X-RISK-CC

PILOT DOSSIER

SORA CATCHMENT IN GORENJSKA

HOW TO ADAPT TO CHANGING WEATHER EXTREMES AND ASSOCIATED COMPOUND RISKS IN THE CONTEXT OF CLIMATE CHANGE

LEAD PARTNER

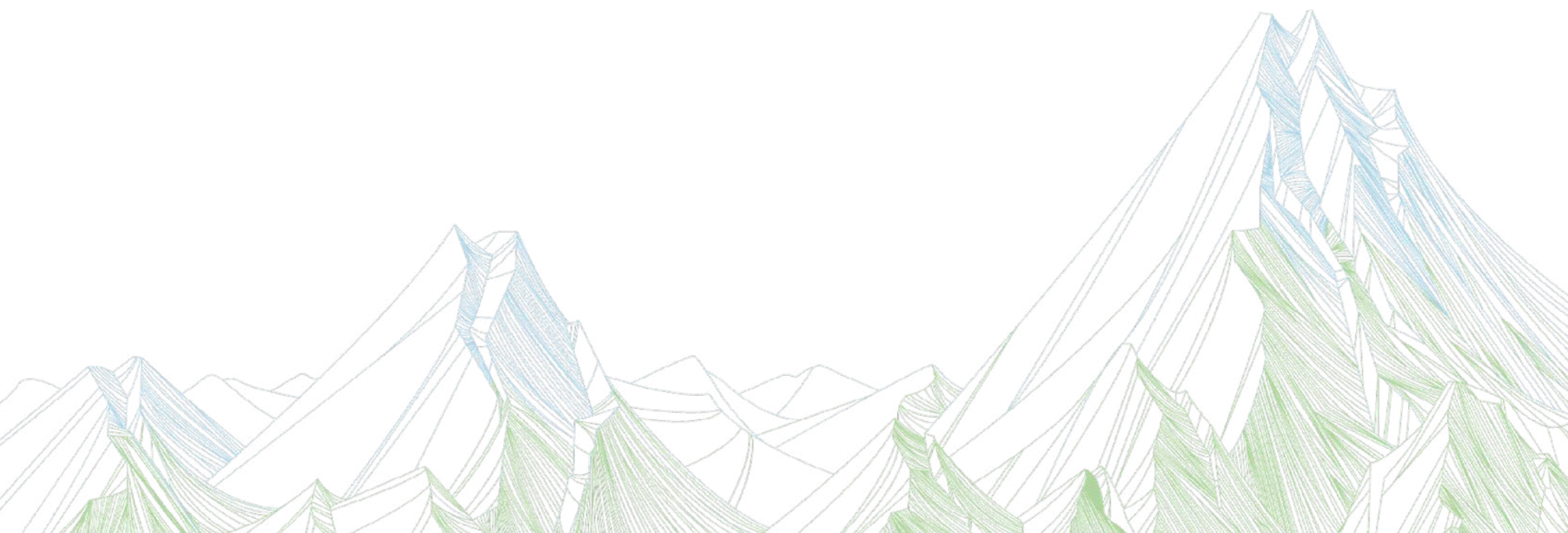
PROJECT PARTNERS

SORA CATCHMENT IN GORENJSKA

HOW TO ADAPT TO CHANGING WEATHER EXTREMES AND ASSOCIATED COMPOUND RISKS IN THE CONTEXT OF CLIMATE CHANGE

THIS DOSSIER

The dossier focuses on the Sora Catchment in Gorenjska (Slovenia) used as a pilot area in the X-RISK-CC project. The dossier is designed to make the local knowledge developed by the project accessible to the general public. It provides information on past and future weather extremes, associated hazards and risks, and proposed actions to improve the future risk management in the area.



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INTRODUCTION

THE BACKGROUND

In recent years, the Alps have experienced unprecedented weather extremes such as heatwaves and droughts, heavy rains and storms, which have had severe impacts on the environment, society and the economy. These events have challenged the risk management capacities of the affected Alpine regions. The scale (*magnitude*) and local severity (*intensity*) of such extremes can lead to multiple simultaneous (*compound*) impacts and cascading effects, resulting in complex, long-lasting or even irreversible consequences. Recent scientific evidence indicates that climate change (CC) is increasing both the intensity and frequency of extreme meteorological events. However, our understanding of their compound and cascading impacts—and how to manage them—remains limited. On the regional level, these events are not adequately addressed within current Disaster Risk Reduction (DRR) frameworks. Similarly, where Climate Change Adaptation (CCA) plans exist, they often underestimate the severity of extreme events and associated risks, and frequently lack concrete, actionable measures.

THE PROJECT AND ITS GOALS

The **X-RISK-CC** project (full title: "*How to adapt to changing weather e***X***tremes and associated compound and cascading* **RISK***s in the context of* ***C****limate* ***C****hange*") is funded by the European Union and aims to improve the management of risks related to extreme weather and natural hazard events under climate change in Alpine regions. This goal is pursued through the collaboration of scientists, risk managers and policy makers on local, national and international levels.

In X-RISK-CC, risks are defined as the adverse consequences caused by weather extremes (e.g., heavy rainfall) triggering natural hazards (e.g., flooding), which in turn affect human systems (e.g., loss of private property). Risk is therefore not determined by weather and natural hazards alone, but by their interaction with exposure (e.g., buildings located in flood-prone areas) and vulnerability (e.g., lack of flood protection infrastructure) within socio-economic systems (***FIGURE 1***).

Understanding and managing current and future risks requires not only the analysis of weather extremes and resulting hazards, but also a consideration of the evolution of human systems and potential risk management solutions. Since weather cannot be controlled, risk reduction must focus on measures that decrease vulnerabilities, reduce exposure or, where possible, mitigate the hazard itself.

