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PILOT DOSSIER

FIEMME AND FASSA VALLEYS IN TRENTINO

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

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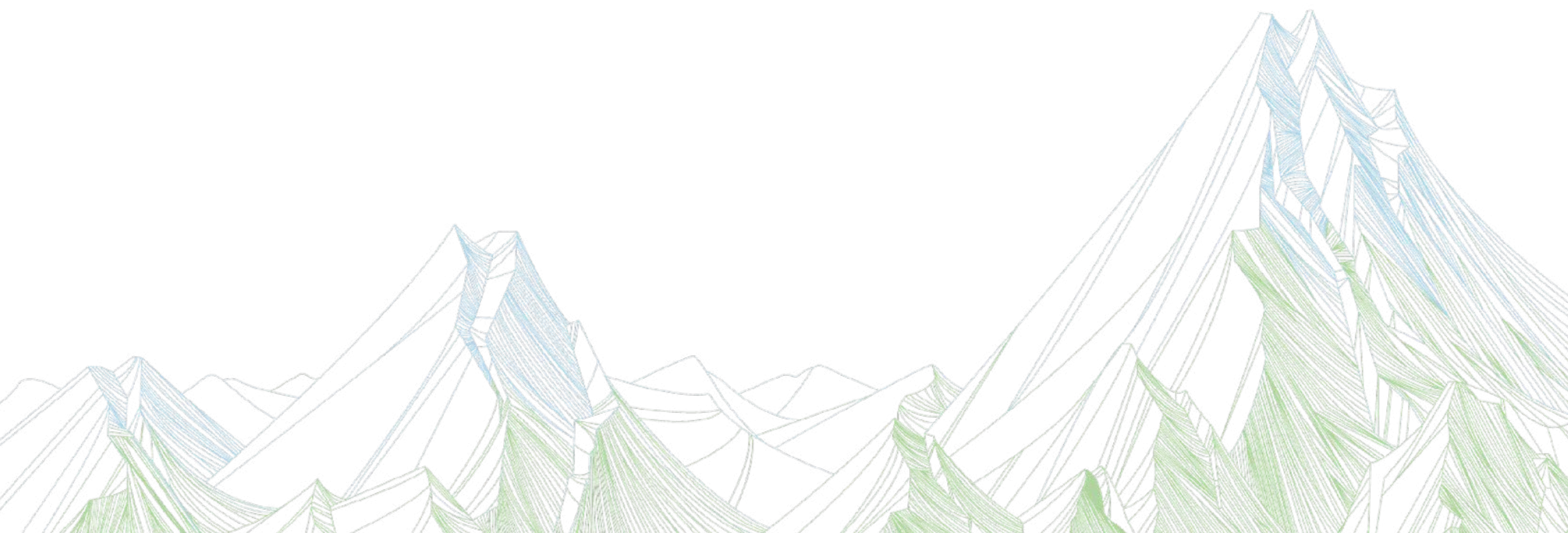
THIS DOSSIER

The dossier focuses on Fiemme and Fassa Valleys in Trentino (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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X-RISK-CC - Alpine Space Programme

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, the 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 in the region 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.

