX framework, Phase 2 focused on enriching the initial assessment through the integration of local and regional data, analyses, and observational knowledge. Following the analytical logic of examining climate risks through the interconnected dimensions of hazard, exposure, and vulnerability, the project team has been able to identify, collect, and utilize additional information that enhanced the level of detail and contextual relevance of the workflow results. This process enabled a more nuanced understanding of local risk conditions and strengthened the practical value of the assessment for municipal planning and decision-making.

Since the completion of the initial risk screening undertaken as part of Deliverable 1, no significant changes have occurred that would warrant a revision of the risks included in the assessment framework. The underlying assumptions, prioritization criteria, and screening outcomes remain valid and continue to accurately reflect the climate-related challenges faced by Svoge Municipality. Consequently, the risk screening findings presented in Deliverable 1 remain fully applicable and provide the foundation upon which the refined analyses and additional insights during Deliverable 2 have been developed.

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 has often been 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.

Classified 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 occurrence, 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 consequences have a high toll on the local population. Therefore, the municipality is putting a very strong emphasis on prevention – an aspect that has been dysfunctional so far, with actions being taken more often than not after the occurrence 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 when 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.

2.2.3 Choose Scenario

In assessing the two priority risks, the analysis considered a range of climate change scenarios alongside potential socio-economic trends and development pathways that may influence future risk levels and impacts.

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, with existing infrastructure largely unequipped to withstand severe flood events, the municipality lacking resources to respond and recover, and the local population with a low purchasing 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 Regionalized Risk Analysis

2.3.1 Hazard #1 - fine-tuning to local context: River Flooding

Table 2-1 Data overview workflow #1: River Flooding

Hazard data	*Vulnerability data*	*Exposure data*	*Impact metrics/Risk output*
JRC high-resolution flood hazard maps in historical climate for Europe	*JRC damage curves for land use*	*JRC LUISA land use data (100 by 100 meter resolution land use in 2018 in Europe)*	*Economic damage estimate, i.e. damage maps based on flood 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*		
Protective infrastructure; *Condition of the riverbed;* *Landslides in proximity that are of significance as flood enhancing factors in the event of very heavy extreme precipitation.*	*Data on presence along the river beds at risk hotspots of buildings, socially important infrastructure – hospitals, social service providers; critical infrastructure - transport, electricity; economy significant facilities – industry; residential areas at risk.*	*National land use data, source: National Plan for Management of the River Flood Risk*	*Enhanced granularity of risk hotspots plotted by the workflow by incorporation of local data crucial for policy-making purposes*

2.3.1.1 Hazard assessment

As part of the second phase of the CRARS project, additional locally sourced information was incorporated into the river flood assessment in order to refine the workflow outputs and improve the identification of areas facing the highest levels of risk. The integration of local data enabled the assessment to address limitations associated with factors that are not captured adequately through climatic datasets alone. In particular, the analysis considered a range of local conditions that influence flood hazard dynamics, including the physical condition of riverbeds, the presence and effectiveness of protective infrastructure, and the proximity of landslides that can exacerbate river flooding if activated in the case of extreme precipitation. These factors the team has come to the realization can significantly influence the extent and severity of flood impacts and therefore play an important role in determining actual risk levels on the ground.

The decision to incorporate these additional data layers was informed by two complementary considerations. First, stakeholders consistently emphasized the need for greater local detail and contextual information to support decision-making and the prioritization of adaptation measures. Secondly, these are data that are important elements of policy-making that unlock a plethora of possibilities for adaptation measures to be considered and initiated.

The locally collected information was used to complement and refine workflow outputs by providing a more detailed perspective on locations already identified as areas of elevated risk. In this sense, the local data functioned as a means to amplify the resolution of the results of the hazard assessment, allowing for a more precise interpretation of local conditions and risk drivers. This approach strengthened the practical relevance of the analysis and enhanced its usefulness for planning and policy purposes.

To facilitate a clear understanding of the assessment process, this section first presents an overview of the workflow computations and their principal outputs. This provides the necessary analytical context before introducing the additional local information used to refine the assessment. The subsequent section then examines in greater detail how this locally derived data contributed to the interpretation of the results and to the refinement of the final river flood risk assessment findings.

The river flood hazard assessment workflow selected and employed in Phase 1 of the CRARS project has been utilized 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. 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 analyse 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 km^2; 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. Batuliyska river, a concern of secondary magnitude, is also plotted.

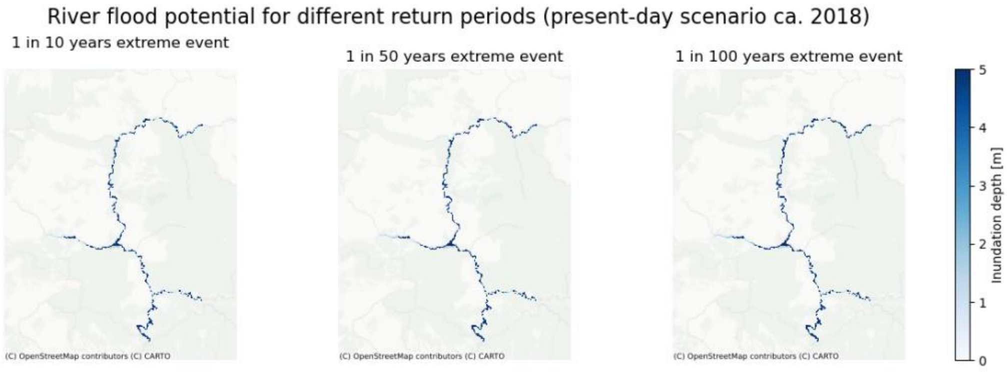


Figure 2-2 Flood inundation maps for the area of the Municipality of Svoge for extreme events with different return periods based on European high-resolution dataset

Another recognized limitation pertains to the dataset's flood modelling, which does not incorporate the presence of existing man-made protective infrastructure such as dams, levees, or dikes. This limitation has been addressed in Phase 2 by adding this layer of local data, plus information on the condition of the riverbed with particular focus on human interventions altering the riverbed and hence increasing the intensity of the hazards – for instance covering the riverbed with concrete or abundant construction in immediate proximity to the riverbed that is located in the natural river floodplain. In a nutshell, the riverbed of all three rives under consideration (Iskar, Iskretsa, Batuliyska) is in bad condition entirely, no recent cleaning has been carried out with the exception of an emergency partial clearing of the Iskretska riverbed in 2024. There is no modern protective infrastructure but currently on the right side of the Iskar river passing through the Svoge city area protective dikes are to be build under an ongoing project for 1086 km of the riverbed (from the end of the city stadium to the end of the city regulation). Iskretsa river in the urbanized Svoge area runs in an artificially created concrete bad - a practice considered protective in the past but currently rather enhancing the risk of flooding. The Ezerishte landslide has been considered as well due to its proximity because its activation during extreme precipitation events can obstruct the Iskar riverbed entirely and augment river flooding substantially.

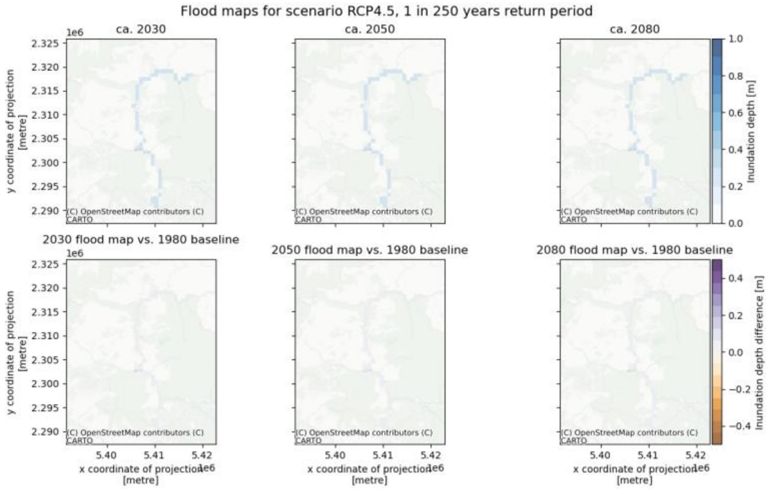


Figure 2-3 Flood maps for the municipality of Svoge for scenario RCP4.5, 1 in 250 years return period

A key advantage of this hazard assessment workflow, which has been of great help to the team, lies in its ability to model the projected impacts of climate change on river flood behaviour under two representative concentration pathways—RCP4.5 and RCP8.5. By analysing 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. 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 informed adaptation planning and long-term resilience building, despite the spatial limitations of the dataset.

