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X-RISK-CC

PILOT DOSSIER

FLERES VALLEY IN SOUTH TYROL

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

LEAD PARTNER

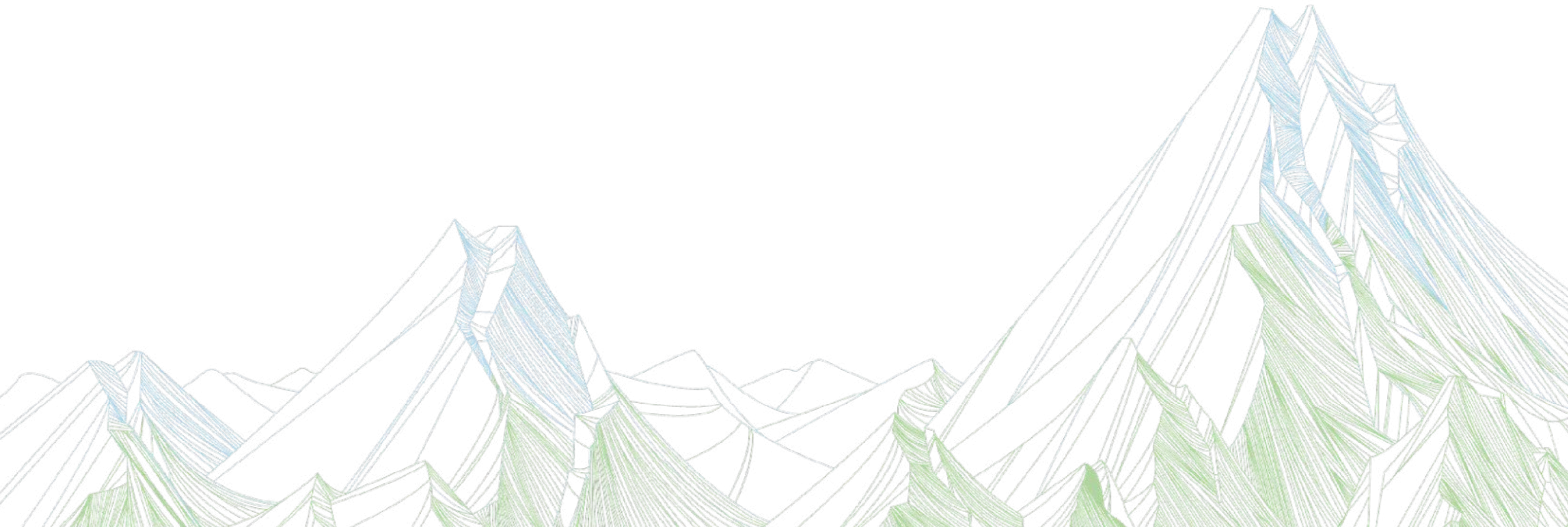
PROJECT PARTNERS

FLERES VALLEY
IN SOUTH TYROL

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

THIS DOSSIER

The dossier focuses on the Fleres Valley in South Tyrol (northeastern Italy) 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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Publication Date:

November 2025

This publication is available on the project website under the "Outcomes" section:

X-RISK-CC - Alpine Space Programme

Interreg Alpine Space | Co-funded by the European Union | X-RISK-CC

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.