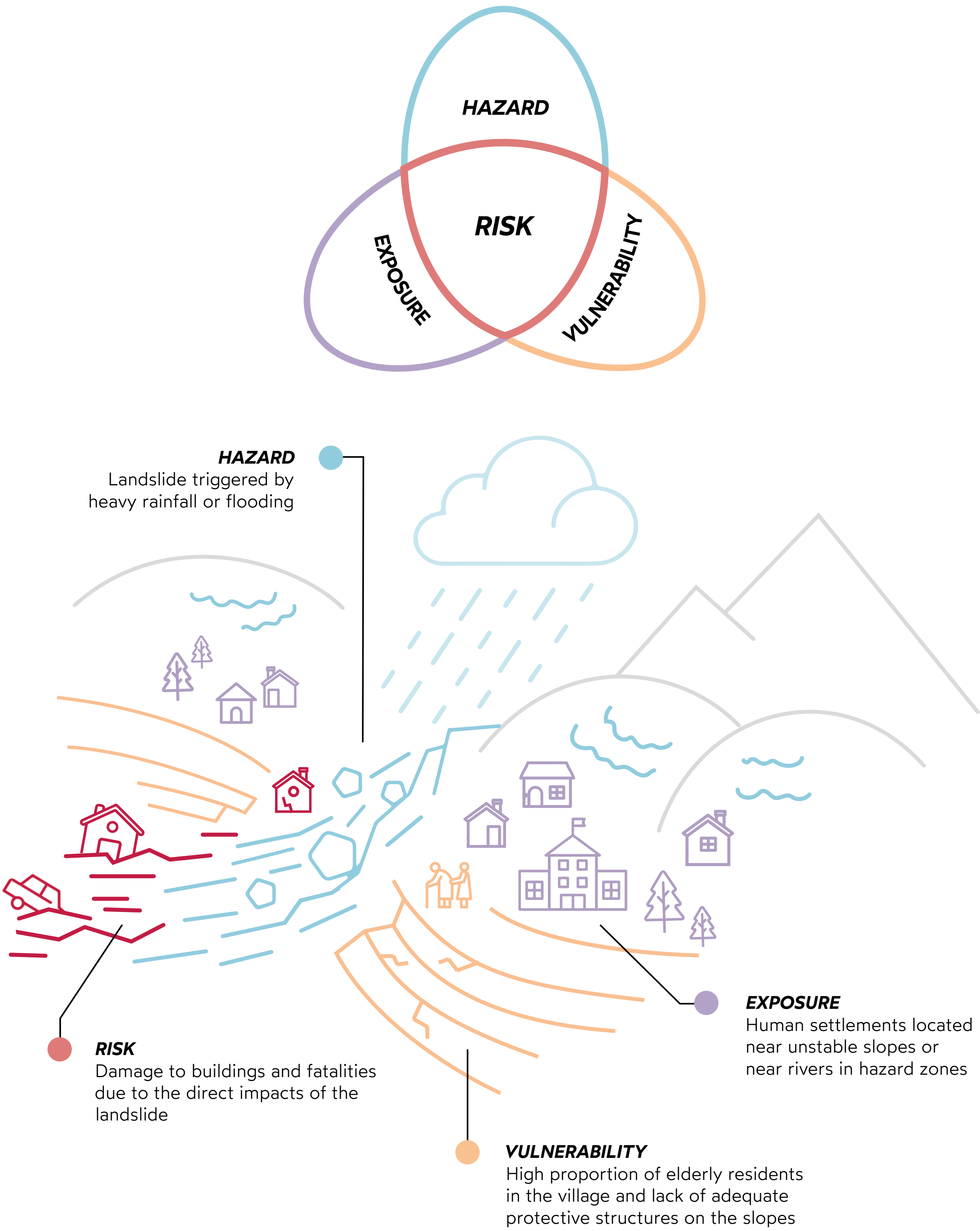


FIGURE 1: *Illustrative examples of hazard, exposure and vulnerability contributing to risk (the concept of risk is based on the framework developed by the Intergovernmental Panel on Climate Change - IPCC).*

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.

Forest area in Trentino after Storm Vaia in 2018, with extensive windthrown trees. (Source: Autonomous Province of Trento)

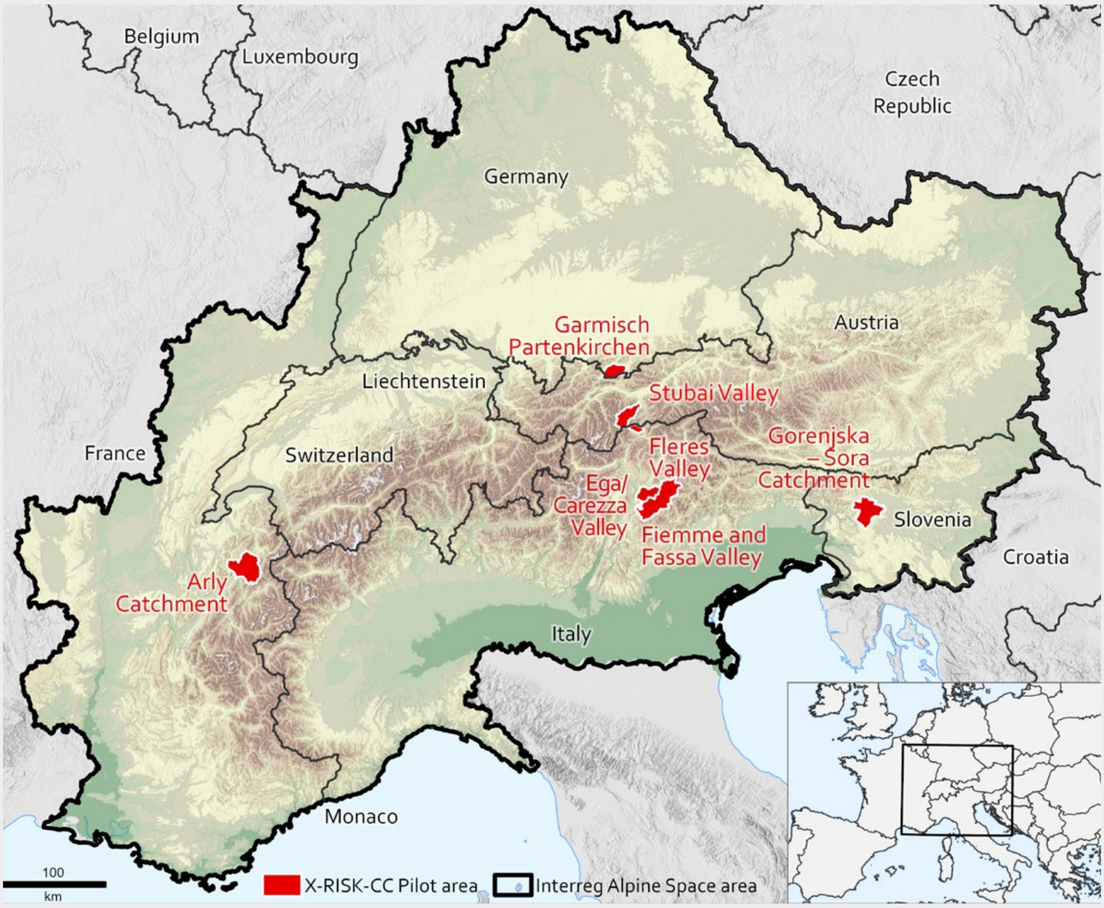


FIGURE 2: *Map illustrating the pilot areas (shown in red) of the X-RISK-CC project.*

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: FIEMME AND FASSA VALLEYS (TRENTINO, ITALY)

GEOGRAPHICAL AND ENVIRONMENTAL SETTING

The Fiemme and Fassa Valleys are located in Trentino, in the eastern Italian Alps (***FIGURE 3***). Together, the two valleys cover an area of approximately 730 km^2, which is mostly mountainous, with elevations ranging from about 600 meters (m) above mean sea level (a. m. s. l.) in the centre of the valleys to nearly 3,300 m a. m. s. l. at the crests.