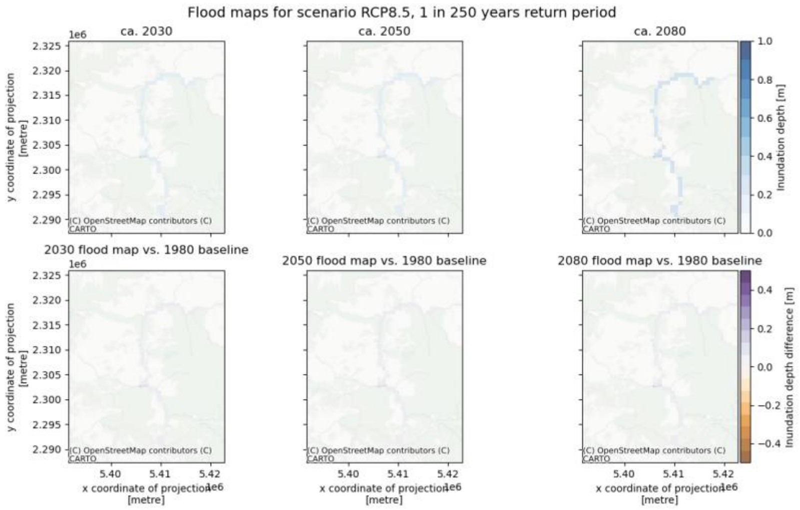


Figure 2-4 Flood maps for the municipality of Svoge for scenario RCP8.5, 1 in 250 years return period

2.3.1.2 Risk assessment

As part of the Phase 2 refinement process, additional locally sourced information was integrated into the vulnerability component of the river flood risk assessment. This included data on the concentration of economic activities – industrial facilities, located within or adjacent to the river floodplain, as well as the location of facilities and buildings of particular social significance, and critical infrastructure related to water supply and sanitation and the electricity grid, residential areas in immediate proximity. Special attention was paid to infrastructure providing essential services to vulnerable population groups, including childcare centres, facilities for social support, and residential care services. The incorporation of these non-climatic vulnerability factors on top of the risk hotspots for potential damages identified by the workflow provided a more comprehensive understanding of the potential consequences of flood events for the local economy, the provision of critical social services, and basic critical infrastructure that if disrupted would cause continued negative impact.

When combined with the supplementary local information incorporated into the hazard dimension of the assessment - such as the condition of riverbeds, the presence and state of flood protection infrastructure, the presence of human-made obstructions to the riverbed, the analysis produced a significantly more detailed picture of areas facing elevated levels of risk according to workflow results. This enhanced understanding of local conditions enabled the identification of priority hotspots where the potential impacts of flooding are likely to be greatest and where adaptation measures would yield the highest benefits. The refined assessment therefore provides a stronger basis for determining the timing, scale, and prioritization of future risk reduction and adaptation interventions.

In the interest of transparency and methodological consistency, it is important to emphasize that the additional local data was used to refine and contextualize the existing workflow outputs rather than replace them. Because the value and interpretation of the newly integrated information depend on the underlying results generated through the original risk assessment workflow, the following section presents a summary of the computations and outputs produced during Phase 1. This overview provides the analytical context necessary for understanding the refinements introduced through the integration of local data and the resulting enhancement of the final river flood risk assessment.

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.

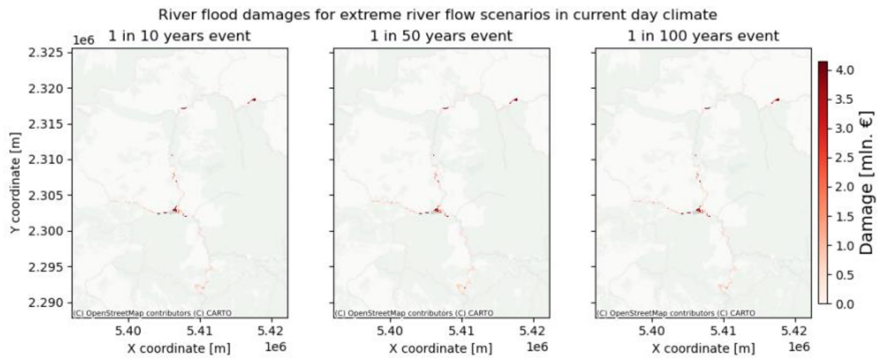


Figure 2-5 River flood damages for extreme river flow scenarios for the municipality of Svoge in current day climate

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 modelled 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 2-5.

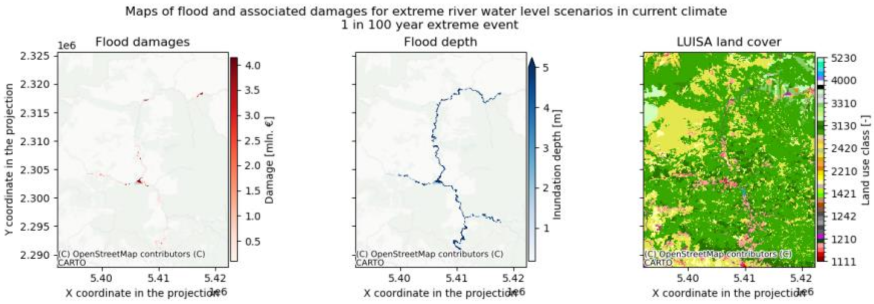


Figure 2-6 Maps of flood depth, associated damages, and land use for the municipality of Svoge for extreme river water level scenarios in current climate, 1 in 100 year extreme event

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 2-6 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 2-6 enabled the identification of key hotspots where significant economic losses from river flooding are most likely to occur under the modelled 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.

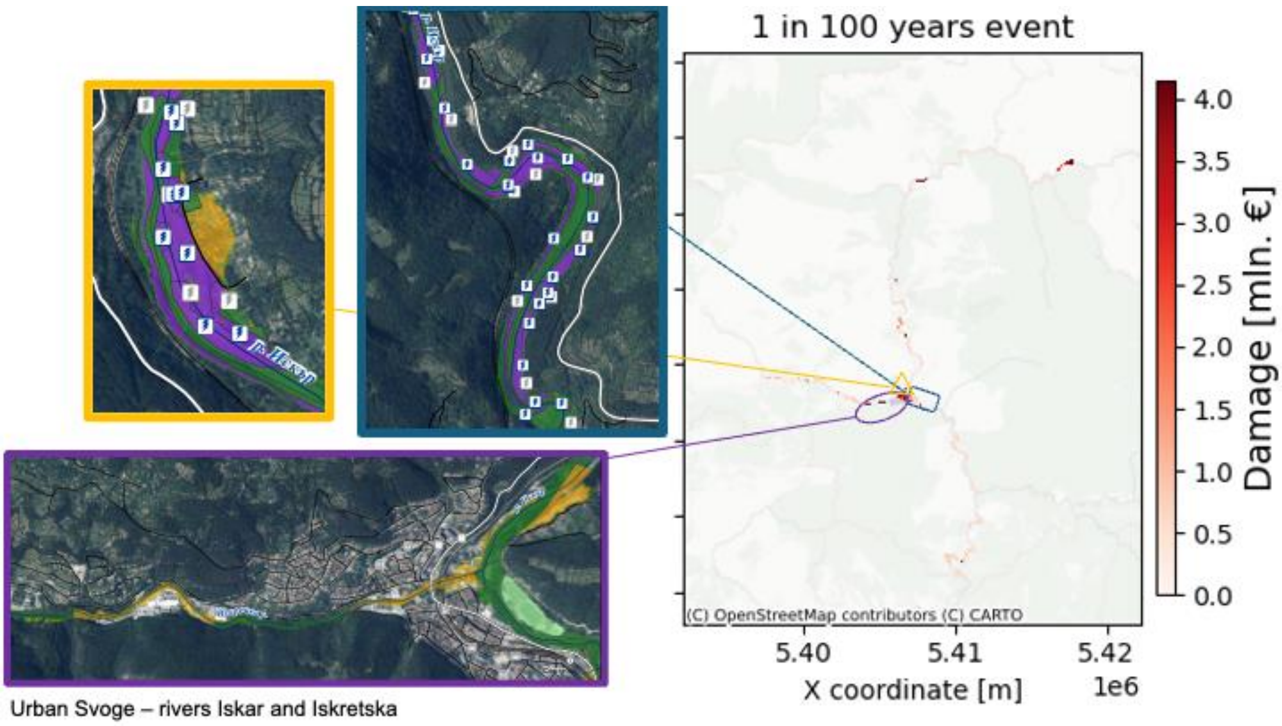


Figure 2-7 Map of flood damage risk with incorporated data of zoomed risk hotspots in URBAN SVOGE on infrastructure (energy and transport – labeled with white rectangular signs; vulnerable, social and economy important facilities (hospitals, schools & other – letter labeled; residential areas – orange colored; concentration of industry – purple colored)

On top of the computed plots, local data has been incorporated and used to granulate select hotspots. Figures 2-7 and 2-8 visualise this granulation by using data from the National Plan for Flood Risk Management to show concentration of economic activities – industrial facilities, located within or adjacent to the river floodplain, as well as the location of facilities and buildings of particular social significance, and critical infrastructure related to water supply and sanitation and the electricity grid, residential areas in immediate proximity. Figure 2-7 focuses on the risk damage hotspots in urban Svoge while Figure 2-8 focuses on the ones in rural areas. Important to note, the visualised segment of the Iskretsa river includes the part that runs in a concrete riverbed in the urban zone and puts in risk residential areas. The Iskar river on entering the urban area from the North, places under risk energy infrastructure and industrial facilities of importance to the local economy. Based on local data, in the non-urban areas in Figure 2-8, two hotspots have been highlighted although not being too high on the damage cost scale – the Zhelen area and the Rebrovo area. The team decided it was essential to include these in the emphasized insights in the refined CRA for the following reasons: in the Rebrovo area river flooding from Batulyiska river could cut critical infrastructure and roads to residential areas where around 1300 people are located; in the Zhelen area this is where the Ezerishte landslide is located in proximity to the riverbed and can potentially exacerbate flooding if activated in the event of extreme precipitation by obstructing the riverbed entirely. Used local data on infrastructure, land use, facilities and amenities has been selected from the National Plan for Flood Risk Management and represents the 20 year return period risk of high probability – this was selected as most useful for policy-making purposes as it provides spatial overview of what needs to be prioritized for adaptation in the short-term.