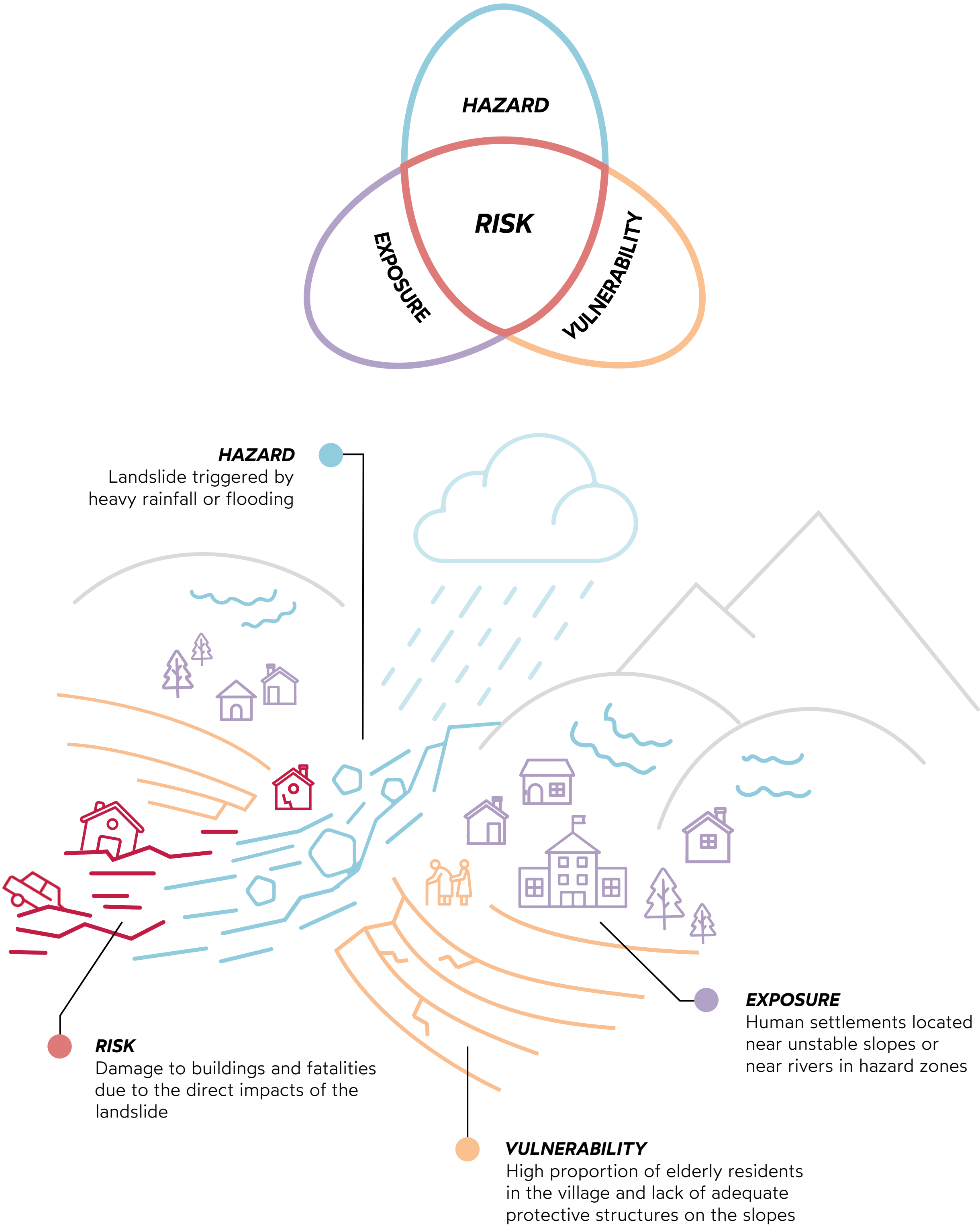


FIGURE 1: *Illustrative examples of hazard, exposure and vulnerability contributing to risk (the concept of risk is based on the framework developed by the Intergovernmental Panel on Climate Change - IPCC).*

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.

Debris flow and flood in Fleres Valley on 16 August 2021 (Source: Civil Protection Agency of the Autonomous Province of Bolzano).

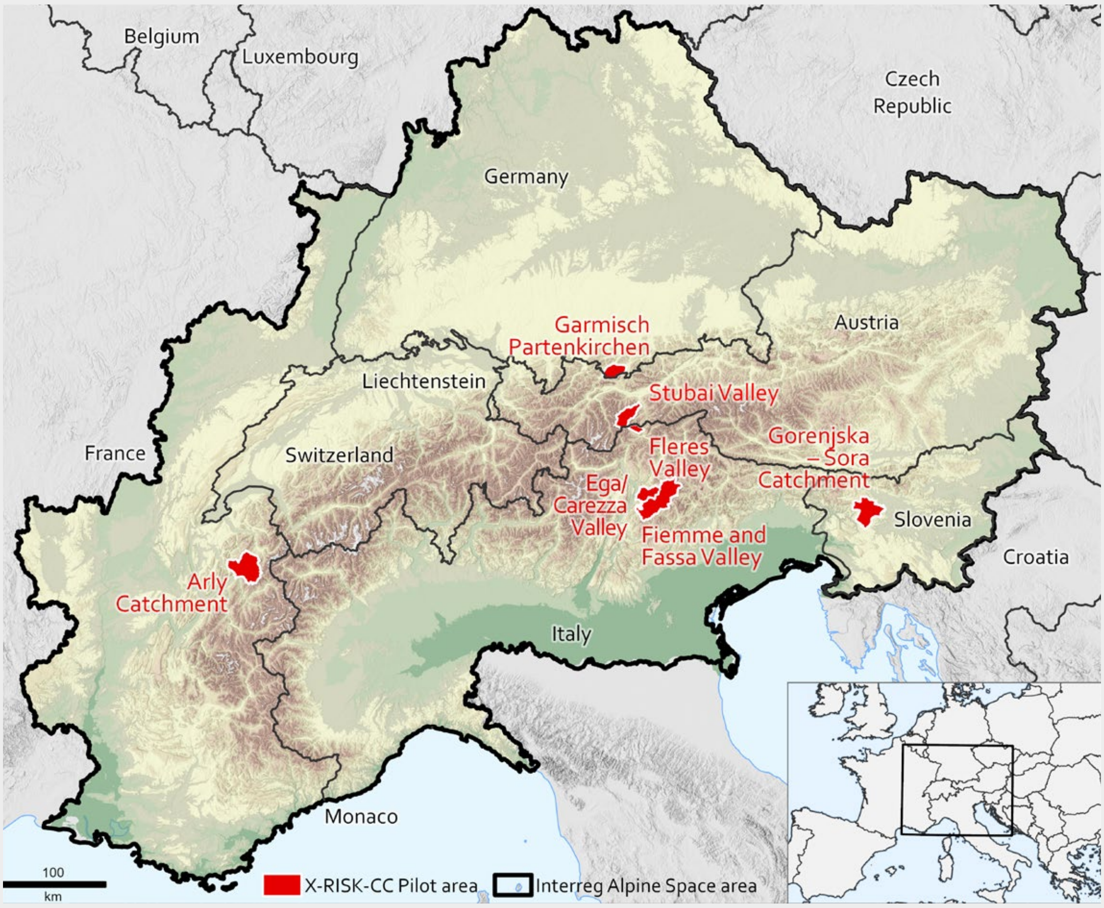


FIGURE 2: *Map illustrating the pilot areas (shown in red) of the X-RISK-CC project.*

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: FLERES VALLEY (SOUTH TYROL, ITALY)

GEOGRAPHICAL AND ENVIRONMENTAL SETTING

The pilot area is located in South Tyrol in the eastern Italian Alps bordering with Austria (***FIGURE 3***). It covers the Fleres Valley, a branch of the Isarco Valley, spanning approximately 75 km^2. The area is mostly mountainous with elevations ranging from about 1,000 m above mean sea level (a. m. s. l.) in the centre of the valley to 3,200 m a. m. s. l. at the northern, western and southern edges.