The pilot area is crossed by the Avisio River and its multiple secondary tributaries. It includes 15 municipalities, such as Predazzo, Cavalese, Moena and Canazei, which are also well-known tourist destinations.

Due to its mountainous terrain, the area is prone to natural hazards - particularly debris flows, landslides and flooding, which can have severe consequences for residents and tourists, especially during peak tourist seasons.

The region is largely covered by spruce-dominated forests, whose protective functions and ecosystem services can be weakened by multiple disturbances, such as windthrow, heavy snow loads, and prolonged drought. Disturbed forests combined with favourable meteorological conditions, increase the likelihood of bark beetle outbreaks, which further damage trees and reduce root stability.

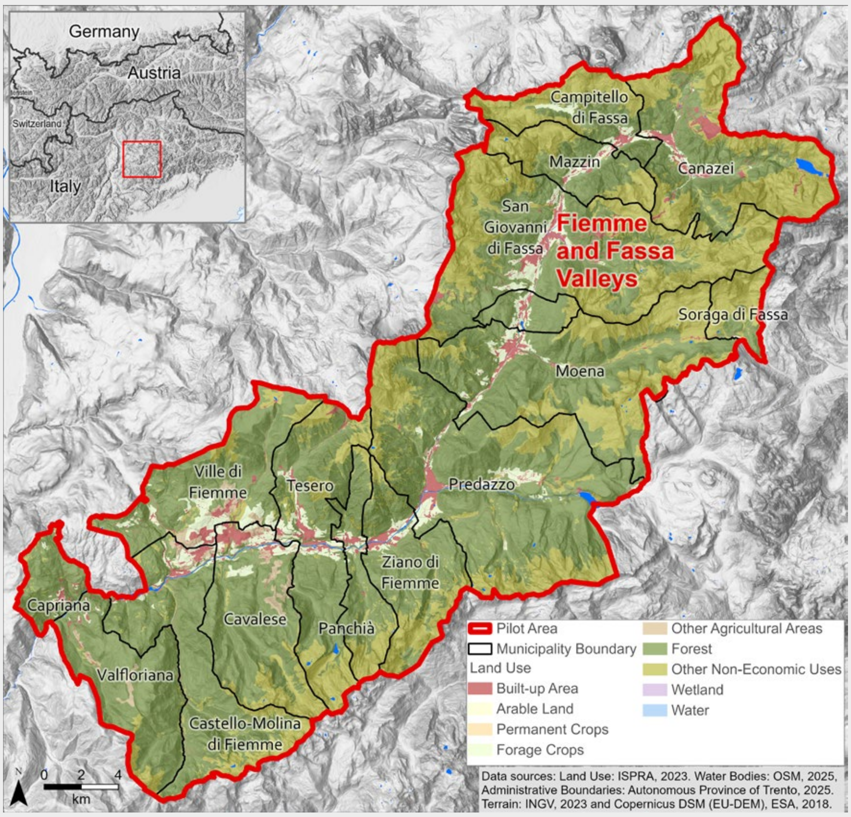


FIGURE 3: *Map of Fiemme and Fassa Valleys (in red).*

Additional details on the Vaia storm in Trentino are available in the report of the Meteorological Office of the Autonomous Province of Trento:

https://contenuti.meteotrentino.it/analisiMM/2018_perturbazione_ottobre.pdf

In 2018, the area was hit by an exceptional Mediterranean storm named **Vaia**, which crossed the eastern Alps between October 27th and 30th, causing severe damage. During the first three days of the event, most observation sites in Trentino recorded **record-breaking cumulative precipitation**, in some cases exceeding 400 mm - and even 600 mm in a few locations, such as Passo Cereda and Passo Pian delle Fugazze.

On October 29th, **exceptionally strong wind** occurred in combination with heavy rainfall. The highest values were observed between 1,500 and 2,000 m a. m. s. l., where wind gusts exceeded 120 km/h. The combination of intense precipitation and extremely high wind speeds triggered several **windthrows, floods and debris flows**.

In Trentino, the Vaia storm affected approximately 20,000 hectares of forested land, a substantial portion of which lies within the pilot area. The vast number of fallen trees **significantly altered the forest landscape**, and the effects of the event are still visible (***FIGURE 4***).

In the X-RISK-CC project, we analysed how risks related to the complex effects of **compounded precipitation and wind speed extremes** – such as those that occurred during the Vaia storm – may evolve in the pilot area in the future.

FIGURE 4: *Fallen trees in Fiemme Valley at the Lavazè Pass after the Vaia storm (Source: Autonomous Province of Trento).*

PAST AND FUTURE WEATHER EXTREMES

In Trentino the most intense precipitation events generally occur in autumn, when the region is mostly exposed to moist air masses from the Mediterranean Sea. Based on the measurements collected by the weather stations over 1991-2020, the annual maximum of daily precipitation is, on average, in the range of 50-100 mm with the highest intensities in the eastern and southern portions of Trentino. Despite some signals of amplification, the statistical analyses of data collected over the last 70 years in Trentino do not highlight a clear trend of change in the frequency and intensity of daily or multi-day precipitation extremes on a regional level. However, records of several weather stations suggest that an extreme event with precipitation amounts like the ones recorded during the Vaia storm could have a shorter return period today than in the past. The large-scale atmospheric circulation patterns that characterized the Vaia storm are also found to become more frequent today, which increases the likelihood of atmospheric conditions favourable for similar extreme weather events.

Looking ahead, more intense and frequent precipitation events are projected. By the end of the century, daily precipitation extremes can become up to + 16 % more intense than today, depending on the global warming level, or, in other words, on the effectiveness of climate change mitigation actions.