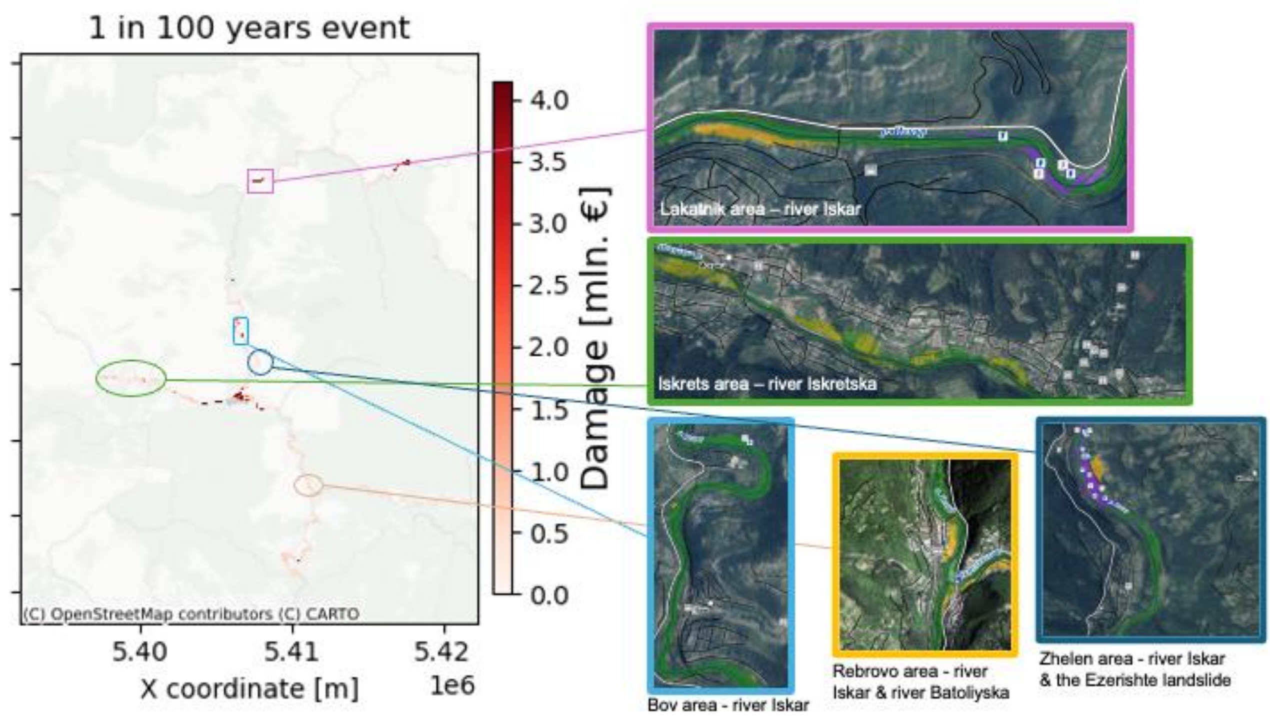


Figure 2-8 Map of flood damage risk with incorporated data of zoomed risk hotspots in RURAL SVOGE areas on infrastructure (energy and transport – labeled with white rectangular signs; vulnerable, social and economy important facilities (hospitals, schools & other – letter labeled; residential areas – orange colored; concentration of industry – purple colored)

2.3.2 Hazard #2 - finetuning to local context: Wildfire

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

Hazard data	*Vulnerability data*	*Exposure data*	*Impact metrics/Risk output*
Fire Weather Index from the Copernicus Climate Data Store (CDS) – EURO-CORDEX data.	*CDS datasets for the following vulnerability indicators: population in WU interface, protected land areas, ecosystem irreplaceability index, population density, restoration cost 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.*
NIMH FWI, Source: NIMH; *Historical analysis of fire incidents, Source: GDFSCP;* *Analysis of type of fire based on historical data, Source: GDFSCP*	*Analysis of fire management capacity based on terrain specificities, Source: GDFSCP*	*Tree species in risk hotspots, Source: State Forestry Enterprise "Svoge";* *Analysis of seasonal variability due to specifics of vegetation and terrain, Source: FEA, GDFSCP*	

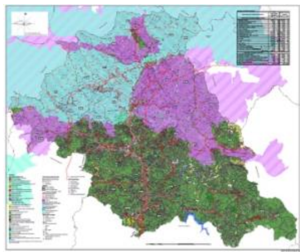
2.3.2.1 Hazard assessment

During Phase 2, the team build on the FWI Wildfire Hazard workflow outputs by incorporating local data on type of fires, local FWI based on NIMH measurements, analysis of the importance of the human factor, and analysis of a historical overview of fire incidents. The NIMH FWI was studied against the workflow outputs, as well as historical and operational data from the fire department, to add an extra layer of local detail to the elements of exposure, vulnerability and hazard in order to obtain a more granular landscape of the intensity, specificity and special and temporal distribution of the risk on the territory of the municipality. An examination of the historical data by the General Directorate Fire Safety and Civil Protection and the Forestry Executive Agency for the last decade (2016-2026), point that the municipality of Svoge is vulnerable primarily to low-lying fires in inaccessible mountainous areas and during autumn droughts. Due to the mountainous terrain in the Iskar Gorge, controlling the fire elements here requires specific logistics and volunteer formations. The usual type of burning is characterized by lowland fires (fallen leaves, dry grass and bushes). The risk of fire onset in Svoge is also differentiated – lower in natural beech and oak forests (where moisture is retained longer) and significantly higher in the artificially created coniferous forests from the past (white and black pines on the slopes of the gorge), which are highly vulnerable to peak fires. This detail is very helpful in reading the workflow results as it adds to local understanding why certain locations identified by the workflow are more at risk of fire and provides an additional set of potential ideas for adaptation. In respect to seasonality, a shift in the fire season has been observed over the past 10 years - in addition to the traditional summer months, serious fires have started to occur in October and November (due to dry and warm autumns) and in March (due to the rapid drying of the previous year's grass vegetation and the burning of stubble). Historically, the average summer FWI values, calculated by the NIMH with own data from measuring stations in proximity, in the Svoge region have ranged from 11.2 to 21.3 (moderate risk). During periods of prolonged drought (such as the extreme summers of 2000, 2007, and 2024), the index for Sofia region reached levels above 38.0–50.0 (Very High to Extreme risk). In general, available local data and studies by the relevant local, regional, and national institutions have confirmed workflow outputs as valid and helped the team see these through a more local lenses to facilitate its integration into policy-making by making them more relatable and understandable for the local decision-maker, especially in terms of causality and local peculiarities.

This data is only useful against the workflow outputs of the FWI Wildfire Hazard workflow to add more detail and explain additionally with local specificities the obtained results. For methodological clarity, an overview of the utilized workflow will be provided. The FWI Wildfire Hazard workflow has been 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 where Svoge municipality is located as this was the administrative division available through bounding box. This however has not posed 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 grey and Svoge in yellow.

Geographical map of Svoge municipality showing the terrain.

