RECIPE

REINFORCING CIVIL PROTECTION CAPABILITIES INTO MULTI-HAZARD RISK ASSESSMENT UNDER CLIMATE CHANGE

CLIMATE CHANGE IMPACTS ON NATURAL HAZARDS RISK MANAGEMENT AND CIVIL PROTECTION OF WILDFIRES, FLOODS, STORMS, AVALANCHES, ROCKFALLS AND LANDSLIDES

European Union
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This publication is the final report summarizing main results of RECIPE (Reinforcing Civil Protection capabilities into multi-hazard risk management) project, co-funded by European Union Humanitarian Aid and Civil Protection (UCPM-2019-PP-AG).

Project description: RECIPE seeks to develop operational recommendations and tools to reinforce civil protection in emergency management and risk planning for different natural hazards across Europe while simultaneously addressing climate change impacts through an integrated risk management approach and exchange of lessons learned and best practice sharing.

Partnership:
Forest Science and Technology Centre of Catalonia - CTFC (Coordinator)
Pau Costa Foundation - PCF
Civil Protection General Directorate of Catalonia - DGPC CAT
Forest Research Institute Baden-Württemberg - FVA
CIMA Research Foundation - CIMA
Austrian Research Centre for Forest Natural Hazards and Landscape - BFW
Institute of Cartography and Geology of Catalonia - ICGC
School of Agriculture, University of Lisbon - ISA

Duration: 2020-2021

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Document reference suggested: Plana, E., Serra, M., Sabella, C., Mayer, C., Hengst-Ehrhart, Y., Hartebrodt, C., Franciosi, C., Giambelli, M., Pagès, D., Gasulla, N., Martí, G., Garcia, C., Bertran, M., Canaleta, G., Vendrell, J., Andrecs, P., Hagen, K., Plörer, M., Sequeira, A.C., Skulska, I., Acácio, V., Ferreira, M., Colaço, M.C. 2021. Climate change impacts on natural hazards risk management and Civil Protection of wildfires, floods, storms, avalanches, rockfalls and landslides. Reinforcing civil protection capabilities into multi-hazard risk assessment under climate change. RECIPE project (Grant Agreement nº 874402). 68 pp

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DL: L 847-2021
ISBN: 978-84-09-36489-3

European Union
Civil Protection and
Humanitarian Aid

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INTRODUCTION

The sixth IPCC report (2021) states that extreme weather events are more frequent and intense than in 1950 in most terrestrial regions. This trend is affecting Europe, where, in some areas, the increase in temperatures is expected to be higher than in other regions. In recent years, Europe has experienced various extreme events such as the flash floods in Germany and Italy (2021), or the wildfires in Portugal (2017), Scandinavia (2018), Greece (2020) and Turkey (2021).

Climate change is modifying natural hazard situations as they are known, increasing their intensity, frequency, and distribution (IPCC, 2021). In parallel, there is a high level of uncertainty about the specific impacts of climate change in each particular natural hazard. Consequently, risk management must deal with new and often unprecedented or very rare situations, making Disaster Risk Reduction strategies (DRR) and decision-making processes more complex, and consequently stressing the risk management system.

The Civil Protection system has a crucial role in coping with natural hazards through different actions and measures throughout the different stages of the risk cycle. This ranges from prevention (e.g., pre-designing and developing confinement and evacuation infrastructures and promoting risk awareness), to preparedness (e.g., updating protocols and putting in practice drills to new risk scenarios) and response/recovery (e.g., with efficient communication to the exposed population, and restoring critical infrastructures and services in the affected areas).

Hence, a proper link between the mitigation measures within the risk cycle under integrated approaches helps to manage the emergency more efficiently. The proper inclusion of emergency-response requirements into risk assessment and planning should contribute to reinforcing DRR strategies, decreasing the impacts of natural hazards on citizens, infrastructures and livelihoods.

Based on the above, the project Reinforcing civil protection capabilities into multi-hazard risk assessment under climate change (RECIPE) provides some reflections and tools to reinforce civil protection in emergency management and risk planning for different natural hazards (wildfires, floods, storms, avalanches, landslides and rockfalls) across Europe in a climate change context. This publication summarizes the main results achieved during the project, which is addressed to operators involved in forest risks management and Civil Protection.