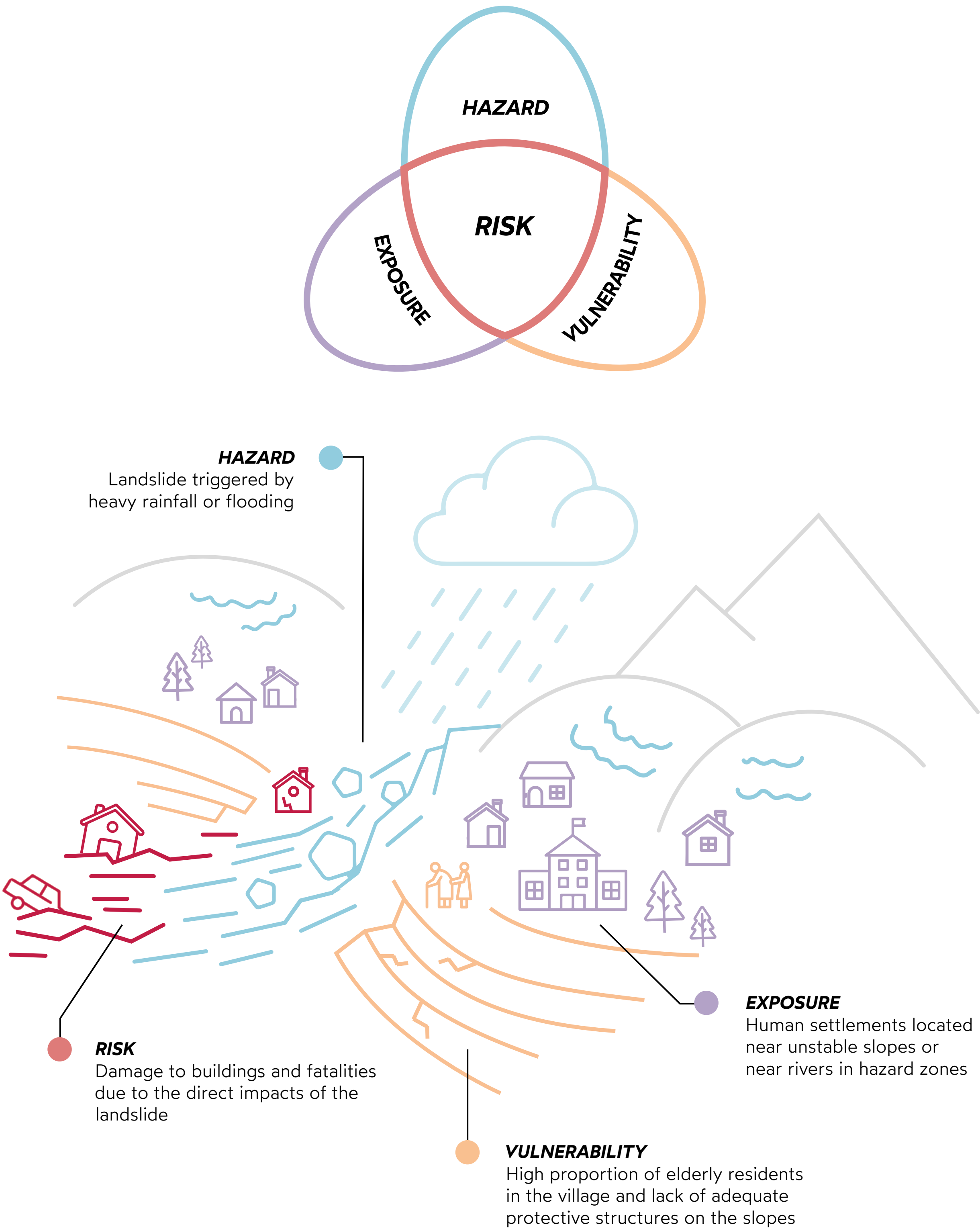


FIGURE 1: *Illustrative examples of hazard, exposure and vulnerability contributing to risk (the concept of risk is based on the framework developed by the Intergovernmental Panel on Climate Change - IPCC).*

The main questions guiding the X-RISK-CC project are:

- → Are we adequately prepared to cope with extreme weather events?
- → What gaps exist in current risk management practices, based on recent experiences?
- → How will weather extremes and related risks evolve in the Alps?
- → How can local risk management practices be improved to address future weather extremes?

The project begins with an analysis of past extreme weather events and their projected future trends, assessing the hazards they trigger and integrating these with data on exposure, vulnerability and impacts. This approach is used to evaluate existing risk management practices and to develop concrete measures that strengthen resilience to future risks.

In a complex system like the Alpine region, which is particularly prone to weather extremes and natural hazards, risk arises from multiple, often interconnected factors. Identifying effective points of intervention requires a thorough understanding of local conditions.

Devastating floods severely affected Škofja Loka on 4 August 2023. The consequences of the floods were catastrophic, with approximately 400 houses inundated, road infrastructure destroyed, and water, electricity, and telecommunications networks damaged. (Author: Mitja Legat)

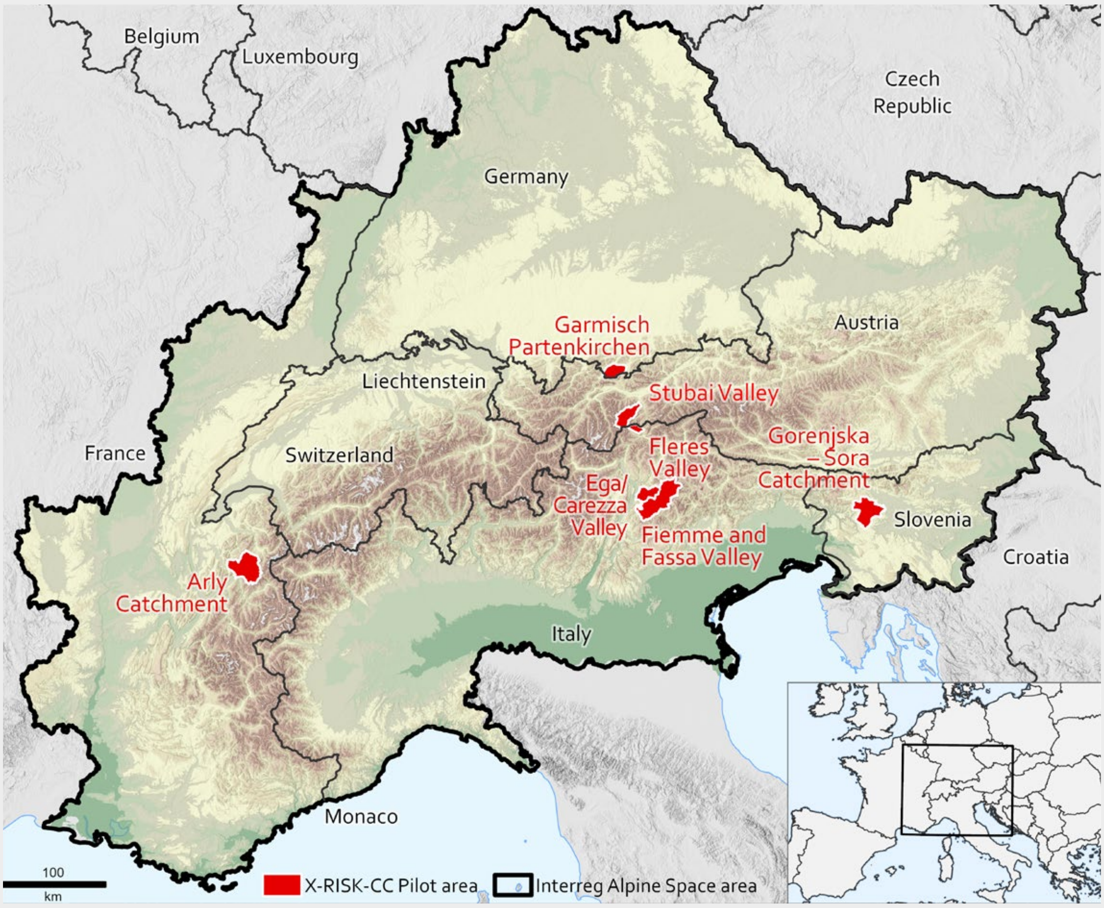


FIGURE 2: *Map illustrating the pilot areas (shown in red) of the X-RISK-CC project.*

To this end, specific pilot areas across the Alps (***FIGURE 2***) have been selected as representative case studies for detailed analyses and the development of tailored risk management solutions. In these areas, progress is driven by close collaboration with local risk managers and stakeholders. Their active involvement is essential both for identifying effective measures and for translating local knowledge into transnational recommendations.

PILOT AREA: SORA CATCHMENT
(GORENJSKA, SLOVENIA)

GEOGRAPHICAL AND ENVIRONMENTAL SETTING

The Gorenjska region is located in the northwestern Slovenia (***FIGURE 3***) in Eastern Alps. The pilot area covers approximately 512 km2, with elevations ranging from about 320 m above mean sea level (a.m.s.l.) to 1,678 m a.m.s.l. (Ratitovec). The Sora Catchment includes two main rivers: the Selška Sora in the north and the Poljanska Sora in the south. The main municipalities crossed by the two rivers are Škofja Loka (350 m a.m.s.l.), Žiri (480 m a.m.s.l.), Gorenja vas – Poljane (420 m a.m.s.l.) and Železniki (450 m a.m.s.l.).