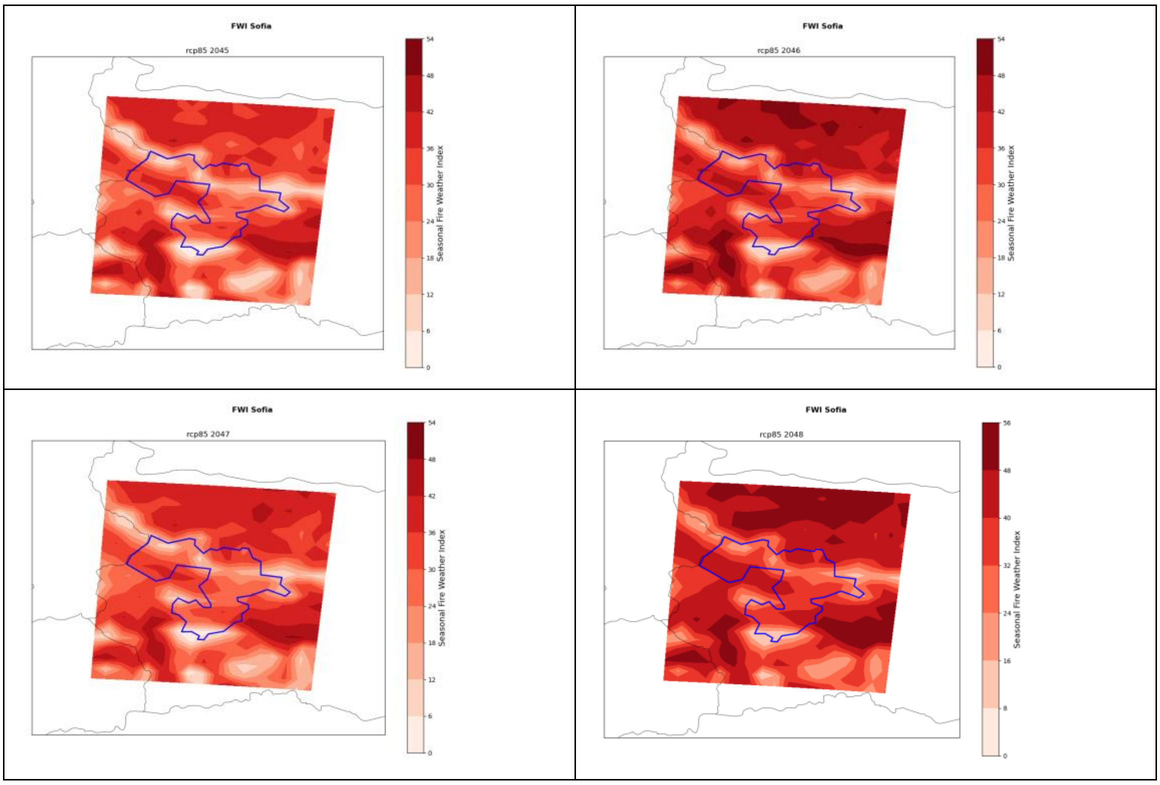


General development plan of Svoge municipality approved in June 2023

Figure 2-9: 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 analysed 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 favourable 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 was selected as this gave 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 sufficiently advanced against the local tolerance threshold and capacity. 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 analysing 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.



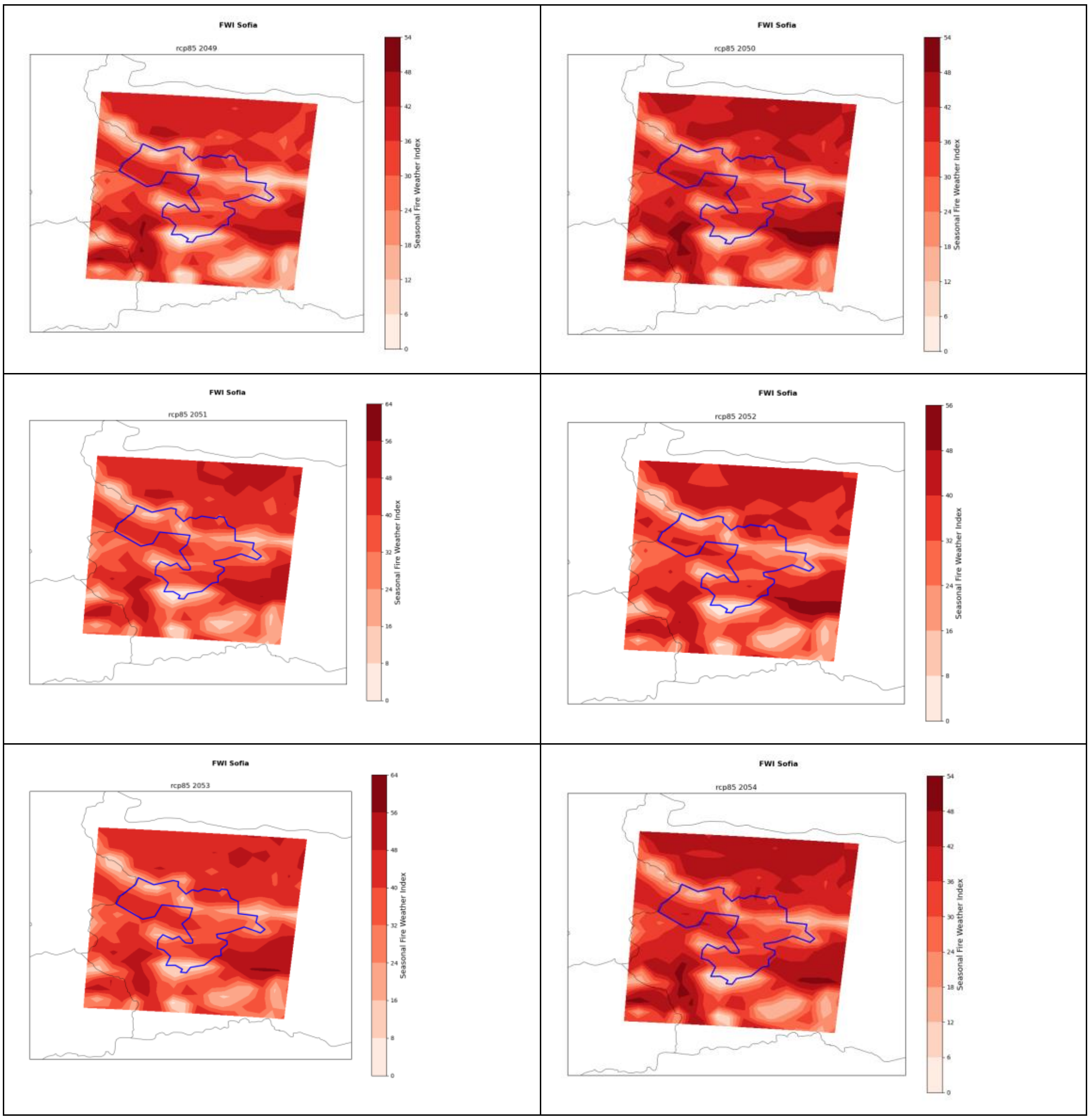


Figure 2-10 Fire Index Intensity Maps for Svoge municipality within the region of Sofia for RCP 8.5 for the 10 year period of 2045-2054

The hazard workflow has 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. This output coincides with the local data on the presence of artificially planted coniferous forests in these areas that are more susceptible to fire as they get sick and dry out due to the unsuitable conditions for these kind of trees in the area as can be seen in the risk section below.

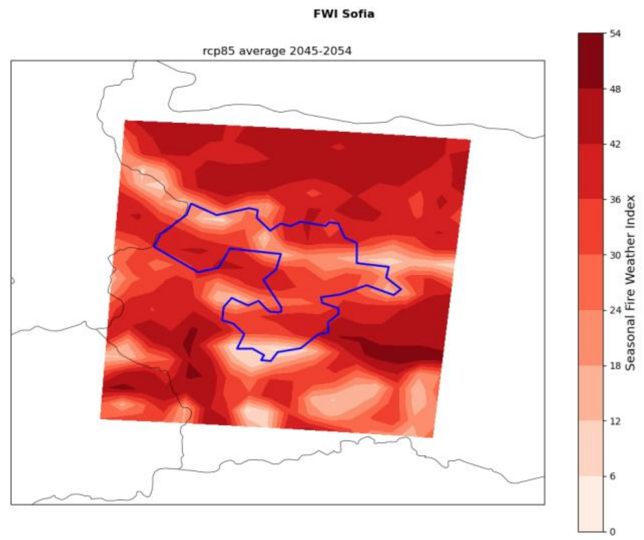


Figure 2-11: Average Seasonal FWI intensity for the period 2045-2054 for Svoge municipality within the region of Sofia.

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 regions. The data on seasonality from local observations adds one important detail to the output in respect to the hazard component as the workflow does not capture the March peak in forest fires, which is a new phenomenon due to the fast drying out of vegetation. This detail is important for local policy-making and capacity planning and once more proves that local observational knowledge and national data can really contribute to operational clarity of workflow outputs.

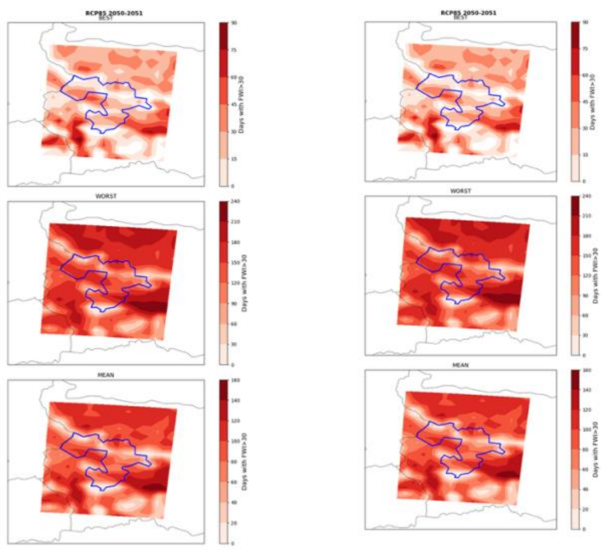


Figure 2-12 Juxtaposition of the maps for the two plots with historical and future data for RCP8.5 for the period 2050-2052 with FWI>30

2.3.2.2 Risk assessment

In Phase 2 we looked into local data that would contribute towards solving the two limitations to the risk workflow mentioned in the methodology. As discussed in Deliverable 1, the first one related to the fact that the workflow 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 occurrences and isolates the instances of fire due to human activity – intentional or unintentional – both of which have proven not only possible but frequent in the municipality. Thus, looking into fire department analyses, it is pointed out that more than 90% of wildfire occurrences in the municipality are the result of human activity and negligence. This information is important as it emphasizes the need to address lack of public awareness in policy-making. Of course, it does not decrease the importance of the fact that climatic conditions is what have created the conducive set of parameters to make human negligence more easily cause wildfire ignition. 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. Additional local data from analysis by the FEA and GDFSCP indicate that fires are difficult to manage and extinguish due to the mountainous terrain so prevention should rather be prioritized.