Dealing with uncertainties

Climate projections are derived from different models, each of them providing different results. For simplicity, projections are often averaged, even though the scenarios consist in a range of plausible values, whose width depends on the level of uncertainty of the models in representing the future evolution of a certain process. Moreover, projected numbers must be interpreted as an estimate of the magnitude of changes and not as exact predictions for specific locations and dates (e.g., rainfall on a particular day in October 2050). Nevertheless, the consistent signal of increasing precipitation extremes is an important message for risk managers: the likelihood of natural hazards and cascading impacts, especially when precipitation extremes occur in combination with high wind speed, is rising.

The **return period**, also known as recurrence interval, is the estimated average time between events of a certain magnitude, expressed in years and based on 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.

A precipitation event like the one recorded during the Vaia storm will be progressively less rare in the future. On average over the whole Trentino-South Tyrol region, the return period of such an event is projected to be halved if a + 3 °C global warming is reached. For example, the accumulated precipitation (194 mm) recorded during the Vaia storm in Cavalese (located in Fiemme Valley), which currently corresponds to a 300-year event, could be characterized by a return period of less than 100 years by 2100.

While the wind speed values measured during the Vaia storm were the highest of the observation record at most weather stations, an in-depth analysis of past changes of extreme wind speed is not possible due to the short period covered by the available observations. For the future, no evident change in wind conditions is projected over the area. However, as consequence of the projected increases of heavy precipitation, a rise in compounded precipitation and wind extremes in the region is expected, especially under the warmest scenarios. With a global warming of + 4 °C, the annual frequency of such events can increase by + 18 % compared to current conditions.

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 the portion of soil which remains frozen (i.e., with a temperature equal or below 0 °C) for at least two consecutive years. Due to warming, permafrost in the Alps is decreasing and shifting to higher elevations. Where permafrost disappears, soil is less stable so collapses become more likely, and more sediments can be mobilized downstream.

HAZARDS IN PRESENT AND FUTURE CLIMATE

Due to the topography of the area and its climatic characteristics, geo-hydrological hazards are the most frequent weather-induced hazardous phenomena occurring in Fiemme and Fassa Valleys. They are generally triggered by intense rainfall or rapid snowmelt and vary from slow valley-floor watercourse overflows to fast-moving debris flows in steeper terrains.

Besides precipitation intensity, permafrost melting also contribute to increase the soil instability and the availability of sediments which can flow from the mountain slopes and impact on the valley floors. Historical data reveal no clear trend in flood frequency, even though certain areas above the tree line exhibit increased debris-flow activity mostly driven by accelerated permafrost degradation and, in some parts of the region, by glacier retreat.

⚠ Natural hazards during the Vaia storm (October 2018)

The Vaia storm, which hit the area the end of October 2018, brought intense and persistent precipitation which caused widespread instability with more than 30 flood phenomena recorded and about 140 stream sections affected, predominantly by liquid floods with solid transport, though debris flows also occurred.

The exceptional wind speed damaged forest, with over 4 million cubic metres of timber affected in Trentino, of which a quarter in Fiemme and Fassa Valleys. Around 12,000 hectares were destroyed, while the remaining 8,000 hectares experienced scattered falls. Damaged forest resulted in a serious loss of natural protection from hazards in many areas. The effects further worsened in the following months when the combination of the massive amount of windthrown stands on the ground, prolonged drought conditions and mild temperatures favoured extensive bark-beetle outbreaks which further destroyed forested areas.

Forest area in Trentino after Storm Vaia in 2018, with extensive windthrown trees. (Source: Autonomous Province of Trento)

Forest has a protective function helping to stabilize slopes and reduce the risk of avalanches, landslides and rockfalls. When root stability is reduced due to tree disturbances and damage (due for example to windthrow or insect infestations), processes of soil erosion and hazardous phenomena might become more likely.

The increase in the intensity and frequency of extreme precipitation events, coupled with accelerated glacier retreat and permafrost thaw due to warming, may raise the likelihood and magnitude of geo-hydrological hazards in the future. Future warming and drought conditions can also cause more forest disturbances, reducing root stability, particularly in the shallow-rooted spruce forests of the area, and make forest more vulnerable to windthrows in case of storm events and bark-beetle infestations. In the areas hit by the Vaia storm, until forest regrows, the probability for hazardous processes due to soil instability is expected to remain high over the next decades, while the risk of further windthrows will be minimal.

Rising temperature and increasing frequency of drought can promote the ignition and spread of wildfires. Even though no significant increase in wildfires has been observed so far, also thanks to the continuous maintenance of the forests, wildfire has been identified as an emerging hazard for the area in the next future. Considering the rapid warming, a review of management practices are needed to ensure the preparedness to future wildfire-related risks in the region.

⚠ Impacts of the Vaia storm (October 2018)

The Vaia storm of October 2018 affected both residents and visitors in the area causing fatalities and injuries, especially due to collapses of buildings. Many private properties, vehicles and urban buildings were damaged and energy interruptions occurred. Roads, cycling paths, pedestrian networks were also impacted, and some areas, especially forested parts, remained inaccessible. Extensive reconstruction and cleaning operations were required in the following days and months. The destruction of existing avalanche and rockfall barriers also posed a major risk in the area, which remained exposed to the hazards until new protective structures were restored. The unexpected volume of wood to stock and sale had negative economic consequences, with a quick price decline and market saturation. The loss of forests also initiated long-term ecological consequences, especially for wildlife, and modified landscape and touristic attractiveness of the most damaged areas. The complex recovery and restoration plan is still ongoing.