The Sora Catchment has experienced several flooding events since the beginning of 20th century, mostly caused by intense precipitation episodes. Two of the most recent and devastating floods occurred in September 2007 and August 2023 (***FIGURE 4***), resulting in extensive damages and, in 2007, also casualties. In addition to floods, heavy rainfall can also trigger other hazards in the region such as landslides and debris flows.

The region is also prone to drought, which occurs when extended periods of below-average precipitation coincide with high temperatures. The magnitude and duration of such dry and hot conditions can

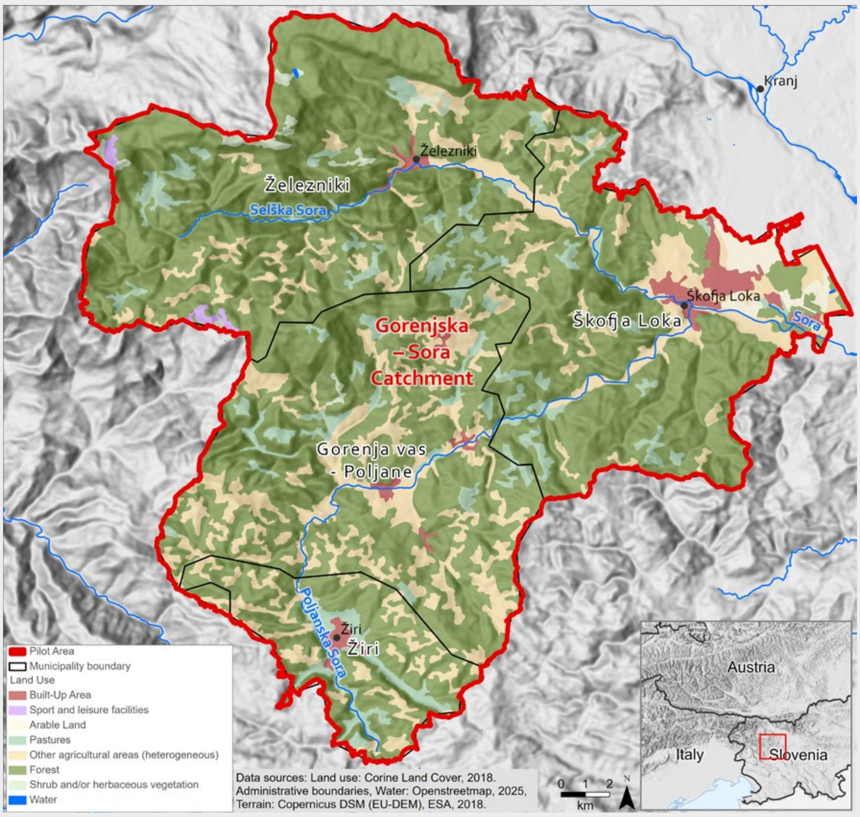


FIGURE 3: *Map of Sora Catchment in Gorenjska region (in red).*

impact topsoil and groundwater in shallow aquifers, with cascading effects on sectors such as agriculture and forestry. In some cases, drought has even contributed to small-scale wildfires and affected water supply. Furthermore, drought-dried soils can contribute to favourable conditions for subsequent flooding, as reduced infiltration limits the soil's ability to absorb rainfall. This was observed in 2022, when an exceptional drought was followed by the 2nd highest river discharge since 1950 on the Poljanska Sora River in Žiri.

Within the X-RISK-CC project, we analysed how risks related to **floods and droughts** may evolve in the pilot area in the future.

PAST AND FUTURE WEATHER EXTREMES

Collected observations indicate an increase in the intensity of extreme precipitation events lasting 2 to 3 days, particularly in the northern parts of the Sora Catchment. These events represent the main drivers for floods, especially during the summer and autumn months. The major floods in 2007 and 2023 were the result of record-breaking 1- to 3-day precipitation events with return periods of at least 200 years, and locally even exceeding 500 years. In August 2023, several locations recorded more than 300 mm of rain over 3 days. Analyses indicate a rising frequency of high-precipitation events over 3 to 7 days since 1950

FIGURE 4: *Škofja Loka during the flood in August 2023. (Author: Mitja Legat)*

at most analysed locations in the catchment, although the signal remains weak. This means that weather conditions that lead to flooding are now more likely than in the past.

Besides precipitation extremes, high temperatures associated with below-average precipitation totals also represent a major threat to the area, as they can determine drought conditions. The most severe droughts in the Sora Catchment over the last 20 years occurred in 2003, 2013 and, especially, 2022 which was estimated to have a return period of 60 years. On average, dry months and severely dry months in spring and summer have become more frequent over the last few decades in the region. Heatwave episodes are also more intense and frequent today than in the 1950s, and when occur simultaneously, they can rapidly intensify the drought situation. It was also observed that large-scale atmospheric circulation patterns during spring and summer associated with warm and dry conditions favouring droughts occur more often today than 70 years ago.

Looking ahead, extreme precipitation events over 1 to 3 days are projected to become more intense and frequent in all seasons. The magnitude of these changes will depend on the level of global warming reached by the end of the century. For example,

⚠ Dealing with uncertainties

Climate projections are produced by different models, each yielding different results. For simplicity, these projections are often averaged, even though they represent a range of plausible outcomes, the width of which depends on the uncertainty in how models simulate the future evolution of specific processes. Moreover, projected values should be interpreted as estimates of the magnitude of change, not as exact predictions for specific places and times (e.g., rainfall on a given day in July 2050).

Nevertheless, the consistent signal of increasing precipitation extremes conveys an important message for risk managers: the likelihood of natural hazards and cascading impacts is rising.

The **return period**, also known as the recurrence interval, is the estimated average time between events of a given magnitude. It is expressed in years and derived from statistical analysis. For example, a 100-year return period for a flood means there is a 1/100 (or 1 %) chance of such a flood being exceeded in any given year.

an extreme daily precipitation event with a current 50-year return period could become up to 2.5 times more likely under the highest global warming levels.

Concurrently, both droughts and heatwaves are expected to become more severe and more frequent in a warmer future. The region could experience up to 5 additional events annually in which both conditions occur simultaneously.

Global warming levels are used to illustrate future scenarios where specific increases in mean global temperature with respect to the preindustrial period (1850-1900) are reached. A global warming level of + 3 °C indicates a world 3 °C warmer than in 1850-1900.

Drought in Škofja Loka area. (Author: N. Kržišnik)

HAZARDS IN PRESENT AND FUTURE CLIMATE

The Sora Catchment is particularly prone to flood events induced by heavy precipitation. These include both river floods, caused by prolonged and intense rainfall, and flash floods, triggered by short and very intense precipitation events. Besides floods, and often concurrently with them, other types of hazards can be triggered by heavy rainfall, such as landslides, debris flows and erosion processes. Based on measurements from the hydrological station near Škofja Loka, the river discharge of a 100-year flood event today exceeds 600 m^3/s. These discharge data are used by the Water Agency to map areas that would be inundated areas during floods with return periods of 10, 100, and 500 years. Such maps represent key tools for spatial planning (***FIGURE 5***).