The Fleres Valley has around 600 inhabitants. Several steep and narrow lateral catchments are drained by streams and secondary rivers flowing into the valley. Due to its morphology, the area is prone to natural hazards, particularly debris flows, which are usually triggered by intense summer rainfall. These events can cause significant damage, as the valley is both residential and a popular tourist destination, with the population nearly doubling during peak tourist seasons in summer and winter.

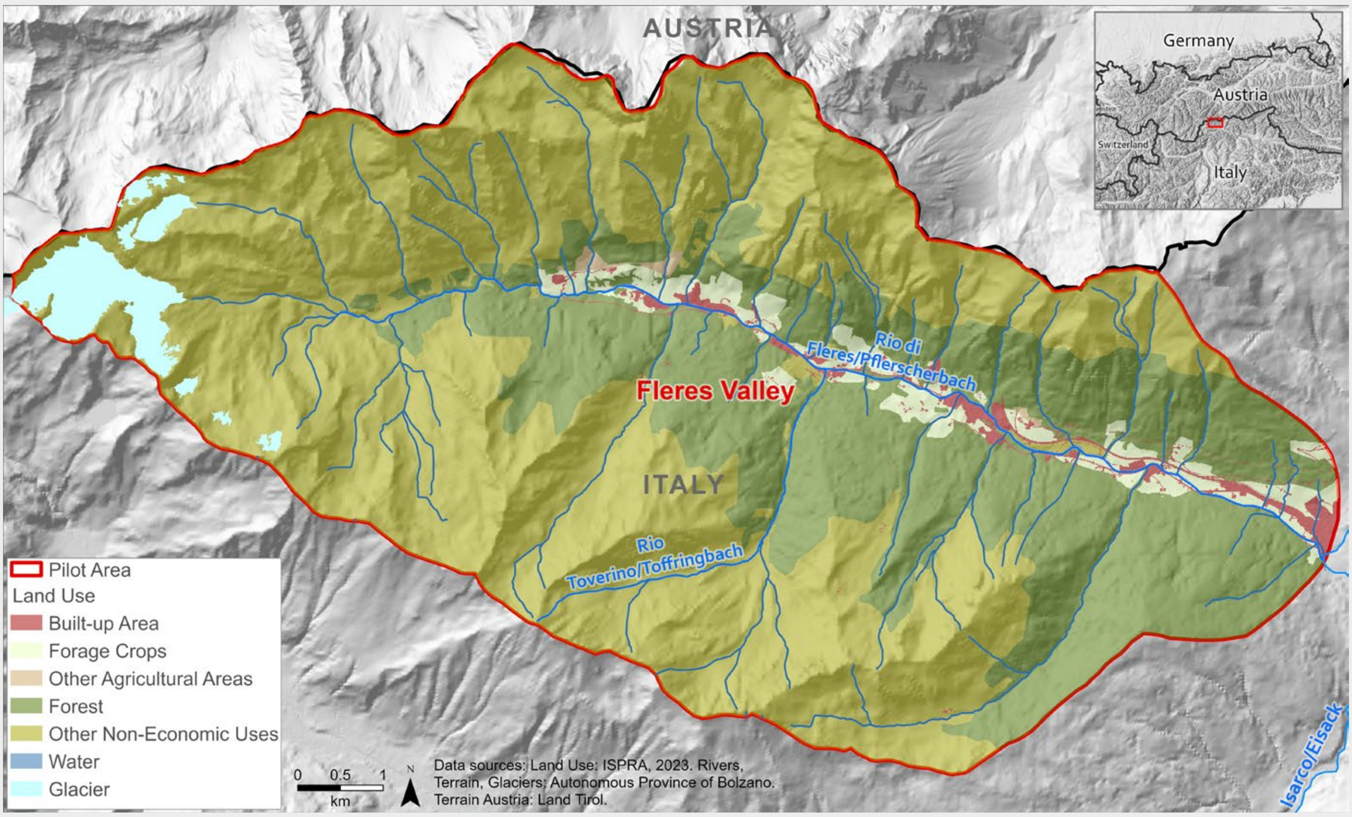


FIGURE 3: *Map of the Fleres Valley showing the actual extent of the Fleres River basin (in red) and land use types.*

A major event occurred on 16 August 2021 (***FIGURE 4***), when thunderstorms with locally intense rainfall - exceeding 80 mm in a single day - triggered a debris flow on the Toverino River, a tributary of the Fleres River. The deposited material, estimated at 35,000 – 45,000 m^3, diverted the main stream and caused flooding that damaged buildings, roads, agricultural land and energy infrastructure. Several residents and tourists were evacuated and some villages remained temporarily isolated.

The X-RISK-CC project analysed how risks associated with **extreme rainfall-induced events**, such as the August 2021 event, may evolve in the pilot area in the future.