The utilized 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.

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 possibility to clearly identify areas by layering and juxtaposing maps. The fire danger definition is composed of two components - the seasonal FWI representing the climatic favourability 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 vegetation is available and the FWI index is higher. This is an area where coniferous forests have been artificially planted in the past which according to local observational knowledge and analysis by the Forestry Executive Agency and the Fire Department are more susceptible to ignition.

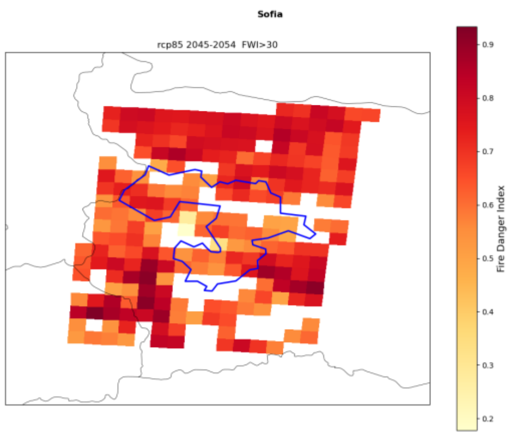


Figure 2-13 Fire Danger Index map for RCP8.5 2045-2054 with FWI>30 for Svoge municipality within the region of Sofia

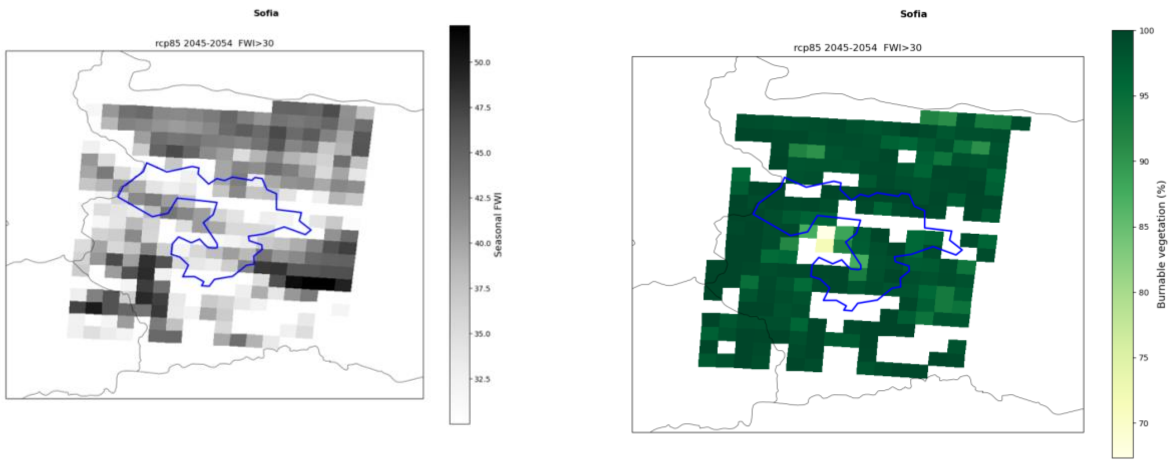


Figure 2-14 Maps illustrating the components of the fire danger index, i.e. seasonal FWI and availability of burnable vegetation for RCP 8.5 for the period 2045-2054 with FWI>30

Looking at local data – records from the fire department, it is visible that instances of wildfire and fires of vegetation outside urbanized areas have been on the increase. Combined with the conclusion that most fires in non-urban areas are the result of human negligence, this is particularly important as it shows that the impact of human negligence, in terms of the probability it would cause fire, has been increasing with the change in climatic conditions as a decisive conducive element for the ignition of fires.

Table 2-3 Number of fire incidents on the territory of Svoge municipality 2021-2025 (excerpt data on particular types of fire)

Type of fire	Year 2025	Year 2024	Year 2023	Year 2022	Year 2021
Forest fires	*5*	*5*	*2*	*4*	*2*
Fires in dry grass and fallen leaves and bushes in non-urbanized areas	*6*	*6*	*6*	*4*	*1*

The vulnerability component of the workflow includes data on the indicators of population from the Wildland Urban Interface, protected areas fraction, ecosystem irreplaceability, 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 spatial resolution of 11x11km, whereby a risk dot indicates the centre 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.

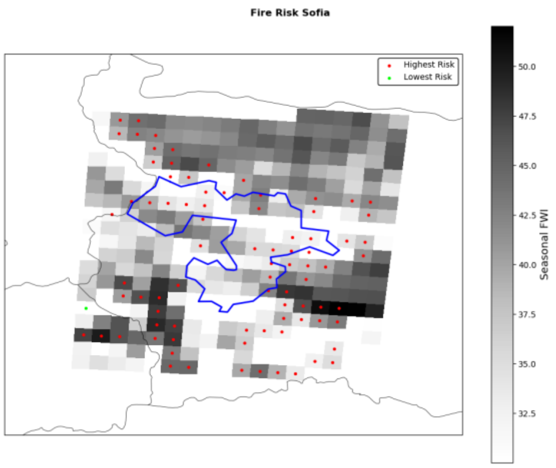


Figure 2-15 Fire risk map for Svoge municipality within the region of Sofia

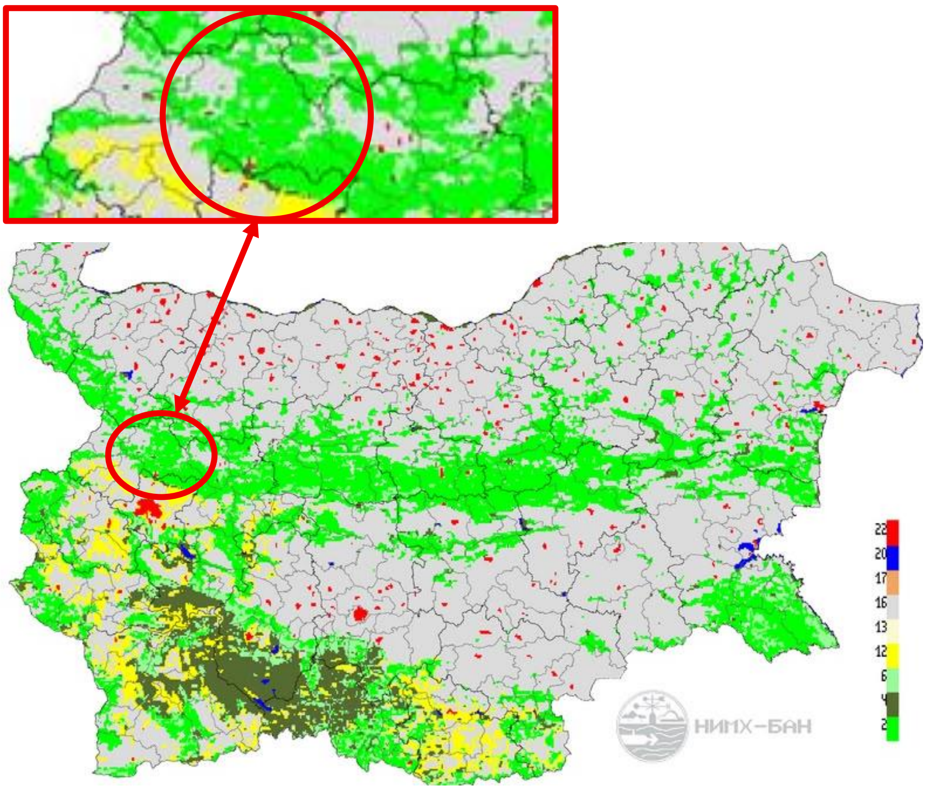


Figure 2-16 Map of tree species in risk hotspots, light green – deciduous forest, dark green – coniferous forest, Source: NIMH map.

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.