With to the projected intensification of precipitation, all flood-related phenomena—including erosion processes, landslides and debris flows—are expected to become more severe in the future. Flash floods triggered by short-duration rainstorms may become more frequent and intense, and also river floods could increase in both intensity and frequency, as prolonged heavy rainfall will saturate soils more quickly and reduce drainage capacity. A recent study conducted by the University of Ljubljana on the Sora Catchment indicates that a 100-year flood today could have a return period of 10 years by 2100. Moreover, the magnitude of discharges leading to severe flooding is projected to increase. For example, river discharges associated with a present-day 500-year flood are expected to rise by approximately 20 % by the end of the century.

⚠ The flood in August 2023

The most extensive and destructive flood in Slovenia occurred between 3rd and 6th August 2023 caused by intense and persistent precipitation falling on already saturated soils. The amount of precipitation in some cases equalled the normal monthly totals for August and was estimated to have a return period of 200 years or higher. Recorded values represented a record in several areas of Slovenia, including the eastern part of the Sora Catchment. High water thresholds were exceeded in 74 rivers in Slovenia, including the Sora River and its tributaries. The unique characteristic of this flood was that even the three largest Slovenian rivers, Sava, Drava and Mura, flooded simultaneously. Record discharges were measured at 31 gauging stations (3 in the Sora catchment), most of which were estimated to have a return period of 100 years or more. Along with floods, multiple landslides also occurred leading to additional damages.

As discussed in the previous chapter, hazards in the region are not only triggered by intense precipitation but also by extended periods of below-average rainfall. Such dry spells can lead to topsoil droughts, which are further intensified when combined with high temperatures and heatwaves. These hot and dry conditions can lower groundwater levels with significant implications for vegetation and local water supply systems. Moreover, droughts can also generate cascading hazards, including wildfires and related air pollution, as well as outbreaks of animal and plant diseases such as bark-beetle infestations. Persistent droughts can increase the likelihood of subsequent floods by modifying the soil's infiltration capacity. Both topsoil and groundwater drought conditions have intensified in recent decades, with one of the Slovenia's most severe droughts recorded in 2022.

⚠ The drought in 2022

Summer of 2022 in Slovenia was characterised by a persistent lack of precipitation, record high temperatures and heatwaves, which led to extreme dryness of the topsoil layer, particularly in the western and central parts of the country. The precipitation deficit lasted from January to the beginning of September 2022, ranking 2022 as one of the driest years in Slovenia. At the beginning of summer, drought conditions were already severe. The concurrent series of heatwaves led to a long period of severe heat and water stress which strongly affected ecosystems. At the end of July, the vegetation was already showing signs of yellowing and leaf fall typical of autumn. In July, high fire risk was also declared for the entire country and the most extensive wildfire in Slovenia broke out in its western part.

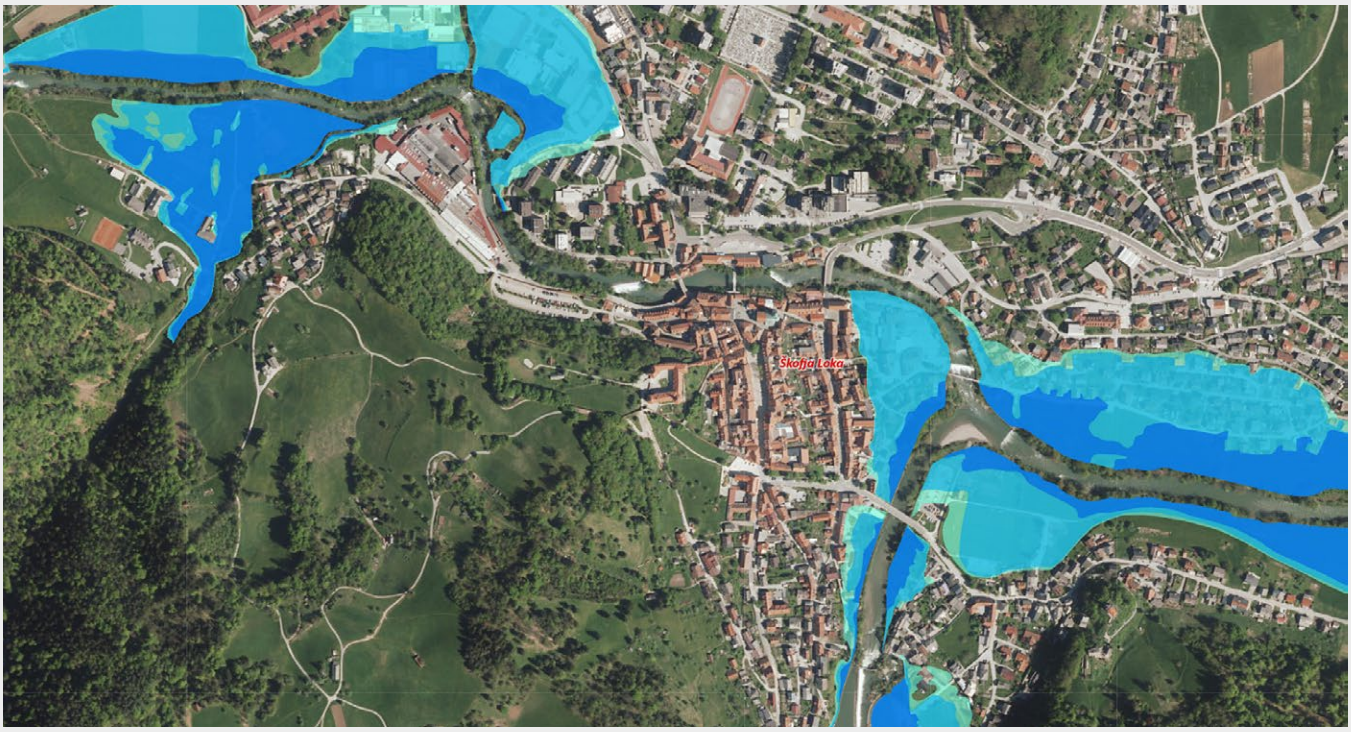


FIGURE 5: *Extent of floods with return period of 10 (dark blue), 100 (blue), and 500 (light blue) years in Škofja Loka (detail). (Source: Water Atlas, 2025)*

In the future, higher temperatures are expected to increase heat stress and evaporation rates, leading to more intense and frequent drought conditions in both topsoil and groundwater, particularly during spring and summer. Consequently, other cascading hazards, such as wildfires and bark-beetle outbreaks, are also likely to become more frequent. Under current climatic conditions, long-lasting droughts persisting over multiple seasons are considered low-probability events in the Sora Catchment. However, in the future, the likelihood of such extended droughts is expected to increase, with significant consequences for ecosystems and human activities.

CURRENT AND FUTURE IMPACTS AND RISKS

In the Sora Catchment, both floods and droughts can have severe consequences for the population—of approximately 43,000 residents—and for socio-economic activities, especially agriculture, forestry, and energy and water supply. As the area is a key part of the national road network, extended floods can severely disrupt the road transport in Slovenia. Moreover, several remote villages could become isolated if roads are damaged or power supply is interrupted due to flooding and/or landslides.

During the **flood events in August 2023** several buildings were flooded or damaged all across the area, and more than 250 landslides were triggered in the municipalities of Škofja Loka, Gorenja vas-Poljane, Žiri and Železniki. The total estimate of direct damage caused by the flood event in Slovenia was 2.98 billion euros.