Additional information about the event of 16 August 2021 can be found in the publications of the Autonomous Province of Bolzano:

→ the Climareport of August 2021

https://meteo.provincia.bz.it/pubblicazioni.asp?publ_action=300&publ_image_id=599001

→ the Report of Natural Hazards 2021

https://assets-eu-01.kc-usercontent.com/f25c3e79-d836-0158-96a2-5418035fd6a5/4e19f413-3db0-4627-9d76-a24672b32c99/Report_Pericoli_Naturali_2021.pdf

FIGURE 4: *Debris flow and flood in Fleres Valley on 16 August 2021 (Source: Civil Protection Agency of the Autonomous Province of Bolzano).*

PAST AND FUTURE WEATHER EXTREMES

In South Tyrol, intense short-duration precipitation events are frequent during summer, when thunderstorms are more likely, amplified by the mountainous topography. Weather station records from recent decades indicate that annual maxima of total daily precipitation typically range from 60 to 70 mm, with the highest intensities in summer and, secondarily, in autumn. In this region, 100 mm of precipitation in a single day has an approximate return period of 50 years. Observations over the past 70 years reveal a trend toward more intense and frequent precipitation events.

Future projections indicate that both the intensity and frequency of extreme daily precipitation events will increase. Under a global warming scenario of + 3 °C relative to the pre-industrial period, precipitation extremes could become 15 % more intense and 45 % more frequent than today, while a current 50-year event could become nearly 30 % more intense. Higher-intensity short-duration extremes are also projected, with rainfall rates increasing by approximately 10 mm/hour under the + 3 °C warming scenario.

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.

HAZARDS IN PRESENT AND FUTURE CLIMATE

Due to the topography and climatic characteristics of the area, debris flows are the most frequent weather-induced hazards in the Fleres Valley. Between 2000 and 2023, nearly 60 events were recorded, occurring mostly in summer and affecting small lateral basins and their alluvial fans. Debris flows are typically triggered by intense rainfall, especially when preceded by periods of persistent precipitation that saturate the soil. Their localised nature often makes them difficult to predict, so they can occur with little warning.

In the future, an increase in the intensity and frequency of extreme precipitation, coupled with permafrost thaw, is expected to raise both the likelihood and magnitude of debris flows. More unstable soils, together with projected intensification of precipitation extremes may amplify peak discharges and enlarge the areas affected by transported material. Based on the climatic scenarios developed in this project, debris-flow simulations for the Toverino River, where the damaging event of 16 August 2021 occurred, indicate that the extent and the volume of deposited material during such events may substantially increase in the coming decades. By 2100, an event comparable to that on 16 August 2021 could cover a larger area and deposit more material, particularly under the worst-case warming scenario.

These climate-related changes are expected to apply not only to the Toverino River catchment but also to other similar catchments in the Fleres Valley and, more broadly, across South Tyrol, with significant implications for local risk management.

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.

The term **permafrost** refers to soil that remains frozen (i.e., at or below 0 °C) for at least two consecutive years. In the Alps permafrost is retreating and shifting to higher elevations due to warming. Where permafrost disappears, soil stability decreases, increasing the likelihood of collapses and the amount of sediment that can be mobilised.

CURRENT AND FUTURE IMPACTS AND RISKS

The Fleres Valley is a mountainous area characterised by small villages, with agricultural land in the valley bottom and forests, managed meadows and pastures at the higher altitudes. The elements most exposed to potential damage from a debris-flow event include residents, private properties and buildings, agricultural land - particularly livestock farms and crops located in the valley bottom or near slopes and rivers – as well as infrastructure such as roads, bridges connecting villages to main towns and water and energy supply systems.

As a popular tourist destination, where the population nearly doubles in both summer and winter, tourist facilities and visitors are also highly vulnerable to hazardous events.

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.

According to the current hazard map, almost 45 % of the road network, more than half of existing buildings and livestock farms, and a substantial portion of the water and energy supply system intersect with at least one hazard zone (***FIGURE 5***).

It is important to note that the consequences of natural hazards— such as interruptions to roads and bridges— can last for several days and, depending on the severity of the damage, even months after the event, especially when major reconstruction is required.