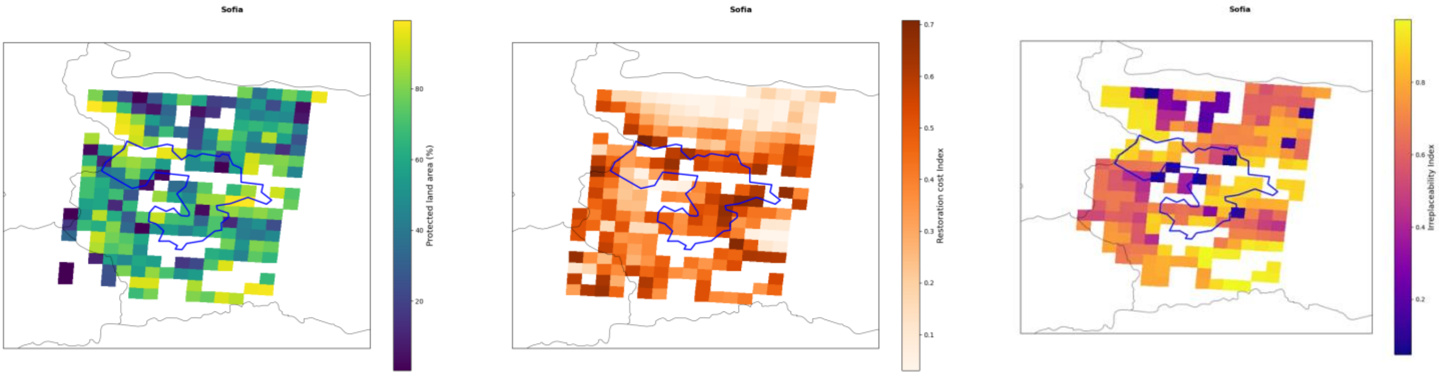


Figure 2-17 Maps showing three indicators from the vulnerability component as follows from left to right: protected land area, restoration cost index, and ecosystem irreplaceability index

2.4 Key Risk Assessment Findings

2.4.1 Mode of engagement for participation

The stakeholder engagement process and communication activities are described in Section 2.1.5. Hence, the current section will focus of feedback received from stakeholders. Feedback collection throughout Phase 2 was primarily aimed at supporting the following priority objectives: to assess the extent to which stakeholders agreed with or challenged the workflow outputs produced under Deliverable 1; to see to what extent stakeholders agreed the CRA should be used as the foundation for policy-making; and to gather additional information and local perspectives that would contribute to refining the Climate Risk Assessment for Deliverable 2.

Prior to the formal consultation process, the project team had already undertaken a series of informal validation actions, such as bilateral exchanges with relevant stakeholders. These preliminary interactions provided an initial indication that the workflow outputs corresponded closely with local observations and experiences.

The consultation process ultimately confirmed the reliability and acceptability of the initial assessment results. Stakeholders consistently expressed confidence in the workflow outputs and broadly agreed that the identified patterns of risk reflected the realities experienced within the municipality and should be placed at the core of policy formulation and decision-making. No significant objections or challenges to the overall findings emerged during the discussions. Instead, participants largely viewed the results as credible and representative of local conditions but expressed concern with their ability to “read” the results and therefore emphasized the need for greater detail and contextualization of the findings. While the identified areas of elevated risk were considered reliably computed, many participants sought a clearer explanation of the specific local factors contributing to these results, apart from climatic conditions, and the practical implications of these in particular with a focus on what needs to change or be initiated to decrease the risk level. In particular, stakeholders highlighted the importance of supplementing the workflow outputs with information on local place-specific conditions that influence risk levels and potential impacts.

A recurring message throughout the engagement process was therefore the need to further refine the assessment through the integration of local data and knowledge. Stakeholders expressed a strong preference for a more detailed and operational understanding of the identified risks that would facilitate the prioritization of adaptation measures and support evidence-based decision-making. In essence, the feedback pointed towards the need to make workflow results more easily readable and understandable in terms of causality, enhancing their granularity and relevance to local circumstances. This additional level of detail was seen as essential not only for making the Climate Risk Assessment more practical for policy-oriented, but also for improving its accessibility and helping stakeholders better understand what is at stake, which areas are most exposed, and where adaptation efforts should be focused as a matter of priority due to their relatively higher level of impact. Stakeholders agreed that this would make the CRA even more indispensable for the policy-making process.

2.4.2 Gather output from Risk Analysis step

A central element of the stakeholder engagement and communication process was the explanation of the analytical framework underpinning the assessment. The project team placed particular emphasis on demonstrating how climate-related hazards interact with the dimensions of exposure and vulnerability to produce risk. Considerable effort was made to illustrate that vulnerability and exposure are often shaped by social, economic, demographic, infrastructural, and other non-climatic factors, which can significantly influence the severity and distribution of climate impacts. This approach proved highly effective in helping stakeholders understand the logic of the assessment and the rationale behind the identified risk areas.

Throughout the assessment process, the project team made extensive use of the outputs generated by the CLIMAAX workflows at both the hazard and risk levels. For the river flood assessment, particular attention was given to the hazard outputs illustrating flood potential under different return periods, which provided an evidence-based understanding of the likelihood and spatial distribution of flood events. These findings were complemented by the river flood risk outputs, including flood damage maps and the identification of hotspots characterized by elevated potential economic losses. Together, these outputs offered a comprehensive picture of both the physical hazard and its potential consequences for the municipality.

In the case of forest wildfires, the analysis relied on workflow outputs showing the fire danger index. Additional information was derived from the mapping of the elements of vulnerability. These outputs enabled the municipality to better understand how wildfire risk is expected to evolve in the future due to climate conditions, and see a spatial distribution of how this evolution of the risk would affect different areas and what that would mean for the municipality.

Feedback received during consultations indicated that stakeholders found the hazard-exposure-vulnerability framework intuitive and useful. Many participants noted that this way of analysing climate risks made the subject more tangible and easier to relate to local realities. Rather than perceiving climate change as an abstract or purely scientific concept, stakeholders were able to connect the impact of climatic hazards to concrete places, assets, disproportionally affected population, and activities within the municipality. As a result, the framework contributed to increasing the practical relevance of the Climate Risk Assessment and facilitated more informed discussions about adaptation priorities and future policy responses.

2.4.3 Assess Severity

The analysis conducted with the incorporation of local data in Phase 2 has confirmed the preliminary conclusion from Phase 1 that both analysed risks – river floods and wildfire will become of increased severity. Work during the Second Phase has contributed to making the workflow results more precise, understandable and relatable for local stakeholders with the aim of adding the necessary elements of detail to enable policy-making decisions based on the CRA. The results from the assessment are interpreted below, including insights both from the risk and hazard workflows and the local data incorporated in Phase 2.

The assessment of risk severity is founded on two complementary sources of evidence: the analytical outputs generated through the CLIMAAX workflows and local data, including knowledge gathered through stakeholder engagement. By combining scientifically derived workflow results with local expertise and practical experience, the assessment provides a more comprehensive and context-specific understanding of the significance of the identified climate risks.

It is important to emphasize that municipal officials and technical experts from the municipal administration were considered key stakeholders throughout the process. Owing to their day-to-day responsibilities, long-term experience, and familiarity with local conditions, they were uniquely positioned to complement the workflow outputs with observational knowledge and operational insights. Their contributions played an important role in validating the analytical findings, interpreting the local implications of the identified risks, and ensuring that the assessment accurately reflects conditions and priorities within the municipality.

The river floods hazard assessment results show an increase in severity under the historic, the RCP4.5, and the RCP 8.5 climate scenarios. Stakeholders have agreed with this trend as most feasible. 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 analysing 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, Lakatnik, and Bov. 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. As seen from local data on land use, facilities and infrastructure in proximity, concentration of industry are all aggravating factors. Local data also points to the bad condition of the river bed and the absence of functional protective infrastructure, which contributes to the increased potential impact of the risk. There are two risk hotspots of lower damage cost – Zhelen and Rebrovo, which have been studied by the team because the non-climatic element of landslides in immediate proximity to the riverbed could in an extreme precipitation events change the magnitude of flooding dramatically if the riverbed is obstructed by land mass.

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. Local data points to the presence of artificially planted coniferous trees as a potential explanation for this. 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 spatial 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 unequivocally confirmed with the workflow is a clear indication that the municipality needs to step up its actions in adaptation and prevention. This trend is also confirmed by local data which shows an increase in number of fires in recent years and the availability of more burnable dry vegetation at certain points in time during the year as seen in the hazard section. Stakeholders emphasized they observe an increase in severity which is of concern in particular for urbanized areas in proximity to areas of heightened risk.

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 spatially 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 approximately 0.6. The irreplaceability 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.

2.4.4 Assess 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. With the incorporated local data on land use, nearby infrastructure, facilities, riverbed condition and protective infrastructure, 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.

2.4.5 Understand Resilience 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. Protective infrastructure is presently absent, the riverbed is in bad condition and not cleared periodically, construction near the riverbed is at points contributing to the potential risk magnitude. 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. Given the nature of fires and the mountainous terrain, which make fire management more difficult, targeted adaptation planning is crucial. As the refined CRA also identifies some of the reasons for heightened risk in some locations that are due to non-climatic factors, action is to be taken to tackle these. Capacity building should also be directed towards awareness raising and building volunteer groups – this is particularly important given the high percentage of human negligence induced fires.