Floods can also destroy cultivated areas or contaminate crops. Especially in riparian zones, they can leave bare areas that are quickly colonized by invasive plant species, which can compete with native species and create significant ecological imbalances.

Devastating floods severely affected Škofja Loka on 4 August 2023. The consequences of the floods were catastrophic, with approximately 400 houses inundated, road infrastructure destroyed, and water, electricity, and telecommunications networks damaged. (Author: Mitja Legat)

Although tourism is not a primary sector in the Sora Catchment, floods can restrict access to sites of interest due to damaged routes, leading to economic losses for local businesses and communities that depend on tourism for income.

Droughts in the Sora Catchment have significant impacts on agriculture. Approximately 25 % of the area is covered by agricultural land, mainly grasslands and pastures. Drought events can lead to crop losses, increase irrigation costs and impact livestock care, placing financial strain to farmers and raising demand for state support. Forests, which cover 71 % of the area, are predominantly composed of conifers. Severe droughts can reduce timber production and increase the risk of cascading effects such as plant diseases and pests, including bark beetles. Forests already damaged and weakened by windthrow or forest fires are more vulnerable to drought and cascading infestations. In same extreme cases, recovery to pre-drought conditions can also take several years.

The exceptional **drought in 2022** was estimated to affect 23,570 people in 211 municipalities in Slovenia. With a final estimated cost of agricultural damage of almost 150 million euros, the 2022 drought was declared a national disaster. In addition to agriculture, natural systems and other key socio-economic sectors, such as energy, were also affected.
The deficit of groundwater level resulted in municipalities and utility companies throughout Slovenia advising people to spare water, and firefighters delivering drinking water to users (including livestock) without access to it, especially to remote villages and settlements at higher altitudes.

Drought in Škofja Loka area. (Author: N. Kržišnik)

Water supply in the Sora Catchment is also affected by drought, as demand rises while water availability declines. The area includes two large water supply systems and several smaller ones, with the latter being more vulnerable to drought. The larger systems benefit from multiple dispersed backup sources whereas some of smaller systems often rely on water deliveries during drought episodes, such as in 2022. Water shortages, particularly when combined with heatwaves, can negatively affect residents' health and impact tourism especially in lowland areas in summer season. However, winter droughts with high temperatures can also affect skiing industry by reducing the efficiency of snowmaking.

The population in the area is relatively stable, with only slight increases, especially in Škofja Loka, the main town of the area, which hosts several educational facilities and services. No major population or tourism growth is expected in the future, thus the number of people potentially impacted by floods and drought is likely to remain stable. Similarly, the proportion of farms and agricultural lands exposed to drought and flood impacts is not expected to change remarkably. Despite a gradual decline in farms, regional strategies aim to maintain agricultural activities and promote the development of rural areas.

However, the increasing intensification of meteorological extremes could extend the areas potentially affected by natural hazards and render existing protection measures—many of which were built several decades ago—unsuitable for managing unprecedented extremes.

Drought in Škofja Loka area. (Author: N. Kržišnik)

THE ROLE OF VULNERABILITY IN RISK

The impacts of a hazard event can be worsened not only by the event's intensity or the number of exposed elements, but also by other factors, such as social aspects (e.g., an ageing population, low risk perception, or lack of awareness) and the condition and maintenance of buildings and infrastructure. Greater impacts may also result from the characteristics of the systems themselves. For example, a water supply system dependent on shallow, small aquifers is particularly susceptible to water shortages. The entire drinking water supply infrastructure is also vulnerable to high temperatures. Much of this infrastructure was built in past decades when air temperatures were lower and snow cover persisted longer. Today, and especially in the future, higher temperatures and snow-free winters are more likely. Consequently, air temperature fluctuations penetrate deeper into the ground, heating pipes and water reservoirs. Warmer drinking water is a concern because system damage can allow the intrusion of various pathogens (e.g., bacteria, viruses, parasites), posing serious health risks to consumers. Another factor influencing risk is the lack of appropriate risk management practices, such as missing rockfall barriers, low preparedness for multiple simultaneous or subsequent hazards (such as river flooding combined with landslides), or absence of coordinated drought management from local to national levels. In this context, a thorough evaluation of current risk management measures and their adaptation to changing conditions is crucial for the safety of people and their activities.

On 4th August 2023, Škofja Loka was hit by the worst flood since 1926. (Author: Mitja Legat)

RISK MANAGEMENT

RISK MANAGEMENT CYCLE

Effective management of natural hazard risks requires systematic planning and coordination. Risk management provides a structured and iterative process aimed at minimizing risks and enhancing community resilience. This process involves a continuous cycle of interconnected actions, as illustrated in the infographic.

The main phases of the **risk management cycle** include:

PREVENTION	**PREPAREDNESS**
RESPONSE	**RECOVERY**

The interphases —the transitions between phases— are critical components of the risk management, as they involve shifts in responsibilities, resources, and attention. These interphases (Prevention-Preparedness, Preparedness-Response, Response-Recovery, and Recovery-Prevention) require particular attention to ensure smooth transitions, clear communication across phase boundaries and to avoid potential gaps in risk management.

First stakeholder workshop on identifying gaps and enhancing collaboration and risk management for flash floods and landslides in Sora Catchment area. (Source: Sora Development Agency Archive)

Activities and measures taken in advance to ensure effective response.

Early warning systems, emergency planning, training and exercises, resource pre-positioning, public awareness campaigns, and establishment of coordination mechanisms.

Capacity to act and prepare before a hazardous event strikes.

Actions taken during and immediately after an event to save lives, reduce impacts, protect the environment and meet basic subsistence needs.

This includes effective coordination, emergency operations, search and rescue, evacuation, emergency communications, and immediate humanitarian assistance.

Emergency response requires the coordinated intervention of all civil protection actors.

Measures taken to mitigate the risk. This includes structural measures and non-structural measures.

STRUCTURAL MEASURES
protective structures, nature-based solutions, retention areas, asset protection measures

NON-STRUCTURAL MEASURES
land-use planning, hazard zone maps, education, communication and legislative frameworks

Supports acceptable levels of risk society is willing to live with.

Actions taken after a disaster to overcome the event and enhance resilience through build back better principles.

This includes restoration of infrastructure and services, economic recovery, psychosocial support,participative reconstruction planning, and implementing lessons learned.

Integrates adaptive actions and long-term thinking.

*Key actions and measures associated with each phase of the risk management cycle, including both **structural** and **non-structural** measures that support prevention, preparedness, response, and recovery.*

STAKEHOLDER INVOLVEMENT APPROACH

In the pilot area, **two participatory workshops and one expert consultation** were organised, all following a shared structure to strengthen local climate risk management. In addition, several meetings with key stakeholders were held to further define solutions addressing the identified gaps. The workshops were anticipated by interviews with municipal civil protection commanders (for floods) and representatives from the agriculture, forestry, and water supply sectors (for droughts) to identify key gaps in existing management. During the first workshop, these gaps are further discussed with stakeholders. In the second workshop, participants were invited to analyse the potential challenges in managing future flood and drought events but in a plausible future context, based on analysed climate projections and possible socio-economic evolution in the area. Concrete measures to improve the managing of future risks related to extreme events were proposed and formulated in an action plan. The action plan was further refined by several one-to-one expert meetings involving municipalities, civil protection and firefighter units, forest and agricultural services, water supply companies, research institutions, NGOs, and representatives from different levels of administration. An additional expert consultation event, which further strengthened cooperation between professional institutions (ARSO) and local civil protection units, helped to deepen the communication and enhance the collaboration on concrete measures.