CURRENT AND FUTURE IMPACTS AND RISKS

Fiemme and Fassa Valleys are characterized by small villages, located in the valley bottoms where most inhabitants live, and extended forests, managed meadows and pastures at higher elevations. The most exposed elements which might be damaged, directly or indirectly, by geo-hydrological hazards include residents, private properties and buildings, roads and bridges, infrastructure for water and energy supply and agricultural activities, especially forestry and livestock farms. Forestry-related activities can be impacted by storm phenomena as direct damage to trees can result in severe losses for the wood market. Moreover, the loss of protective forest acting as natural barrier on the slopes can require important interventions for installing artificial protections. Being a popular touristic destination visited all around the year, also touristic facilities, tourists and hiking trails can be severely impacted by hazards driven by precipitation extremes and storms. While trail damage and road interruptions may be resolved in relatively short time, rebuilding accommodations and infrastructure can require months or years, with negative impacts also on the touristic offer in the longer term. Additionally, substantial changes on landscape might reduce its aesthetic value and lower the touristic attractiveness of the area.

If the increasing trends in residents and tourists will continue in the future, it means that the overall population exposed to risks will continue to growth, especially if it concentrates in the valley floors where floods and torrential events are more likely. The expected rise in visitors can exacerbate overtourism in Fiemme and Fassa Valleys. If new infrastructure and buildings will be required to answer to the increasing request, the potential expansion of hazard-prone areas in future in such a complex region poses challenges on how to accommodate the new constructions without exposing them to risks. The loss of protective forests concurrent to the intensification of precipitation phenomena can heighten the risks for infrastructure due to geo-hydrological hazards also in areas previously considered at lower risk.

Forest area in Trentino after Storm Vaia in 2018, with extensive windthrown trees. (Source: Autonomous Province of Trento)

THE ROLE OF VULNERABILITY IN RISK

The impacts of a hazard event can be exacerbated not only by the event 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, e.g., as in the case of the storm of October 2018.

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. Also forest planning and management should reflect the future challenges and increasing resilience to extremes. In particular, as a monoculture spruce ecosystem was recognized to be particularly vulnerable to windthrow, a more diversified ecosystem should be preferred.

Forest area in Trentino after Storm Vaia in 2018, with extensive windthrown trees. (Source: Autonomous Province of Trento)

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.

Forest area in Trentino after Storm Vaia in 2018, with extensive windthrown trees. (Source: Autonomous Province of Trento)

Activities and measures taken in advance to ensure effective response.

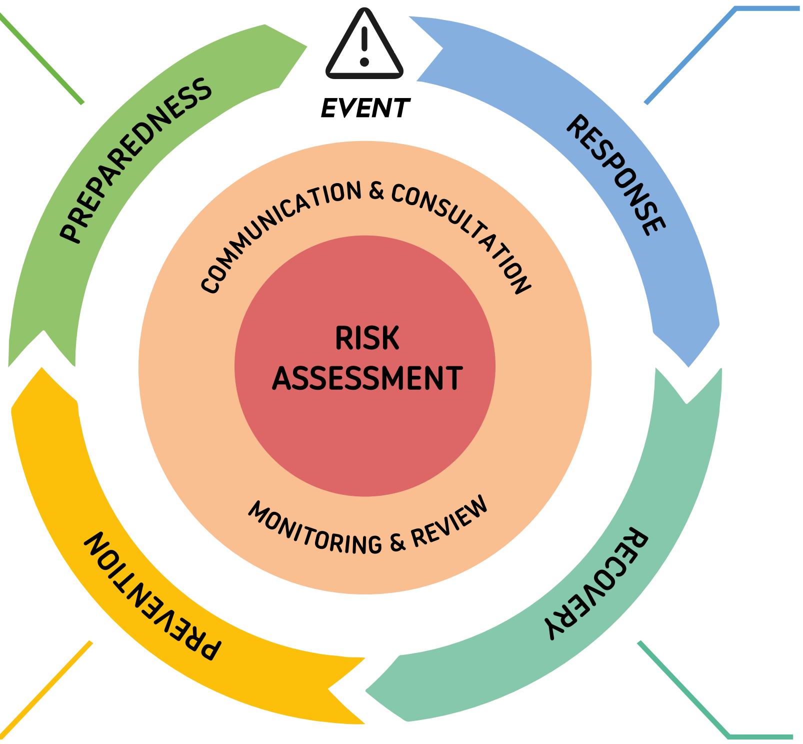
Early warning systems, emergency planning, training and exercises, resource pre-positioning, public awareness campaigns, and establishment of coordination mechanisms.

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 Fiemme and Fassa Valleys

- → Basin Service of the Autonomous Province of Trento
- → Environment Protection Agency of the Autonomous Province of Trento
- → Risk Prevention Service and Single Emergency Center
- → Forestry Department
- → Fire service of Trento, Fassa Valley and Fiemme Valley
- → Department of road services
- → EURAC Research
- → Magnificent Community of Fiemme
- → Stakeholders from the municipalities of Predazzo, Cavalese, Molina of Fiemme, Soraga of Fassa, San Giovanni of Fassa, Tesero
- → ASUC (Amministrazione Separata dei beni frazionali di Uso Civico)
- → Red cross

RISK MANAGEMENT GAPS

The debriefing and reanalysis of the Vaia storm in the Fiemme and Fassa Valleys during the first workshop—conducted with stakeholders, first responders, and those involved in reconstruction—highlighted both strengths and key gaps in civil protection and risk management. While mitigation structures generally performed well, civil protection plans did not cover all scenarios, especially the effect of windstorm, and were often not well known by local administrations or the population.