2.4.6 Decide on Risk Priority

The prioritization of climate risks was undertaken using the CLIMAAX Key Risk Assessment Protocol and the associated assessment dashboard. The evaluation process combined the structured methodology provided by the CLIMAAX framework with the collective knowledge and professional judgement of the project team. Risk scores were determined through a series of internal discussions drawing on the team's expertise, practical experience, and understanding of local conditions, while also as a priority incorporating evidence gathered through stakeholder engagement activities.

Stakeholder input formed an important component of the prioritization process. Information and perspectives collected during bilateral meetings, the public consultation organized as part of Phase 2 of the CRARS project, and other relevant feedback were systematically reviewed and taken into consideration. Stakeholder observations and feedback were used to complement the analytical assessment and to ensure that the prioritization reflected both scientific evidence and local experience.

At the same time, the project team acknowledged that stakeholder perceptions of risk inevitably contain a degree of subjectivity, influenced by personal experience and individual proximity to the identified hazards. For this reason, the assessment of adaptive capacity was weighted more heavily towards the judgement of the municipal administration and the project experts. Given their institutional responsibilities, access to relevant information, and comprehensive understanding of municipal resources, planning processes, and operational capabilities, they were considered best placed to evaluate this component of the assessment. Consequently, external stakeholder feedback played a more limited role in determining the adaptive capacity score than it did for the other elements of the risk prioritization process.

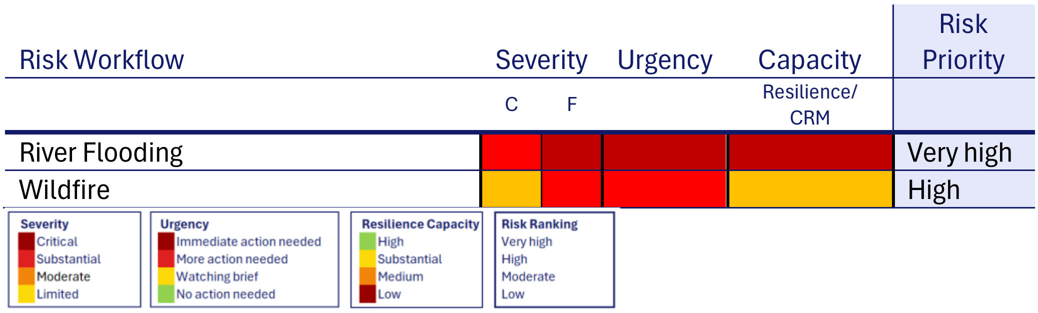


Figure 2-18 Risk prioritization of the two selected risks to analyse under the CRARS project

2.5 Monitoring and Evaluation

The second phase of the CRARS project proved instrumental in strengthening the evidence base for the climate risk assessment through a detailed exploration of locally available information, expert knowledge, historical records, and institutional memory related to the two priority risks under analysis. A key challenge encountered during this process was the limited availability of verified and accessible climatic data at the municipal level. As a result, considerable effort was invested in identifying, collecting, organizing, and interpreting information from a variety of local sources that had previously not been systematically utilized for climate risk assessment purposes.

This process highlighted the significant value of local knowledge and demonstrated that the manifestation of climate risks is often shaped not only by climatic factors but also by a range of environmental, infrastructural, and socio-economic conditions. In the case of flood risk, for example, discussions with local experts and stakeholders underscored the importance of factors, such as riverbed maintenance, land-use practices, infrastructure condition, and human activities in determining the severity and distribution of impacts. Consequently, the refinement of the Climate Risk Assessment relied on a combination of locally sourced information, expert input, municipal records, and relevant national and regional data capable of capturing critical dimensions of hazard, vulnerability, and exposure.

The experience gained during Phase 2 suggested that the European datasets utilized within the assessment framework were generally sufficient for understanding the climatic dimensions of the identified risks. Greater added value was generated through the collection of information related to non-climatic drivers and local conditions, which allowed the analysis to become more detailed, poignant, and relevant for local decision-making. Recognizing the long-term importance of locally generated evidence, Svoge Municipality intends to explore opportunities for establishing or supporting mechanisms for the systematic collection and storage of climatic and non-climatic information in the future.

An important lesson learned throughout the implementation process concerned stakeholder engagement and communication. Initially, climate change and climate risk assessment concepts were perceived as complex and difficult for some stakeholders to fully understand. However, experience showed that these barriers could be largely overcome by presenting findings through practical examples, discussing results in relation to observed local events, and encouraging stakeholders to validate conclusions based on their own experience and knowledge. Stakeholder consultations therefore became not only a tool for gathering information but also an effective mechanism for improving understanding, increasing trust in the assessment process, and strengthening local ownership of the results.

The consultations confirmed the overall validity of the workflow outputs while simultaneously highlighting areas where greater local detail was needed. In response, the project team focused on refining the assessment through the integration of locally relevant data and information, particularly in relation to the exposure and vulnerability components of the risk analysis. Stakeholders consistently emphasized that these dimensions made climate risks more tangible and understandable than hazard information alone. They also noted that the assessment helped illustrate how climate-related risks can influence policy choices, strategic planning, infrastructure investments, and adaptation measures. Participants expressed appreciation for the municipality's proactive approach and recognized the CRARS project as an important step toward improving local resilience and preparedness for future climate challenges.

One of the most significant difficulties encountered during Phase 2 remained the scarcity of local data – both climatic and non-climatic, collected systematically in respect to the priority risks. This challenge was repeatedly identified during consultations with municipal experts and external specialists and reinforced the importance of complementing quantitative data with local observations, institutional knowledge, and stakeholder input.

Phase 2 also sustained the substantial internal learning within the municipal administration. Regular coordination meetings and reflection sessions allowed team members to review progress, discuss challenges, exchange ideas, and identify opportunities for improving future practices. Through this process, several proposals emerged regarding the creation of municipal databases and monitoring systems capable of supporting future climate adaptation and risk management activities. Among the ideas discussed was the establishment of a centralized inventory of protective and risk-reduction infrastructure, including information on condition, maintenance status, and upgrades over time. Another proposal focused on developing a systematic database of flood events and associated hydrological information, which would provide a stronger evidence base for future assessments and planning efforts. Additionally, maintaining records on forest fires, such as location, air temperature, humidity, condition of the vegetation, has also been identified as a future useful practice.

To ensure broad dissemination of project outcomes, Svoge Municipality intends to organize an additional public consultation following the completion of the refined Climate Risk Assessment. This event will provide an opportunity to present the final findings and demonstrate how stakeholder contributions and locally collected information helped refine and strengthen the assessment. More importantly, it will include citizens in a codesign process of altering existing and shaping future municipal policies and actions. Beyond the local level, the municipality also plans to communicate key results and lessons learned to regional and national stakeholders through formal correspondence and knowledge-sharing activities. Particular emphasis will be placed on demonstrating how the methodologies, experiences, and insights generated through the CRARS project can support climate risk assessment, adaptation planning, and resilience-building efforts in other municipalities and at higher governance levels.

From an organizational perspective, the project demonstrated the effectiveness of close collaboration between the municipal team and external experts. Municipal staff played a role in data collection, validation, stakeholder engagement, and contextual interpretation of findings, while external specialists provided expert and analytical support. The process contributed significantly to enhancing institutional understanding of the relationship between hazards, vulnerability, and exposure as the fundamental components of climate risk. Even in situations where comprehensive quantitative modelling was not possible, the analytical framework provided a clear structure for organizing information, interpreting findings, and guiding decision-making.

The data collection process itself became an important learning exercise as data collection strategies were adapted in response to emerging challenges and opportunities. As a result, the municipality is now better positioned to design and implement a more systematic monitoring framework capable of supporting future climate risk assessments and resilience planning efforts.

Overall, the impact of the CRARS project extends far beyond the production of the final assessment document. The process has strengthened stakeholder engagement, increased public awareness of climate risks, improved institutional capacities, and enhanced understanding of local vulnerabilities and adaptation needs. It has provided the municipality with a stronger evidence base for strategic planning and enabled a more coherent and forward-looking approach to climate resilience. Equally important, the project has served as a valuable capacity-building exercise for municipal staff and stakeholders alike. Looking ahead, the refined Climate Risk Assessment will provide a solid foundation for securing national funding, accessing European financing opportunities, and attracting investment in climate adaptation and resilience measures. By grounding future proposals and policy initiatives in a robust evidence base, the assessment will support more effective advocacy, better-informed decision-making, and the implementation of actions that enhance the long-term resilience of Svoge Municipality.

2.6 Work plan Phase 3

The Workplan for the remaining third phase of the project includes the following planned actions: 1/. The external expert team and the CMMT will 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 will review the Municipal Climate Change Adaptation Strategy and recommend amendments based on the refined assessment, with an emphasis on concrete adaptation measures. It will also identify other municipal regulations relevant to these measures and propose amends to make them more efficient in supporting the municipal climate adaptation strategy and policy; 3/. The CMMT will review the proposed changes and pass them to the leadership for adoption.