The contents are organised into two Section. In the first one, a common methodological scheme of analysis has been conducted for each natural hazard, identifying the attributes of the territory in terms of Hazard, Exposure and Vulnerability (HEV - IPCC, 2012) that influence risk. Understanding these HEV factors and how they are co-related is a fundamental step towards comprehensive risk management approaches.

Section II explores the potential impacts of projected climate change scenarios on natural risk management. Accordingly, the operational requirements for Civil Protection to face climate change impacts have been identified, including data resources and procedural aspects related to Decision Support Systems. This Section describes the operational tools developed at different pilot sites for different natural hazards.

During the project, an active participation of practitioners and end-users has been promoted through interviews, workshops and across the operational tools development, which has enabled lessons learned and best practice exchange.

All project results are available on the project website.

SECTION I.

HOW CLIMATE CHANGE IS AFFECTING NATURAL RISKS? THE CASE OF WILDFIRES, FLOODS, STORMS, AVALANCHES, ROCKFALLS, LANDSLIDES AND MULTI-RISK INTERACTIONS

1.1 WILDFIRES

Key drivers

Wildfires are a socionatural hazard, as they are associated with a combination of natural and anthropogenic factors[1].

In general, this hazard is heavily human-influenced due to the vegetation management, distribution in the landscape, and to the fire ignitions that are mainly caused by anthropogenic actions. Meteorology also has an important role affecting the availability of the vegetation to burn (low moisture and high temperatures), and the velocity of fire spread influenced by the wind velocity or by the topography.

In fact, fire by itself is not necessarily a hazard since it is planned and controlled in time and space. On the opposite wildfires are a big hazard all over the world since they are described as "any unplanned and uncontrolled vegetation fire which, regardless of the ignition source, may require suppression response or other actions according to agency policy" (Rego and Colaço, 2013). Wildfires only becomes a risk when there are exposed elements that have value to the society.

These exposed elements can be humans, buildings, critical infrastructures, natural environment (e.g., loss of forest cover related to environmental services provision), as well as the economic activities and cultural heritage associated. Depending on their vulnerability, which is an intrinsic condition of the element, the damage can be high or low.

There are two types of damages: (1) direct damages, which are the immediate impacts during or shortly after the hazard event, such as fatalities, health impacts or impacts on infrastructures and economic activities; (2) secondary damages, resulting from indirect damages due to the interruption of the daily life of the society, decrease of some ecosystems services like the loss of the forest protection function to prevent other type of natural hazards, as avalanches or landslides.

Given that some of the exposed elements cannot be removed from the wildfire "path", main factors determining vulnerability of the exposed elements should be considered. They are related, on the one hand, to the total potential damage due to the fire front line impact on them, and, on the other hand, and in a broader scale, to the impact of the burnt area on the territory. The several impacts on population, infrastructures and forest environmental services will be strongly related to wildfire intensity, landscape resilience and the economic activity present in the territory. In this case, the coping capacity will be crucial to increase or decrease the vulnerability of the elements exposed.

Different measures can be applied to reduce each of the risk components:

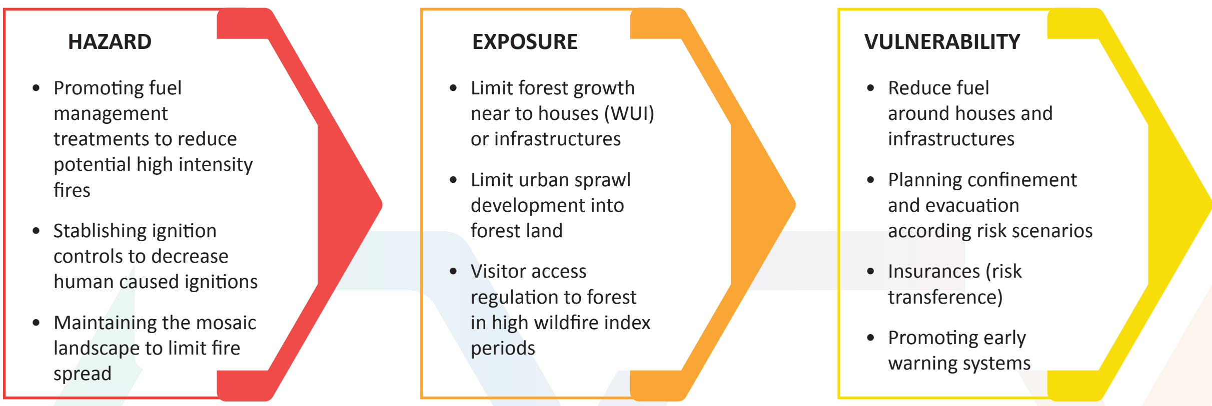


Figure 1. Example of measures to mitigate hazard, exposure, and vulnerability in case of wildfire risk.