The alert system and provincial apparatus were effective but limited public awareness and scarce technical instrumentation hampered communication during the event. The response phase was supported by regular exercises and local coordination, but unpredictable hazards and equipment shortages complicated efforts. Volunteer networks played a crucial role, though concerns remain about future capacity. Recovery was efficient in part—like rapid tree removal—but lacked coordination, equitable resource distribution, and participatory evaluation. Institutional learning was limited due to the absence of structured debriefing.

After the event, hazard maps were updated, introducing areas for further investigation on the hazard synthesis map corresponding to forest zones affected by windthrows during the Vaia storm. However, the protective function of forests was significantly reduced, and infrastructure such as riverbanks requires reinforcement. Wind-resistant construction remains a challenge, and undergrounding linear infrastructure was identified as a future need.

⚠ 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.

Looking ahead, participants emphasized moving beyond outdated concepts, like the return period, toward climate-informed risk management. Recovery should integrate resilience and prevention. Recommendations included increasing funds for maintaining hydraulic and forest protection systems, providing training activities for citizens and officers to improve risk perception, and promoting youth engagement in volunteer work. The proposed approach to look into the event in a future plausible context proved useful for testing future scenarios and identifying protection gaps, though participants often struggled to shift focus from present conditions to long-term risks.

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.

GAPS PER PHASE

PREVENTION

- There is currently a lack of updated information on avalanche-prone areas that were initially delineated after the Vaia storm in windthrown forest zones. Six years later, these areas may have significantly changed, yet a systematic update of the Hazard Synthesis Map is still missing.

- Municipal Civil Protection Plans are not regularly updated, and many municipalities rely on documents developed years ago. As a result, procedures, vulnerability assessments, and resource inventories are often outdated, reducing the effectiveness of the plans during real emergencies. Regular revisions based on new data, territorial changes, and lessons learned are essential to keep these plans functional and aligned with evolving risk conditions.

- Municipal Civil Protection Plans do not include climate change scenarios and emerging hazards, and often do not account for compound extremes such as strong winds and intense precipitation, prolonged drought periods and heatwaves. This limits municipalities' ability to anticipate future risks and adapt preparedness measures. Integrating climate scenarios, updated modelling, and sector-specific impacts would enable more effective planning for increasingly unpredictable and severe events, strengthening long-term resilience.

- The current Hazard Synthesis Map does not include detailed information on forest structure, composition, or post-disturbance conditions, which are essential to understand forest vulnerability and its role in hazard dynamics.

- Reliance on the "return period" concept for designing protective structures has become misleading in times of rapid climate change. Scientific research has not yet provided robust alternative approaches.

- There is no structured and shared archive of historical natural hazard events at the provincial level. Existing information is often scattered across different offices and formats, making it difficult to access, compare, and analyze past events systematically. The absence of an integrated database limits the ability to identify trends, validate models, and support evidence-based planning for disaster risk reduction and climate adaptation. A centralized, standardized, and continuously updated archive is needed to strengthen knowledge management and decision-making capacities.

PREPAREDNESS

- Weather forecast and alert communication needs improvement. There is little public understanding of the differences between alert levels and of the appropriate actions to be taken or avoided.
- Lack of short-term forecast sharing (nowcasting) with the population during weather alert situations, which could improve preparedness and timely responses.
- The current provincial warning system and its thresholds—i.e., the predefined numerical limits for rainfall, wind speed, snowfall, or temperature that trigger alert levels—are based on past events and historical data. These thresholds might not adequately reflect the intensification of extreme events projected under climate change scenarios, nor the emergence of new hazards such as droughts or forest fires. As a result, the system may not fully capture the complexity of future risk conditions, highlighting the need for updated tools and criteria that better align with evolving climate realities.
- Despite the existence of a structured alert system, many citizens are not familiar with the meaning of alert levels or with the appropriate actions to take during emergencies. This lack of knowledge reduces the effectiveness of early warning and response mechanisms. Strengthening communication strategies, improving accessibility of alert information, and promoting education and participation at the community level are essential to ensure that warnings translate into effective preparedness and action.
- The lack of harmonised and updated data concerning landslides and wind-related impacts, particularly regarding the frequency, intensity, and spatial distribution, makes it difficult to assess expected patterns and secondary effects triggered by extreme weather conditions.
- The absence of a comprehensive hazard and risk mapping framework that integrates climate change projections and cascading impacts limits the capacity to understand how different hazards interact and amplify each other. Without such an integrated system, it is challenging to anticipate multi-risk scenarios—such as windthrow leading to slope instability or forest degradation increasing flood susceptibility—and to develop coordinated prevention and adaptation strategies at regional and local scales.

RESPONSE

- The Vaia storm highlighted coordination challenges among provincial and local authorities in managing the operational units involved in the emergency response. The location and activities of volunteers were not always clearly defined, leading in some cases to overlapping interventions in certain areas while others remained uncovered. This revealed the need for improved coordination mechanisms, clearer communication protocols, and shared operational tools to ensure efficient and balanced resource deployment during future emergencies.

- The coordination among provincial authorities and volunteer organisations requires improvements to increase the overall efficiency and coherence of emergency response. Roles and responsibilities are not always clearly defined, opportunities for cooperation are often reactive rather than planned, and regular joint training sessions and simulation exercises involving all relevant stakeholders are lacking.

- Communication with the population during emergencies is often unclear, delayed, or fragmented across different authority levels. Official and recognisable communication channels are not sufficiently established or promoted during normal times, which allows misinformation to spread quickly during crises.

- There are currently no robust backup mechanisms to ensure the transmission of critical information during blackouts or network disruptions.