1. Workshop

ANALYSE THE GAPS AND DEFINE CHALLENGES

2. Workshop

MAKE THE PLANS

3. Expert consultation

REFINE THE ACTIONS

Participants in the workshops in the Sora Catchment Pilot Area

- Administration for Civil Protection and Disaster Relief
- Center for Sustainable Rural Development Kranj
- Chamber of Agriculture and Forestry of Slovenia (Regional Unit Kranj)
- Civil protection and firefighter unit
- Development Agency Sora
- Development Centre of the Heart of Slovenia
- Environmental Agency Slovenia (ARSO)
- Komunala Škofja Loka d.o.o. (public utility company)
- Local Energy Agency of Gorenjska
- Local fishing associations
- Municipality of Škofja Loka
- Municipality of Železniki
- Municipality of Gorenja vas-Poljane
- Municipality of Žiri
- Radio SORA
- Slovenia Forest Service, Regional Unit Kranj
- Slovenian Water Agency

RISK MANAGEMENT GAPS

In the Sora Catchment, the combination of drought and flooding—two hazards with different temporal dynamics—poses a complex challenge for risk management and mitigation. The interviews and workshops addressed both issues, producing distinct outcomes.

The pilot identified several key gaps in **flood risk management.** These include the irregular maintenance of watercourses due to insufficient and unstable funding, the absence of a fully implemented push-notification alert system for the population (SI-ALARM). During the most recent extreme event (August 2023), the SI-ALARM public alert and warning system had not yet been in place. It is now already

What is a Hazard Map?

A hazard map illustrates areas potentially affected by a specific natural hazard. It uses colour coding to represent the **likelihood and intensity** of a hazard occurring in each location. Hazard maps are essential tools for **disaster risk management** and **spatial planning**, as they help guide land use decisions, infrastructure development, and emergency preparedness.

The results of the first workshops and the collaboration with highly active stakeholders from a wide range of institutions provided exceptional insights into extreme events and established solid connections for future work. (Source: Sora Development Agency Archive) underway to improve the protection of people and property and to enable the rapid delivery of emergency warnings. The pilot also highlighted the lack of more precise, locally tailored flood forecasts to support decision-making by Civil Protection commanders during flood events. In addition, public awareness in flood-prone areas regarding individual self-protection measures remains limited, and there is a clear need to further strengthen regional emergency communication and alert centres. Also hazard maps typically focus on single threats, rarely considering how multiple hazards—such as landslides blocking rivers—can combine to create unexpected risks. Recovery relies heavily on local knowledge, but weak coordination across sectors on national level hinder long-term resilience and adaptation.

Drought management in Slovenia faces a different set of challenges. The country lacks a comprehensive, binding framework covering prevention, preparedness, response, and recovery, leaving many measures uncoordinated. Irrigation systems remain underdeveloped due to complex water rights procedures and fragmented land ownership, while agricultural zoning is limited, exposing crops to unsuitable soils and future climate conditions. Existing drought risk maps are outdated and need updating with future climate projections. In forested areas, delayed implementation of foresters' recommendations further undermines proactive risk reduction. Preparedness tools, such as the web-based Droughtmeter, provide general updates but lack impact-based forecasting and high-resolution data. Activation of drought response

Participants at the first workshop beside organizers Slovenian Environment Agency and Development Agency Sora included municipal Civil Protection Managers, the Fire Brigade Command, representatives from the municipalities of Škofja Loka, Železniki, Gorenja vas – Poljane, and Žiri, the Slovenian Water Agency, the Agricultural and Forestry Institute (OE Kranj), the Slovenian Forestry Service (OE Kranj), and the Škofja Loka Fishing Association. (Source: Sora Development Agency Archive) depends on the official declaration of drought as a natural disaster, which occurs only after significant damage. Moreover, the absence of a formal early-response protocol limits proactive mitigation. Recovery largely relies on subsidies, which now covers a declining share of losses, while structured evaluation and cross-level dialogue for improving long-term drought management remain limited. The area is also underprepared for compound risks, such as simultaneous droughts and wildfires, which can amplify the crisis.

Overall, in both flood and drought management, addressing these gaps requires integrated, multi-hazard planning and intersectoral cooperation, updated monitoring and forecasting systems, investment in resilient infrastructure, raising awareness and stronger community involvement to enhance preparedness and adaptive capacity in a changing climate.

Droughtmeter is a web-based tool developed by the Slovenian Environment Agency (ARSO) for near-real-time monitoring of drought conditions in Slovenia. It provides the public with weekly updates on drought status across 15 regions of Slovenia, along with a one-week outlook based on weather forecasts. The portal brings together drought information for all key components of the water cycle — topsoil, surface water, and groundwater — presented on a unified spatial and temporal scale.

https://vreme.arso.gov.si/uploads/probase/www/agromet/bulletin/drought/sl/

GAPS PER PHASE

PREVENTION

FLOODS

- Many **rivers and flood barriers are not maintained frequently enough** (cleaned, repaired). In case of heavy rainfall events, these structures can fail or lose effectiveness, thus increasing instead of decreasing the risk of flooding. Regular maintenance and stable funding is essential to keeping communities safe.
- During recent floods, it has been shown that **storage of hay bales** near riverbanks can be swept away, causing blockages that lead to jam floods and increase flood damage. Raising awareness among farmers and providing clear storage guidelines—for example, relocating hay bales to safer areas—are key preventive measures.
- **Outdated municipal protection and rescue plans** often fail to account for recent changes in infrastructure, flood defences, and emergency service capacities. This gap in planning reduces the efficiency and timeliness of emergency response during flood events.
- **Municipal Spatial Plans (OPNs) often face long delays before adoption**, largely due to demanding requirements set by national institutions — for example, the obligation to prepare hydrological studies when planning flood-protection measures. Progress therefore moves very slowly. Newly identified flood-prone areas can further halt many important municipal investments, as the institutional framework does not allow partial approval of OPNs; they can only be adopted as a complete, fully finalised document. This gap highlights the lack of coordinated cooperation between national and municipal institutions, which significantly slows down planning processes and the timely implementation of necessary measures.
- Due to the **torrential nature of the rivers** in the Sora Catchment, flood safety could be significantly improved by introducing torrent-control structures such as **timber check dams and sediment basins**, as well as by designating appropriate floodplain areas along watercourses.
- Most participants agreed that improving the condition of watercourses would require transferring their management from the **national level to the regional or local level**, together with securing financial support for these activities including continuous and up-to-date field monitoring.

DROUGHT

- At both national and local levels, there is **no overarching, binding drought management framework** (an action plan with defined protocols, defined institutions involved, their tasks and responsibilities) **that covers all phases of drought management**: prevention, preparedness, response, and recovery.
- Slovenia has a **drought risk map that evaluates risk** at the national level, including the level of risk for each municipality as a whole. However, the current maps and vulnerability assessments are **outdated**. A new assessment is underway and needs to incorporate the latest climate change projections.
- The **development of irrigation systems remains limited**, which reduces the ability to mitigate drought impacts. Key challenges include lengthy procedures for obtaining water rights and difficulties in system placement due to fragmented land ownership. Effective planning would require an assessment of farmers' interest, an evaluation of available water resources, and strategies for water retention.
- A gap in agriculture is **the absence of land zoning for crop cultivation**. Such zoning would align agricultural practices with soil characteristics and projected climate conditions, ensuring more resilient production.
- A challenge is the **delayed response of many private forest owners**, who often postpone implementing foresters' recommendations (e.g., due to bark-beetle infestation), which undermines timely risk management.
- In hilly areas, many households rely on **small private water supply systems that depend on local water sources**. During severe drought, these often run dry, **requiring water deliveries** by firefighters.