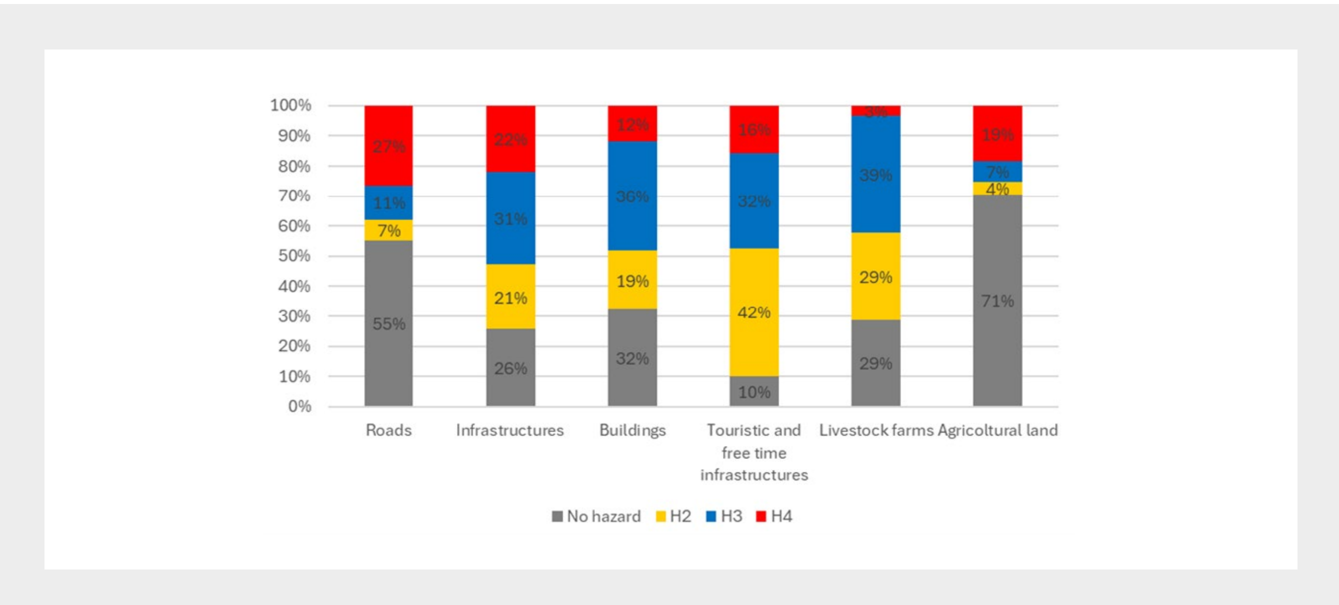


FIGURE 5: *Percentage distribution of hazard levels by type of exposed structures in the Fleres Valley pilot area. The colours correspond to the classification of hazard levels of the Autonomous Province of Bolzano system (grey = areas that did not present hazard levels at the time of analysis; H2 = medium hazard, H3 = high hazard, H4 = very high hazard).*

If the population and tourist growth trends observed over the past 20 years (Provincial Statistics Institute – ASTAT) continue, additional built-up areas will be needed to accommodate new buildings and infrastructure. However, the mountainous morphology of the Fleres Valley, characterised by steep slopes and narrow valley bottoms, limits the space available for construction. As a result, new development sites may fall within hazard-prone areas, according to the current hazard map classification.

Moreover, with the potential increase in the frequency and magnitude of debris-flow events under climate-change, the current classification of hazard zones may change, with new areas potentially designated as hazard zones or assigned to higher hazard classes.

Flood in the Fleres Valley
(August 2021)

On 16 August 2021, a debris flow from the Toverino River catchment directly damaged vehicles, buildings and bridges. The interruption of both main and secondary roads left some villages and buildings isolated for several hours. The debris flow also blocked and diverted the main Fleres River, causing flooding and multiple power outages due to damage to the local power plant. In total, 30 residents and tourists were evacuated and reconstruction and cleaning operations continued for several days following the event.

THE ROLE OF VULNERABILITY IN RISK

The impacts of a hazard event can be exacerbated not only by the event's intensity or the number of exposed elements, but also by other factors such as social characteristics (e.g., an ageing population, low risk perception, or lack of awareness) and the condition and maintenance of buildings and infrastructure. Tourists—particularly international visitors—are expected to be especially vulnerable, as they often lack the same level of risk awareness and familiarity with local emergency procedures.

Greater impacts are also more likely when risk management practices are inadequate—for example, in the absence of protective measures such as rockfall barriers—or when preparedness for multiple simultaneous or cascading hazards is low, as in the case of the debris flow triggering flooding as occurred in the Fleres Valley in August 2021.

In this context, a thorough evaluation of current risk management measures and their adaptation to changing conditions is crucial for the safety of residents, visitors and their activities.

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.

Debris flow and flood in Fleres Valley on 16 August 2021 (Source: Civil Protection Agency of the Autonomous Province of Bolzano).

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

Three participatory workshops were held in the pilot area to analyse and improve local risk management of natural hazards driven by weather extremes. Participants included different entities dealing with risk: municipalities, forest services, civil protection, torrent control authorities, local enforcement bodies, technical experts, research institutions, and representatives from different levels of administration. During **the first workshop** the recent extreme events were reviewed to evaluate what worked well and what failed in terms of risk management so to identify entry points for future improvements; in **the second workshop** participants were invited to evaluate the current capacity and potential challenges in managing similar events but in a plausible future context, based on analysed climate projections and possible socio-economic evolution; **the third workshop** was focused on developing concrete action plans for improving the management of future risks related to climate extremes. All workshops were guided by the SMART approach—setting goals that are **Specific, Measurable, Achievable, Relevant, and Time-bound**—to ensure the results were realistic, actionable, and tailored to the region's needs.

1. Workshop

ANALYSE THE PAST AND FIND THE GAPS

2. Workshop

LOOK AT THE FUTURE AND DEFINE CHALLENGES

3. Workshop

MAKE THE PLANS

Participants in the workshops in the pilot area of Fleres Valley

- Civil Protection Agency Autonomous Province of Bolzano
- Mayor and Administration of Brennero Municipality
- Forest Inspectorate and Forest Station of Sterzing
- Provincial Office for Torrent and Avalanche Control
- Provincial Office for Hydrology and Dam Structures
- Provincial Office for Meteorology and Avalanche Warning
- Provincial Warning Center
- Provincial Department of Road Services
- Provincial Department of Agriculture
- Provincial Geological Service
- Local Electricity Operators
- Provincial Professional Fire Brigade
- Local Volunteer Fire Brigade
- Brennero Avalanche Commission

RISK MANAGEMENT GAPS

The first workshop showed that the prevention phase is particularly critical in case of a debris-flow event like the one occurred on 16 August 2021 in Fleres Valley. Specifically, it was realized that current classification of areas prone to natural hazards does not account for complex scenarios, i.e., a river flood induced by a debris flow, which is crucial to adopt more effective risk prevention measures. The need of strengthening non-structural prevention measures was also identified.

Despite the unexpected nature of the event, the response was effective: the response from the firefighters was prompt, and the warning system ensured that excavators were already available for intervention.

The analysis also highlighted the effective collaboration among key responders involved during the event and in the "post-event" phase, including the municipal administration, the mayor—as the holder of legal responsibility—firefighters, decision-making chains, local companies providing excavators, on-site responders, the Civil Protection, and the Torrent Control Office.