- A shortage of staff and volunteers is expected in the future, threatening the capacity to respond effectively to emergencies. There are currently no registries tracking available volunteer personnel, making it difficult to identify and mobilize resources quickly. Strategic measures to attract, retain, and coordinate volunteers are missing.

RECOVERY

- Resources for reconstruction are often fully committed in the immediate aftermath, without longer-term strategies. Recovery should be organized across different time scales, considering secondary impacts, and plans for reconstruction should already exist in peacetime (e.g., mapping local companies capable of carrying out specific works).

- A structured and shared debriefing phase after emergencies, aimed at collective learning and improvement, is still lacking. The Vaia storm experience showed that debriefings, when carried out, do not involve all operational bodies or volunteer associations. The population is also scarcely engaged, missing the opportunity to collect valuable feedback and build shared knowledge.

- The reconstruction timelines for infrastructure and forestry services following Storm Vaia have created a transitional phase that must be managed through non-structural measures while awaiting the restoration of forest cover. Post-emergency forest restoration, despite having access to sufficient and timely funding, could benefit from improved coordination between the provincial and local authorities involved. Reconstruction efforts have focused primarily on restoring pre-event conditions, without systematically considering long-term forest resilience and the need to adapt to future climate change impacts. A restoration framework that accounts for climate change effects is necessary to ensure that reconstruction strengthens adaptation and reduces vulnerability over time.

GAPS PER INTERPHASE

PREVENTION → PREPAREDNESS

- Specific training and awareness initiatives for residents and tourists in high-risk areas are missing. The dissemination of practical knowledge on how to recognize risks and respond during emergencies remains limited. In many mountain and tourist zones, people are not sufficiently informed about local hazards, alert systems, or safe behaviors. Strengthening education, communication, and targeted training programs is essential to improve preparedness and reduce vulnerability.

- Inadequate maintenance of critical infrastructures such as forest trails, check dams, and hydraulic works increases territorial vulnerability to extreme events. Poor upkeep reduces the effectiveness of protective structures and limits accessibility during emergencies, compromising overall resilience. Strengthening monitoring and maintenance strategies is essential to ensure long-term safety and preparedness.

- Scientific knowledge and climate data are difficult to be translated into practical emergency plans accessible to local decision-makers. Information is often too technical or fragmented, making it hard for municipalities to integrate climate projections and risk scenarios into planning. Strengthening collaboration between researchers and practitioners is crucial to ensure that scientific data effectively supports decision-making and fosters more resilient territorial management.

PREPAREDNESS → RESPONSE

- Bureaucratic complexity and limited coordination between governance levels delay the timely activation of emergency measures. Multiple administrative layers and unclear responsibilities often lead to overlaps and slow responses during critical phases. This fragmentation reduces the efficiency of early interventions and the overall effectiveness of the civil protection system. Streamlining procedures and clarifying roles are essential to ensure faster and more coherent emergency management.

- There is a lack of integrated technological systems for real-time monitoring, data sharing, and communication between agencies and volunteer organizations. Without interoperable platforms, it is difficult to maintain a shared, up-to-date overview of evolving emergencies, leading to delays and inefficiencies in coordination. Developing integrated digital tools and communication protocols is essential for timely information flow and more effective emergency management.

RESPONSE → RECOVERY

- The transition between emergency response and reconstruction needs to be improved. This handover is often fragmented, with limited coordination and continuity between response teams and those managing long-term recovery. The lack of clear procedures and communication channels leads to information loss, planning delays, and inconsistent priorities. Defining roles, establishing shared frameworks, and integrating recovery planning from the outset would enable a smoother, faster, and more resilient post-event recovery process.
- The collection of georeferenced data in real time should be improved and used to establish post-emergency intervention priorities.

RECOVERY → PREVENTION

- Recovery interventions and long-term prevention or adaptation strategies should be better integrated. Reconstruction efforts often focus on restoring pre-existing conditions instead of reducing future vulnerability, missing the opportunity to "build back better". Linking recovery with prevention and adaptation through updated standards, forward-looking design, and coordinated planning would turn reconstruction into a driver of safety, sustainability, and resilience.
- Structural measures like levees or check dams are often prioritized for their immediate effectiveness, while nature-based solutions—such as river or forest restoration—remain underused. Spatial constraints, land-use conflicts, and limited coordination between environmental and civil protection authorities further hinder their implementation. Promoting integrated planning and recognizing the long-term co-benefits of nature-based approaches are key to achieving sustainable and resilient territorial management.
- Reconstruction processes are often top-down, with little engagement of local communities or civil society. Participatory and bottom-up approaches are not yet standard practice, limiting the inclusion of local knowledge and social needs. Strengthening participatory planning and co-design mechanisms would make recovery and adaptation measures more context-specific, inclusive, and resilient.
- Current hazard maps overlook evolving conditions such as extreme wind events and their cascading impacts like the bark beetle infestation that followed the Vaia storm. Post-event mapping is not systematically conducted or linked to long-term assessments, limiting knowledge updates and preparedness. A consistent methodology combining climate projections and post-event data is needed to better reflect the dynamic nature of risks in a changing climate.

UNDERSTANDING RISK TERMINOLOGY

What is the Municipal Civil Protection Plan?

It is a protection plan tailored for a specific municipality and used during emergencies. This document serves both emergency management professionals and the general public. In Trentino, each municipality is required to prepare its own plan within the provincial framework. These plans define the local organisation of emergency response, identify potential hazards (such as floods, landslides, or avalanches), and outline procedures, roles, and available resources to manage crises effectively. Drafting it is only the first step: it must be put into practice with the support of the Volunteer Fire Brigades, Civil Protection volunteer organisations, and the collaboration of the Civil Protection Department of the Autonomous Province of Trento. Active participation by municipal administrations and citizens is essential to ensure widespread understanding and effective implementation.