FLOODS AND DROUGHT

- In Slovenia, including the Sora Catchment, **hazard maps usually analyse only one hazard** at a time without considering how events can combine. A landslide could block a river and cause a flood, creating risks where we do not expect them. To be prepared, we need tools that reflect these complex connections.

PREPAREDNESS

FLOODS

- **Flood forecasts** and alerts are available, but they are **not always detailed enough for smaller local areas** due to the torrential nature of the rivers in the Sora Catchment. In case of heavy downpour in combination with steep terrain this can cause sudden floods (flash floods) that forecasts may not fully predict. The flood can happen extremely quickly (in a couple of hours), leaving little time for civil protection and inhabitants to response.
- During past events analysed, **an automated SMS alert system for floods and extreme weather events was not yet in place**. Consequently, critical warnings may not have reached all residents or visitors, particularly tourists lacking local knowledge. The establishment of a national-level SMS notification system is currently underway.
- Residents are not sufficiently informed about the actions they can take independently during floods—the so-called **self-protection measures**. Public awareness remains low, and many people do not know simple steps that can reduce damage and improve safety in the event of flooding.

DROUGHT

- The web-based **tool Droughtmeter** provides weekly updates on drought conditions and forecasts across 15 regions in Slovenia, even when no drought is present. However, it does not yet include impact-based forecasting. Stakeholders have also highlighted the need for more precise, higher-resolution data.
- The area is **not fully prepared for complex, multi-risk situations** such as those experienced in 2022 in the Karst region, when severe water shortages coincided with extreme fire danger. In such conditions, wildfires can spread rapidly, amplifying the crisis.

FLOODS AND DROUGHT

- In Slovenia, **responsibilities across the risk management and risk assessment chain are distributed among multiple institutions**. One institution monitors weather and hydrological extremes, another carries out landslide hazard mapping, a third provides flood hazard maps, and a separate institution conducts fire risk assessments. At the same time, the collection and management of impact data are carried out by different entities, resulting in further fragmentation of the system and lack of a comprehensive information source for risk management.

RESPONSE

FLOODS

- During extreme weather events like **the August 2023 floods, the Regional Information Centre became overloaded** and could not process all calls, alerts, and messages in a timely manner. This gap makes it harder to quickly inform residents, emergency services, and local authorities about the situation, which can slow down response actions and reduce safety.
- **Local volunteer groups**, such as young firefighters or community helpers, are **becoming smaller**. This reduces the community's ability to support emergency response during floods.

DROUGHT

- In Slovenia, the activation of the **response phase is contingent upon the official declaration of drought as a natural disaster**, which occurs only under severe conditions and after significant damage has been observed.
- The **absence of a formalized early-response protocol** limits the ability to mitigate drought impacts proactively.
- Coordination and collaboration among sectors during periods of water use restrictions are still weak at the local level.

FLOODS AND DROUGHT

- The current system for **assessing drought and flood damages,** primarily in the agricultural sector, relies on the AJDA application. However, both the assessment process and the subsequent **allocation of financial aid** are **time-consuming and administratively burdensome**.

RECOVERY

FLOODS

- At the local level, **cooperation is generally strong**, and people working on recovery often have a deep knowledge of their communities. However, there is a noticeable lack of cross-sectoral cooperation — particularly at the national level, as well as between ministries and municipalities. Responsibilities are often shifted from one institution to another, resulting in weak coordination and delayed action.

DROUGHT

- Drought recovery efforts in Slovenia depend largely on the Agricultural Disasters Mitigation Scheme, which provides subsidies to affected farmers. Over time, the share of total damages compensated through this mechanism has declined.
- While documentation of past drought events is relatively comprehensive, structured evaluation and cross-level dialogue aimed at improving drought management—especially in agriculture—remain limited.

GAPS PER INTERPHASE – **FLOODS**

PREVENTION → PREPAREDNESS

→ **UNCLEAR PUBLIC ACTION DURING WARNINGS**

Though roles in our pilot locally, regionally and nationally are well defined and coordinated, public awareness of how to interpret warnings should be improved.

→ **LACK OF COMMUNITY AWARENESS PROGRAMS**

Communities may have some knowledge of flood risks, but educational campaigns, training, or drills are infrequent. As a result, residents may not be fully aware of how to self-prepare or respond when floods happen.

→ **CLIMATE-CHANGE ADAPTATION**

Protective measures are usually not designed with future climate change projections in mind.

PREPAREDNESS → RESPONSE

→ **GOOD LOCAL COOPERATION, BUT STILL SOME PERCEIVED LACK OF SERIOUSNESS IN WARNING SYSTEMS**

Beside good local cooperation, some residents do not take official alerts seriously enough or are unsure how to act on them. This can slow evacuations and increase the risk of injuries or property damage during floods.

RESPONSE → RECOVERY

UNDERDEVELOPED EMERGENCY ACTIONS NOT CONNECTED TO LONG-TERM SUSTAINABLE RECOVERY

During floods, temporary solutions (like quickly repairing a road or a bridge) are often made under pressure and are not linked to long-term recovery planning. While these quick fixes help restore access in the short term, they can lead to repeated damage in future events and higher costs over time if permanent solutions are delayed.

RECOVERY → PREVENTION

LIMITED USE OF LESSONS LEARNED PROCESSES

Following demanding response and recovery phases, typically involving the same stakeholders, limited capacity often remains for systematic lessons-learned processes and forward-looking planning. As a result, valuable operational experience gained by communities and authorities during recovery is not always documented, shared, or translated into concrete improvements and long-term resilience measures, increasing the risk of repeated shortcomings in future events.

INSUFFICIENT COMMUNICATION AND PUBLIC AWARENESS

Recovery efforts rarely include long-term public education or risk communication campaign raising awareness among public and people living in flood-prone areas.

GAPS PER INTERPHASE – **DROUGHT**

Across all phases of drought management, it is essential to establish strong cooperation and communication channels, ensuring regular information exchange and data flow among all institutions involved. Particular attention should be given to coordination between different sectors at both local and national levels.

On 3 September 2025, an expert consultation on communication during extreme weather and hydrological events was held in Škofja Loka. The event was organised by the Sora Development Agency and the Slovenian Environment Agency. Representatives of Civil Protection and municipal authorities from Škofja Loka, Gorenja vas–Poljane, Žiri, Železniki, and Medvode attended. (Author: Anita Pokorn Oman)

UNDERSTANDING RISK TERMINOLOGY

What is the Municipal Spatial Plan (OPN)?
OPN is a legally binding local planning document that defines land use, zoning, protected areas and spatial development within a municipality. It also serves as the basis for issuing preliminary decisions and building permits in accordance with construction regulations.

What is a municipal protection and rescue plan?
It is a document prepared by each municipality that explains how the community will protect people, property, and the environment in case of disasters like floods, fires, or earthquakes. The plan lists available resources (such as firefighters, equipment, shelters), assigns responsibilities, and describes the steps to take before, during, and after an emergency.

The **zoning of agricultural land** is a process of classifying and assessing the suitability of land for various types of agricultural production, based on the analysis of natural conditions such as soil type and climate, as well as economic factors. Its main objectives are to optimise land use, ensure the sustainable utilisation of resources, and adapt agricultural production to climate change.