[1]https://www.undrr.org/terminology/hazard

How projections of climate change may influence wildfire regime

It is difficult to mention specific future impacts of climate change in wildfire regimes at different scales (global, national or regional), as there are a lot of uncertainties related to climate change effects.

Anyhow, there are some relevant studies or reports that point to an increase of wildfires intensity, frequency and areas of occurrence, implying a general increase in European landscapes related to extreme weather events (e.g., droughts, heat waves). Some of the highlighted points are:

- Despite the heterogeneity in methods and results of the literature review, all projection that are based on the FWI System agreed on a generalized future increase in fire danger and fire season length in southern Europe. The relative increase in mean seasonal fire danger, ranges between 2% and 4% per decade in the Mediterranean regions of Europe (Dupuy et al., 2020).
- When fuel load/continuity dynamics are ignored, burnt areas are projected to increase everywhere in southern Europe, just as the potential fire danger does, but with substantially higher rates of increase (15% to 25% per decade for most areas, and much more for Spain). Large uncertainties remain when considering fuel dynamics. The area at risk should expand to new fire-prone regions, such as western and central France, the mountains surrounding the Mediterranean basin or central-eastern Europe, where fuel load is not expected to be a limiting factor. In the warmest and driest fire-prone regions (e.g., central and southern Iberian Peninsula), fuel availability is, or will become, the main limiting factor of fire activity (Dupuy et al., 2020).
- Climate change is leading to more extreme weather events, which means it drives to fires with more extreme wildfire behaviour. Fire management will have to adapt to the new conditions as high intensity wildfires will occur also outside the traditional/historical fire season challenging their response. Global projections depict also more extreme droughts and a general increase in global aridity (Robinne et al., 2018).
- Regarding the feedback effects, in rainforest there is a positive feedback of increasing wildfire frequency, forest desiccation, and increased fire severity continues to lead to a strong deforestation. In mountain areas, small-scale wildfires often penetrate litter and humus layers, exposing the soil and leading to rockfalls, landslides and mudslides on steep slopes. More generally, the large opening of the canopy caused by wildfires may lead to landscape dryness, through the loss of soil moisture storage. It then could affect the future loss of evapotranspiration outputs to downwind locations and reduce precipitation (Dupuy et al., 2020).
- In forests there is a vicious circle between wildfire and pests. Fire damaged trees are more likely to be affected by pests. These insects can spread and attack healthy trees which can lead to dead dying and dry trees creating a more prone landscape to wildfire hazard. Other positive feedbacks are the opportunity of the invasive plants to spread which can change the fuel availability, changing fire behaviour and fire regime in favour of the invasive plant (Dupuy et al., 2020).

Implications of climate change for wildfire risk management

The effects of climate change in wildfires will directly affect planning for wildfire prevention, preparedness, response and recovery, making necessary to modify and adapt the measures and actions designed to mitigate risk impacts. Some of the key points on major climate change impacts on each phase of the risk management cycle, are:

- Some of the future challenges of the wildfire risk management in Europe would be: current and new fire-prone areas will require better implementation of insurances schemes, better public policies, more community awareness and involvement. Generally, more and better cooperation and exchanges among authorities, corporations and services (e.g., fire service, weather service, etc.), an increase of legislation competence of districts (in planning, building affairs and disaster measures execution) and municipalities (land-use planning, local disaster management), the implementation of training programs to improve community resilience, and a clear understanding of fires in context, population awareness and preparedness, will be needed (EEA, 2017).

- Forest management will require a stronger effort to effectively plan and implement wildfire prevention measures in the territory. In ecosystems where fires are a natural disturbance, fire suppression can lead to fuel accumulation that have the potential to lead to extreme fire behaviour in the future. In this sense, more prescribed burns and less fire suppression under safe conditions is needed to restore original forest adapted to the local fire regime. Forestry practices, charge or fee for homeowners in fire risk areas, budgetary contributions for companies with facilities in fire risk areas, identification of key areas for fire prevention and protection to be more cost-efficient with prevention budget and build resilient communities (fuel breaks at WUI, fire drills, emergency plans, smart gardening, urban planning), should be also promoted (Bailey et al., 2019).