What is nowcasting of Trentino?

Nowcasting is the very short-term forecasting of weather conditions, typically up to a few hours, based on real-time data from observation networks and models. In the Province of Trento, this service is operated by the Department of Civil Protection, Forests and Wildlife. This internal nowcasting service processes real-time data from all local weather stations, nearby areas, radar observations, and model updates to produce 30-minute forecasts of basin-level variables. These forecasts focus on precipitation wind, temperature, and variables such as the probability of freezing rain. This short-term, high-resolution data is essential for immediate emergency management and timely local response planning.

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.

What is the difference between Permanent Civil Protection and Volunteer Organizations?

Volunteer organizations: operational support in emergencies, including rescue, logistics, firefighting, helicopter rescue, and territorial prevention.

Permanent Civil Protection: Operates in all emergencies and disasters, ensuring forecasting, prevention, alert, rescue, and reconstruction in collaboration with local and national authorities, while also overseeing the daily maintenance of the territory and infrastructure.

What is a Hazard Synthesis Map?

The Hazard Synthesis Map is a normative map and identifies the areas characterised by different degrees of penalty for land use purposes, due to the presence of hydrogeological, avalanche, seismic and forest fire hazards described in the Hazard Maps. It is one of the constituent elements of the Provincial Urban Plan and represents the reference tool for urban planning.

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.

eg: instead of rebuilding the same road on landslide-prone slope, rerout it or add protective measures

CO-DESIGNED TAILORED ACTIONS FOR THE PILOT AREA

The participatory workshops for Fiemme and Fassa Valleys elaborated 10 measures to include in the Action Plans and addressing the most relevant risk management gaps. The Action Plans were also integrated by two specific consultancy activities, commissioned to address known competence gaps internally recognized by the project team. The first consultancy addressed the absence of clear guidelines for the coordinated management of the territory in the phase immediately following a hydrogeological emergency (the transitional phase between acute event and restoration), especially for non-state-owned watercourses. The consultancy provided guidelines for improving coordination between the Mountain Basins Service and the municipalities in the post-emergency phase, introducing standardized monitoring using Inspection Points (ordinary maintenance) and Presidium Points (intervention during alert), which are essential for updating the Municipal Civil Protection Plans. The second consultancy addressed the need for an objective tool for re-evaluating the avalanche risk in forest areas damaged by the Vaia storm. It developed a quantitative analytical system for technicians with the goal of updating hazard maps for avalanches and informing structural or silvicultural interventions.

It is important to emphasize that the Action Plans integrate with activities and tools already under internal development within the Province of Trento. In particular, the guidelines for post-emergency management were designed to directly feed into the updating of Municipal Civil Protection Plans. Proposed actions are also in synergy with the ongoing work to strengthen the Provincial Alert System. The identification of Presidio Points and the standardization of information flows are directly functional to making the alert system more widespread and effective.

The complete list and details of the tailored action plan devised for the pilot area of Fiemme and Fassa Valleys are published in a separate document called "Tailored Action Plan: Fiemme and Fassa Valleys" 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 Fiemme and Fassa Valleys during the X-RISK-CC project (Source: Autonomous Province of Trento)

CHALLENGES AND PERSPECTIVES

The tailored Action Plans elaborated within the X-RISK-CC project are expected to strengthen the local resilience to extreme events and their consequences. Two significant gaps remain that are not easy to overcome in the short term: the management and review of the return period concept in planning instruments and the sustainable forest management in response to climate change and extreme events.

Looking ahead, the pilot area, and more generally the Autonomous Province of Trento, will continue to face challenges in ensuring that post-event recovery integrates long-term prevention and adaptation strategies, promoting the "build back better" principle. The shared framework for knowledge exchange and debriefing, fostered by the X-RISK-CC project, will be maintained as the basis for a more coordinated, data-driven, and resilient risk management across the territory.

Despite these challenges, the participatory workshops demonstrated a strong commitment among institutions, civil protection actors, and research partners in Trentino to advance towards a more coordinated, data-driven, and climate-resilient risk management system. The process fostered dialogue between technical services, municipalities, and academia, laying the foundation for future collaboration and the continuous improvement of emergency governance in the province.

Participatory workshop held in the Fiemme and Fassa Valleys during the X-RISK-CC project (Source: Autonomous Province of Trento)

USEFUL RESOURCES

Risk Prevention Service and Emergency Operations Center

https://www.provincia.tn.it/Amministrazione/Strutture-organizzative/Servizio-prevenzione-rischi-e-centrale-unica-di-emergenza

Provincial Environmental Protection Agency

https://www.appa.provincia.tn.it/

Civil Protection of Autonomous Province of Trento

http://www.protezionecivile.tn.it/

Report "The State of the Climate in Trentino"

https://www.appa.provincia.tn.it/Documenti-e-dati/Documenti-tecnici-di-supporto/Lo-stato-del-clima-in-Trentino

Torrent Control Service

https://bacinimontani.provincia.tn.it/

X-RISK-CC - Eurac Research

https://www.eurac.edu/it/institutes-centers/center-for-climate-change-and-transformation/projects/x-risk-cc

Meteorological Office of Trentino (provincial meteorological service)

https://www.meteotrentino.it/index.html#!/home

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

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Participatory workshop held in the Fiemme and Fassa Valleys during the X-RISK-CC project (Source: Autonomous Province of Trento)

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LEAD PARTNER

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