The outcomes of the key risk assessment findings will be the foundation for the foreseen policy updates and pragmatic planning in terms of identifying adaptation measures. Both policy update and adaptation measures planning are at the heart of the activities in Phase 3 and the team is convinced that with the refined CRA at hand the activities will deliver actionable results with a long-standing impact on local and regional adaption design and implementation.

Additionally, with sustainability of CRARS results in mind, the project team will make sure to include in the suggested policy updates and upgrades the establishment of key local databases that the team has realized are missing and will greatly benefit climate risk monitoring and the rerun of the workflows in the future, such as: a database with records of river floods – location, inundation, availability and condition of local protective infrastructure, damages; a database on wildfires (which currently does not exist even with the local fire department division) – data and time, location, temperature, humidity, availability of dry vegetation, damages. The creation of these databases and their maintenance will be foreseen to be codified in local regulations/policy strategy documents by adoption by the Municipal council, which would make their creation and update obligatory for the administration and subject to oversight by the council as the local legislative body.

3 Conclusions Phase 2- Climate risk assessment

The second phase of the CRARS project focused on enhancing and refining the initial Climate Risk Assessment through the systematic integration of local information, expert knowledge, and stakeholder input. Building upon the results generated through the CLIMAAX workflows, the project team applied the analytical framework of hazard, exposure, and vulnerability to enrich the assessment with locally relevant evidence. This process made it possible to move beyond broader-scale findings and develop a more detailed understanding of climate risks within Svoge Municipality. The resulting assessment is therefore considerably more practical, accessible, and relevant for local decision-makers, municipal experts, and community stakeholders. Furthermore, the refinement process was strongly influenced by stakeholder feedback collected following the completion of the initial assessment, ensuring that the final outputs respond directly to local concerns and information needs. As a result, the municipality considers the refined Climate Risk Assessment sufficiently detailed and operational to serve as a foundation for future policies, strategies, and adaptation measures.

The primary objective of Phase 2 was to strengthen the analytical robustness of the assessment through the incorporation of additional local data and contextual information. Much of the effort invested during this stage focused on identifying, collecting, validating, extracting, and organizing information from a variety of sources. As anticipated, the availability of local climatic and hydrological datasets remained fragmented and limited. Consequently, the refinement process concentrated largely on expanding the exposure and vulnerability dimensions of the assessment, where local information could provide the greatest added value. By combining the climate-related outputs generated through European-scale datasets with local information on social, economic, infrastructural, and environmental conditions, the project significantly improved the clarity and practical usefulness of the assessment. This integrated approach has produced findings that are easier to interpret and apply in local planning, investment decisions, and adaptation initiatives .One of the most important lessons emerging from Phase 2 was the realization that non-climatic factors often play a decisive role in determining the magnitude and distribution of climate-related risks. This framework lends a more comprehensive understanding of how hazards interact with vulnerabilities and exposure patterns at the local level. The refined CRA now provides a strong foundation for future planning, prioritization of actions, and implementation of adaptation measures across the municipality.

Having established the technical infrastructure, software environment, and methodological procedures during the first phase of the project, Phase 2 was characterized by a smoother implementation process and fewer technical difficulties. In this regard, assistance provided through the CLIMAAX initiative remained a highly valuable point of reference. The continued activities of the CLIMAAX Community of Practice also proved beneficial. The increased emphasis of webinars on implementation, funding opportunities, lessons learned from individual workflows, and policy development was especially appreciated by the municipality. Exposure to practical examples, emerging funding opportunities, and experiences from other regions strengthened the municipality’s confidence and reinforced its commitment to translating assessment findings into concrete adaptation actions.

Stakeholder engagement continued to play a crucial role throughout the refinement process. Local knowledge and experience helped ensure that the assessment remained grounded in real-world conditions. Stakeholder participation contributed not only to validating findings but also to identifying areas where additional detail and clarification were needed. One of the recurring challenges was communicating some of the more technical aspects of the assessment methodology to non-specialist audiences. To address this, the project team placed greater emphasis on explaining results, implications, and practical applications rather than focusing exclusively on methodological details. This approach proved successful and generated constructive feedback that directly informed the refinement process.

Stakeholders repeatedly emphasized the need for more localized information capable of explaining why certain areas emerged as risk hotspots and what specific non-climatic factors, which are within the power of the municipality or local community to impact, contributed to their vulnerability. Questions regarding the condition of protective infrastructure, characteristics of riverbeds, concentrations of industry, and the presence of critical facilities highlighted the need to supplement workflow outputs with additional contextual information. Responding to these requests, the project team incorporated local data and observations that enhanced the practical relevance of the assessment and supported the prioritization of adaptation measures and investments.

The key findings emerging from Phase 2 can be grouped into two broad categories. First, substantial effort was dedicated to verifying whether the conclusions generated during the initial assessment accurately reflected local realities and stakeholder experiences. This validation process demonstrated a high degree of consistency between workflow outputs and stakeholder perceptions of climate risks. European-level climate datasets and associated analyses were generally accepted as representative and appropriate for the municipality's context. Second, the project focused on improving the level of detail and precision contained within the assessment. Through the integration of additional local information, the municipality was able to operationalize the findings and make them more useful for practical decision-making.

For the river flood risk, the refinement process generated valuable new insights by incorporating information on flood-prone areas, the condition and effectiveness of protective infrastructure, characteristics of the river bed, concentrations of economic activities, and the location of socially significant facilities. Particular attention was given to infrastructure and services that support vulnerable populations and may face challenges during emergency situations. These findings contributed significantly to identifying priority areas for intervention and sequencing future adaptation measures.

For the forest fires, the integration of local data has considerably improved the understanding of hazard, exposure and vulnerability patterns across the municipality. The analysis has thus added to the understanding of causes for certain risk hotspots in terms of species of vegetation and type of fire. The inclusion of information on recent peculiarities observed in seasonality and the reasons for these, as well as the role of human negligence, have contributed to guiding towards concrete adaptation priorities. This additional level of detail provides a stronger basis for policy-making and motivation to work on building local ownership of adaptation measures.

At the strategic and political level, the findings generated during Phase 2 reinforced the municipality's commitment to addressing both priority risks without delay. The refined assessment has provided a clearer understanding of where interventions are needed most urgently and which actions are likely to deliver the greatest benefits. As a result, Svoge Municipality has reaffirmed its intention to begin implementing adaptation and risk-reduction measures as soon as feasible.

4 Progress evaluation

In Phase 2, the initial CRA has been further refined by integrating reliable local data to improve both its detail and accuracy. This local data has been incorporated into the workflows to generate a more granular and robust version of the CRA for the current second deliverable.

The refined CRA produced in Phase 2, as well as the insights from fine-tuning the workflows with local data and its availability, quality and relevance, will guide the work in the third phase. Phase 3 will build directly on the refined CRA, focusing on updating the municipality's climate adaptation strategy and reviewing other relevant policy documents with proposals for their update to reflect the CRA results and conclusions.

The refined CRA will serve as the foundation for stakeholder engagement and dissemination activities planned for Phases 3 and beyond the project timeline. Stakeholder engagement in Phase 3 will build both on 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 amended 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;	Completed.
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.	Two consultation meetings have been conducted, as well as additional ad hoc consultations with various relevant stakeholders, where their input was needed. The remaining co-design meeting will be held during phase 3.
at least 5 stakeholders relevant to municipal and regional climate resilience engaged through project activities (residents, local and regional media, business, regional authorities, national authorities, nongovernmental organizations/associations) (KPI applies throughout the project);	Ongoing KPI for the entire project. For Deliverable 1 predominantly local stakeholders with observational knowledge and experience were engaged. For Deliverable 2 outreach efforts have been expanded to a broader range of stakeholders and local residents.
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

Key performance indicators	*Progress*
	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 phase 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).	Completed on 15 December 2025.
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).	Completed.
M12: Workflows are refined with local data (Phase 2).	Completed.
M13: The refined climate multi-risk assessment is produced and submitted to the CLIMAAX Coordinator as Deliverable 2 (Phase 2).	Completed.
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.

Milestones	*Progress*
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

- Deliverable 2 main report in PDF – current document, submitted on the CLIMAAX Deliverable Platform.
- Press release on the municipal team's participation in the Barcelona workshop in June 2025 (submitted on Zenodo, DOI: 10.5281/zenodo.17092827).
- 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).
- Deliverable 2 supporting documents (submitted on Zenodo, DOI: 10.5281/zenodo.21026534), including the following:
    - Workflow 1 visualization for non-urban Svoge with local data from the NPRFM for D2.
    - Workflow 1 visualization for urban Svoge with local data from the NPRFM for D2.
    - Historical overview of fire incidents in Svoge municipality 2021-2025.
    - Maps of Forests in Svoge region from the State Forestry "Svoge".
    - National Institute of Meterology and Hydrology, Map of Geographical distribution of vegetation types and land use in Bulgaria.
    - National Plan for River Flood Management – flood risk maps.
    - Official Spatial Development Plan for Svoge Municipality, June 2023.

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