It emerged how responsibilities related to the post-event recovery phase are interlinked, thus shedding light on the importance of coordination during the recovery efforts.

GAPS PER PHASE

The key gaps identified for past events and for the projections for the future through the participatory workshop process are reported in the following sections, first for each phase of the risk management cycle, then for the interphases between them.

Participatory workshop held in the Municipality of Brennero during the X-RISK-CC project (Source: Civil Protection Agency of the Autonomous Province of Bolzano).

GAPS PER PHASE

PREVENTION

- In South Tyrol, hazard maps are usually developed for single hazards without considering how events can combine. A landslide could block a river and cause a flood, creating risks where we don't expect them. To be prepared, we need tools that reflect these complex connections.
- The hazard mapping should not stop at confluence points of rivers but continue along larger watercourses where risks may still be significant.
- Non-structural prevention measures can be strengthened to help keep communities safe by ensuring people know the risks, what to do, and how to communicate in emergencies. This awareness building is often undervalued when compared to the building of physical defences. Strengthening it improves prevention and cooperation, making communities more prepared when disasters strike.
- Some areas, like Kogbach and Allrissbach, may be at risk of more frequent or intense debree flow and flood events than originally planned for and need protective measures for these cases. In Kogbach, for example, there is no retention basin to manage floods. Protective infrastructure was mainly built based on past rainfall record, but in recent years, we need a push to strengthen it to handle more intense weather conditions due to climate change.
- Part of prevention is to make sure the citizens and people present in the region know what each alarm (sirene) means and to know how to act according to each one. Practice drills are needed and the importance of being prepared for emergencies should be understood by administrations and civil society alike, so that everyone can react quickly and safely.
- Improving coordination between emergency services—such as fire brigades, police, and municipal staff—is a key prevention measure to ensure smoother response during events. Even with well-structured plans, real-time cooperation can falter without preparation. Regular joint exercises to help clarify roles, build trust, and speed up decision-making are needed.

PREPAREDNESS

- It is important that citizens understand the uncertainties inherent in weather forecasting and the warnings that result from them, in order to be able to appropriately assess and respond to risks.
- When heavy rain or snowfall hits the northern parts of the Province of Bolzano, roads and highways often become bottlenecks, with traffic slowing down and long jams forming. While the responsibility for the highways is not of the municipality, the operational consequences of managing immobilized traffic and displaced vehicles on local level require emergency response coordination and traffic diversion.
- The communication framework between the Brennero corridor Railway company and the municipalities situated along the railway can be strengthened. This coordination is necessary for emergency evacuation procedures, to avoid operational inefficiencies and to avoid strain on emergency response resources.
- Current warning systems work well for those who know them, but they often don't reach travelers, tourists, or cross-border workers effectively. Language barriers and lack of familiarity reduce the effectiveness of warning systems. Local businesses—like hotels and restaurants— can act as valuable information multipliers for risk communication and warnings.
- Short-term warnings need to be strengthened, especially for fast-moving weather events like thunderstorms. Improved radar coverage, lightning and hail prediction can help detect risks earlier.
- Raising risk awareness from a young age is key to long-term safety. School education should include lessons on warning systems, alert symbols, and how to respond correctly. Early knowledge builds a culture of preparedness for the future.
- Current administrative emergency protocols are effective for localized incidents but show critical gaps during large-scale, multi-valley events where coordination capacity is exceeded and mutual aid mechanisms remain undefined.
- Electrical and communication networks are equipped with backup systems including batteries and generators. Given projections for larger, more frequent extreme weather events, these backup capacities must be enhanced to ensure continued functionality in case of more widespread or prolonged power outages.
- A known challenge in narrow valleys is the lack of space to store debris brought by watercourses during extreme events, which can slowdown emergency response and block access routes. Potential debris storage areas should be identified and mapped in advance within emergency plans as part of land-use planning.

RESPONSE

- During multi-municipal emergencies, stakeholders have identified the need for an better structured coordination between individual municipalities and the provincial crisis center. While the fire brigade operation center provides operational support, it lacks political leadership at the mayoral level. Effective emergency response requires unified command with clear decision-making authority across all responding organizations.

- Declining volunteer availability threatens emergency response capacity for large-scale events. While this poses significant human resource challenges, increased coordination and organization of volunteer organizations may help address the gap.

- Clear protocols for emergency road management could be improved, particularly for minor local roads. Where guidelines exist, the communication with responsible services can be strengthened to avoid operational delays and confusion during critical response phases. Standardized, well-disseminated procedures are needed.

- Authorities must establish themselves as the primary trusted information source during emergencies. The rapid spread of unverified information on social media necessitates stronger official communication channels to ensure accurate, timely information reaches all affected populations.

- Evacuation remains a critical challenge during response phases. Insufficient risk awareness sometimes leads to evacuation refusals, requiring enforcement by authorities. Additionally, evacuation poses significant logistical challenges, including securing adequate shelter spaces—often in neighbouring municipalities—and coordinating multiple agencies and resources.