Impact-based forecast is a type of weather or hazard forecast that goes beyond simply describing the expected meteorological or drought conditions. Instead, it focuses on what those conditions mean for people, infrastructure, and the environment. These forecasts often use risk matrices or color-coded warning systems (like yellow, orange, red alerts) to communicate both the likelihood of a hazard and the severity of its potential impacts, making them more actionable for decision makers, emergency services, and the public.

The **AJDA application** is a GIS application managed by the Administration for Civil Protection and Disaster Relief and is intended for entering data on damage assessments to agricultural crops and property following natural disasters. Compensation is paid on the basis of these assessments.

CO-DESIGNED TAILORED ACTIONS FOR THE PILOT AREA

Following the identification of critical gaps in risk management capacity and participatory workshops with local stakeholders from various sectors and municipal administrative authorities in the Sora Catchment, several priority actions have emerged to strengthen community resilience. Key flood-related initiatives include the establishment of a hydrological forecast system tailored to the local area, faster communication channels between the hydrological service and civil protection at the local level, updating municipal protection and rescue plans and implementing various more technical flood protection measures. For drought management, the first step would be the development of a concept for tasks and inter-institutional cooperation at the local level before, during, and after drought events, which has already begun within the framework of the X-RISK-CC project. Other actions relate to enhancing monitoring and conducting research in the local area for more efficient implementation of drought measures. All participants agreed that significant effort should also be devoted to raising awareness and communication activities.

Numerous proposals for actions were put forward during the workshops, and the most feasible measures for the local community are included in the action plan.

The complete list and details of the tailored action plan devised for the pilot area of Sora Catchment are published in a separate document called **"Tailored Action Plan: Sora Catchment"** which can be found at:

X-RISK-CC - Alpine Space Programme

https://www.alpine-space.eu/project/x-risk-cc/

During the second workshop, participants actively explored solutions to address floods and droughts in the Sora Catchment area. (Source: ARSO – Slovenian Environment Agency Archive)

CHALLENGES AND PERSPECTIVES

Many gaps in managing flood and drought risks exceed local capacities and require national actions. Key challenges include securing long-term funding for river management and flood protection, clarifying institutional responsibilities, and developing reliable national alert and communication systems. Addressing these at the national level is crucial to strengthen local efforts and build a comprehensive, resilient risk management system.

The identified gaps in risk management have been formulated into concrete measures within the action plan, focusing on those that are most feasible and implementable at the local level. In 2025, Gorenjska became the first Slovenian region to adopt a climate change adaptation strategy, accompanied by an action plan for climate resilience that will incorporate selected measures developed within the X-RISK-CC project. Furthermore, flood-related actions and measures will be integrated into the updated municipal flood protection and rescue plans.

Looking ahead, challenges remain in risk management, particularly in adapting to climate change and managing compound extreme weather and hydrological events such as concurrent major floods and multiple landslides, or severe drought conditions with the co-occurrence of hydrological drought, heatwaves, and forest fires.

At the second workshop, we offered stakeholders a glimpse into the future through climate-risk storylines, guiding participants into the year 2040.
(Source: ARSO – Slovenian Environment Agency Archive)

USEFUL RESOURCES

X-RISK-CC - Alpine Space Programme

https://www.alpine-space.eu/project/x-risk-cc/

X-RISK-CC – Web GIS: information on intensity and frequency of weather extremes in the entire Alpine Space

https://cct.eurac.edu/x-risk-cc

X-RISK-CC - The Sora Development Agency (RAS)

https://www.ra-sora.si/projekt/x-risk-cc-prilagajanje-ekstremnim-vremenskim-dogodkom-in-z-njimi-povezanimi-kaskadnimi-ucinki/

X-RISK-CC – Slovenian Environment Agency (ARSO)

https://www.gov.si/zbirke/projekti-in-programi/x-risk-cc/

Water Atlas (platform of Slovenian Water Agency)

https://geohub.gov.si/portal/apps/webappviewer/index.html?id=f89cc3835fcd48b5a980343570e0b64e

eVode (platform of Slovenian Water Agency)

http://www.evode.gov.si

URSZR – flood-related materials and guidance

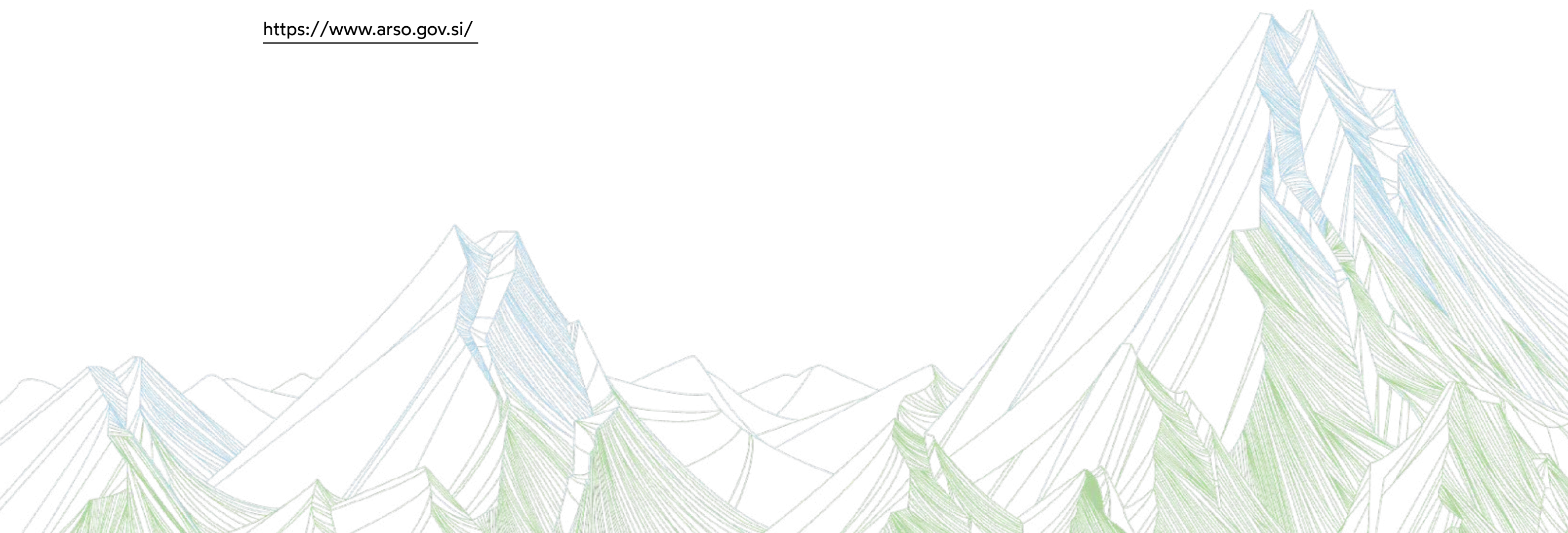
https://www.sos112.si/medijsko-sredi%C5%A1%C4%8De/plakati/poplave

URSZR – audio and video content

https://www.sos112.si/medijsko-sredi%C5%A1%C4%8De/avdio-in-video-vsebine

Information on weather warnings, hydrological conditions and forecasts, drought conditions and forecasts (Droughtmeter) is available on the Slovenian Environment Agency (ARSO)

https://www.arso.gov.si/



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