RECOVERY

- Individual institutions—Forest Department, Fire Brigade, Torrent Control Service, and Civil Protection—operate effectively within their mandates. However, recovery efforts are frequently delayed by bureaucratic processes,, and inter-organizational coordination gaps. A dedicated recovery coordination center is needed to consolidate information, align multi-agency activities, and streamline reconstruction funding.
- Building a strong risk culture requires involving the whole community through both technical and public meetings. In the recovery phase, a clear point of contact for citizens is essential—providing updates, answering questions, and encouraging involvement. Ongoing communication in the months and also years after an event helps build trust and supports a transparent, inclusive recovery process.
- In South Tyrol, there is currently no standard system for insuring buildings against natural hazards, regardless of their location within hazard-prone areas based on the official hazard maps. Introducing a model that links risk exposure to insurance could enhance individual preparedness and strengthen recovery capacity. This approach may also promote more responsible development in high-risk areas.
- Post-disaster reconstruction offers a key opportunity to build back better and reduce future vulnerability. Known risks should be systematically addressed during reconstruction, integrating climate change projections and future hazard scenarios to prevent repeating past errors. However, no formalized post-event evaluation process currently exists, and reconstruction insights are not systematically incorporated into hazard map updates or risk assessments.

GAPS PER INTERPHASE

PREVENTION → PREPAREDNESS

→ SLOW SHIFT FROM RISK INSIGHT TO PREPAREDNESS ACTION

Despite knowing where risks exist, lengthy procedures often delay translating this knowledge into timely, concrete preparedness steps.

→ PROTECTIVE STRUCTURES AND CLIMATE CHANGE ADAPTATION

While protective structures are well-defined with calculated design volumes, they are not designed with future climate change projections in mind, and methods for parametrizing these changes remain unclear.

→ PREPAREDNESS GAPS FOR OVERLOAD SCENARIOS

Planning rarely accounts for situations where protective systems are exceeded, leaving critical gaps in emergency logistics and readiness.

→ UNCLEAR ROLES AND ACTIONS DURING WARNINGS

Though roles are legally defined, public and administrative awareness of how to interpret warnings and respond appropriately have to be improved.

PREPAREDNESS → RESPONSE

→ RIGID PLANNING AND UNCLEAR DECISION FRAMEWORKS IN COMPLEX CRISES

Emergency preparedness often relies on fixed scenarios, lacking the flexibility to adapt to unpredictable events. Early response is also slowed by unclear decision-making structures and a lack of prioritization—especially in fast-moving or black swan situations.

→ PUBLIC AND TOURISTS LACK CLEAR GUIDANCE FOR FIRST RESPONSE

Many residents and visitors are unsure how to interpret alerts or act during emergencies, weakening community-level responses and delaying critical protective measures.

→ INSUFFICIENT OPERATIONAL PLANNING FOR CROSS-MUNICIPALITY EVENTS

Emergencies spanning multiple jurisdictions face fragmented planning and unclear leadership, making it difficult to mobilize resources and coordinate a timely, unified response.

RESPONSE → RECOVERY

LOSS OF KNOWLEDGE AND TRAINING GAPS

Recovery efforts can be affected by staff turnover and limited systems for retaining and transferring institutional knowledge and specialized technical skills.

LIMITED STRUCTURE AND LONG-TERM VISION IN RECOVERY

The shift from response to recovery lacks clear frameworks and dedicated planning, with limited emphasis on building back better through resilient and sustainable reconstruction.

INSUFFICIENT COMMUNITY ENGAGEMENT AND INFORMATION SHARING

Community input, local knowledge, and transparent information flow are not always integrated into recovery processes, missing opportunities to strengthen trust, cooperation, and preparedness for future events.

UNDERDEVELOPED PLANNING FOR SUSTAINABLE AND ADAPTIVE RECOVERY

Recovery planning and training often stop at the response phase, leaving limited room for long-term.

RECOVERY → PREVENTION

LIMITED LEARNING FROM PAST EVENTS

Insights gained during recovery are not always systematically documented or shared, reducing the opportunity to inform and improve future risk assessments and preventive measures.

DELAYED OR MISSED OPPORTUNITIES FOR STRUCTURAL IMPROVEMENTS

The **post-event phase** often lacks mechanisms for timely land acquisition and infrastructure upgrades, missing a critical window to implement more resilient or relocated solutions.

GAPS IN RISK REASSESSMENT AND PLANNING

Risk zones and contingency plans are not always updated after events, leading to repeated exposure and underpreparedness in areas shown to be vulnerable.

INSUFFICIENT INTEGRATION OF COMMUNICATION AND PUBLIC AWARENESS

Recovery efforts rarely include **long-term public education or risk communication strategies, weakening the prevention culture** among residents and tourists alike.

FRAGMENTED COORDINATION ACROSS ACTORS AND TERRITORIES

Collaboration between municipalities, sectors, and regions (especially cross-border) **tends to weaken once the immediate crisis ends**, hindering prevention efforts that depend on long-term cooperation.

UNDERSTANDING RISK TERMINOLOGY

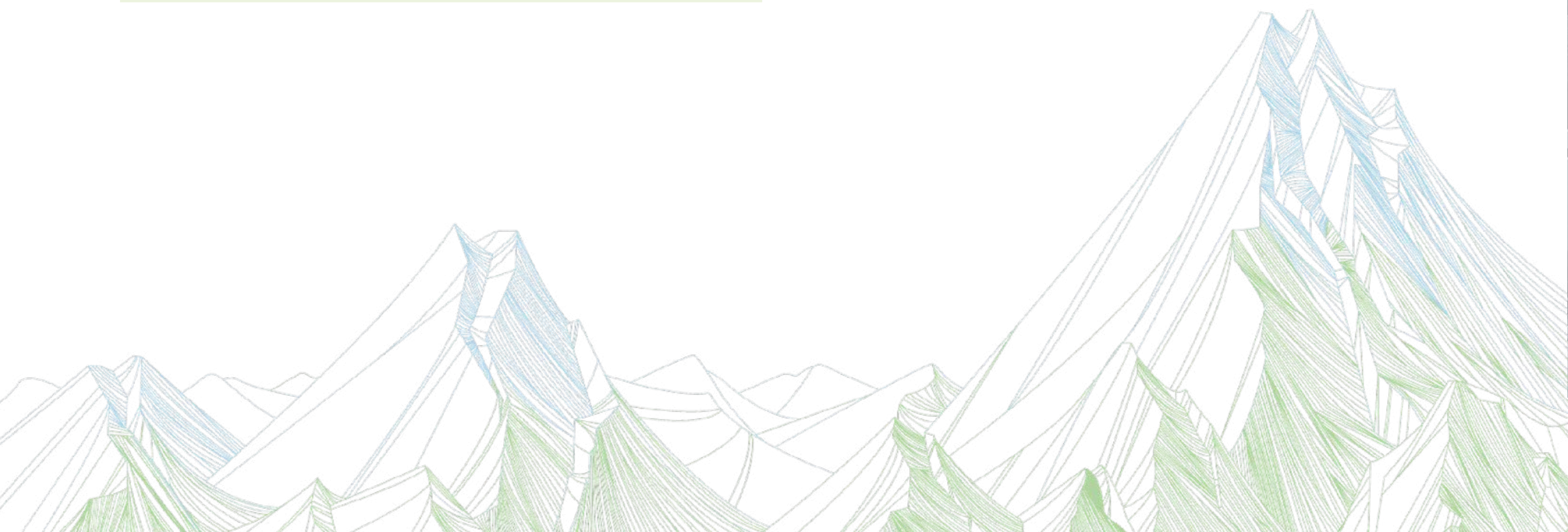
Risk awareness is understanding local hazards and their potential impacts, knowing how to respond and stay safe.

Risk communication is receiving clear, timely information about existing risk.

Self-protection in risk management means the actions individuals or families take to keep themselves safe before, during, and after a dangerous event—like securing their home before a storm, following evacuation advice, or having emergency supplies ready.

Build back better means improving things during reconstruction rather than just rebuilding exactly as they were before. This approach uses lessons from the disaster to reduce future risks and prepare for climate change.

For example, instead of rebuilding the same road on a landslide-prone slope, it can be rerouted or protective measures can be added.



CO-DESIGNED TAILORED ACTIONS FOR THE PILOT AREA

Following the identification of critical gaps in risk management capacity and participatory workshops with local stakeholders and administrative authorities in the Brennero municipality, a priority action plan has emerged to strengthen community resilience. Key initiatives include starting a working table to establish faster communication channels with the railway authority and highway operators and plans to enhance training and preparedness programs for emergency responders and civil protection volunteers. A nowcasting system for thunderstorm forecasting is currently being implemented to improve short-term weather predictions. The Provincial Warning Center is developing a risk communication strategy for warnings to residents and tourists.

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

X-RISK-CC - Alpine Space Programme

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

Participatory workshop held in the Municipality of Brennero during the X-RISK-CC project (Source: Civil Protection Agency of the Autonomous Province of Bolzano).

CHALLENGES AND PERSPECTIVES

In the South Tyrolean pilot area of Fleres Valley, a major challenge lies in the distribution of responsibilities. For instance, during heavy snow events along the highway, responsibilities range from the state to individual municipalities. Communication across these levels is not always straightforward and requires regular exercises, which demand coordination and effort. Nonetheless, in this project, cooperation between the Province and the municipality was exemplary, marked by a consistent willingness for exchange and mutual support. The Fleres Valley demonstrated how effective coordination can strengthen preparedness and response.

Some identified gaps have already begun to be addressed. In civil protection, the municipality of Brennero—together with around 90 % of South Tyrolean municipalities—participated in targeted information events organised by the Province. These initiatives reinforced collaboration and ensured that local administrations remain up to date on civil protection plans and the provincial warning and alerting system.

Another gap was the absence of a short-term thunderstorm warning system—the type of event that triggered the situation in Fleres Valley. In response, the Province has begun developing a forecast model capable of predicting storm cell locations up to one hour in advance, providing first responders with crucial preparation time.

Looking ahead, challenges remain in risk management, particularly in adapting to climate change. This project represents an important first step toward greater resilience.

Participatory workshop held in the Municipality of Brennero during the X-RISK-CC project (Source: Civil Protection Agency of the Autonomous Province of Bolzano).

USEFUL RESOURCES

The portal of Natural Hazards in South Tyrol

https://naturgefahren.provinz.bz.it/de/home

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

Climate Risk Analysis South Tyrol

https://klimaanpassung-suedtirol.eurac.edu/de

X-RISK-CC - Alpine Space Programme

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

Municipality of Brennero - Homepage - Thematics - Civil Protection

https://www.gemeindebrenner.eu/de/Themen/Zivilschutz

Civil Protection Broschure

https://www.provinz.bz.it/sicherheit-zivilschutz/zivilschutz/veroeffentlichungen.asp#download-area-idx151565

ACKNOWLEDGMENTS

We extend our sincere gratitude to all participants who contributed their time, expertise, and local knowledge throughout the project and the workshop series in the Fleres Valley pilot area. Representatives from municipal administrations, provincial agencies, emergency services, infrastructure operators, and community organisations engaged with professionalism and openness, sharing valuable insights from their direct experience in managing extreme events in this Alpine territory. Special recognition goes to the Municipality of Brennero for their collaborative spirit and ongoing commitment to enhancing risk management practices.

Debris flow and flood in Fleres Valley on 16 August 2021 (Source: Civil Protection Agency of the Autonomous Province of Bolzano).

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