- The European Green Deal, from economic point of view, claim to incorporate climate and environmental risk into the financial system. This means better integrating such risks into the EU prudential framework and assessing the suitability of the existing capital requirements for green assets. It will be important to ensure that across the EU, investors, insurers, businesses, councils and citizens are able to access data and to develop instruments to integrate climate change into their risk management practices. The Commission will work on building capacity to facilitate grassroots initiatives on climate change and environmental protection.

- New wildfire environments within climate change will need more research on fire science: Extreme fire behaviour and climate change call for more effective science-based forest fire management and risk-informed-decision-making. This also means shifting the focus from suppression to prevention and increase awareness and preparedness of populations at risk. Furthermore, specifically at each risk phase stage highlighted some measures or challenges as cutting edge early-warning systems, species selection and regeneration cuttings as part of adaptive management, long-term adaptation of forests to climate change, adopting both short- and long-term preventive measures. The preparedness of agencies and communities to deal with extreme wildfire events requires adequate evaluation and timely communication through the development of early-warning systems, as well as training personnel for efficient emergency operations, including evacuation or confinement plans. This also entails developing public awareness and education and addressing the misconceptions that fire protection is the sole responsibility of the fire department (Faivre et al., 2018).

1.2 FLOODS (FLASH FLOODS)

Key drivers

According to the EU Floods Directive, flooding is the temporary covering by water of land not normally covered.

Within RECIPE, the focus is on flash flood that can be defined as those flood events where the rise in water is either during or within a few hours of the rainfall that produces the rise. It causes threats to humans, buildings, critical infrastructure, and economical activities of being flooded and damaged in a short time. The resulting risk needs to be assessed, analysed, evaluated and managed in all its components of hazard, exposure and vulnerability.

Image 1. (Left) Floods events in Italy (Liguria region, October 2021. ©CIMA) and (right) in Spain (Gloria storm, January 2020 ©Bombers Generalitat de Catalunya).

Flash floods are driven by different factors, of both “natural” and “human” categories.

Flash floods **hazard** is typically triggered by short, high-intensity rainstorms that activate small catchments, where the response time of the drainage basin is short.

Moreover, many hydrological factors have relevance to the occurrence of an event: topography (terrain gradients and catchment size), soil type that influences the values of water infiltration, vegetative cover (types and growth density) that can offer or not forest soil protection to erosion, antecedent rainfall, etc. In general, land use influences the flash floods generation and in particular the discharge rate: as an example, large urbanization reduces flood propagation times and infiltration rates and, consequently, increases peak runoff rates.

Finally, pluvial floods and flash floods, which are triggered by intense local precipitation events, are likely to become more frequent throughout Europe due to climate change (EEA, 2019).

Moving to flash flood risk, it is highly influenced by the presence of elements at risk in areas affected by the hazard process. The driver factors that influence the dimension **exposure** to flash floods reflect well the elements at risk - as well as the elements at risk identified by the EU Floods Directive (2007/60/EC) - and appeared in the following categories: population, critical facilities, buildings, economic activities, infrastructure, environment and environmental services. The presence of people and tourists, settlements, economic activities, cultural heritage, critical facilities, infrastructures etc., in flood prone areas and the amount, value, and importance of them influence the level of risk. Generally, two types of damages can be discerned: direct damage, which have an immediate impact during or shortly after the hazard event, such as buildings be flooded or loss of lives, or secondary damage, resulting from indirect damages due to interruption of the day-to-day functioning of society, such as the disruption of economic activities due to road damages in the aftermath of a hazard event or such as the disruption of schools activities. Moreover, it should be considered also the possible accidental pollution cascade effect in case of critical plants.

Moreover, the flash flood risk is defined also by the vulnerability of the aforementioned exposed elements. **Vulnerability** (and Coping capacity) could be related to different factors, some of them encompassing the physical dimension, some other the capacity of the civil protection system and all other stakeholders. Vulnerability factors of the population are linked with their risk awareness and risk culture also in terms of early warning (even considering tourists and visitors) and Prevention / Preparedness / Response and Recovery capacities (including "build-back-better" capacity) of the Civil Protection system at all the levels, including the capacities of Civil Protection planning and early warning. Factors in the other categories describe the properties of the elements and their capacities to withstand direct (physical structure of buildings) damages, also taking into account the existence of protective measures, to maintain operationality and to withstand to secondary damages (financial reserves of businesses).

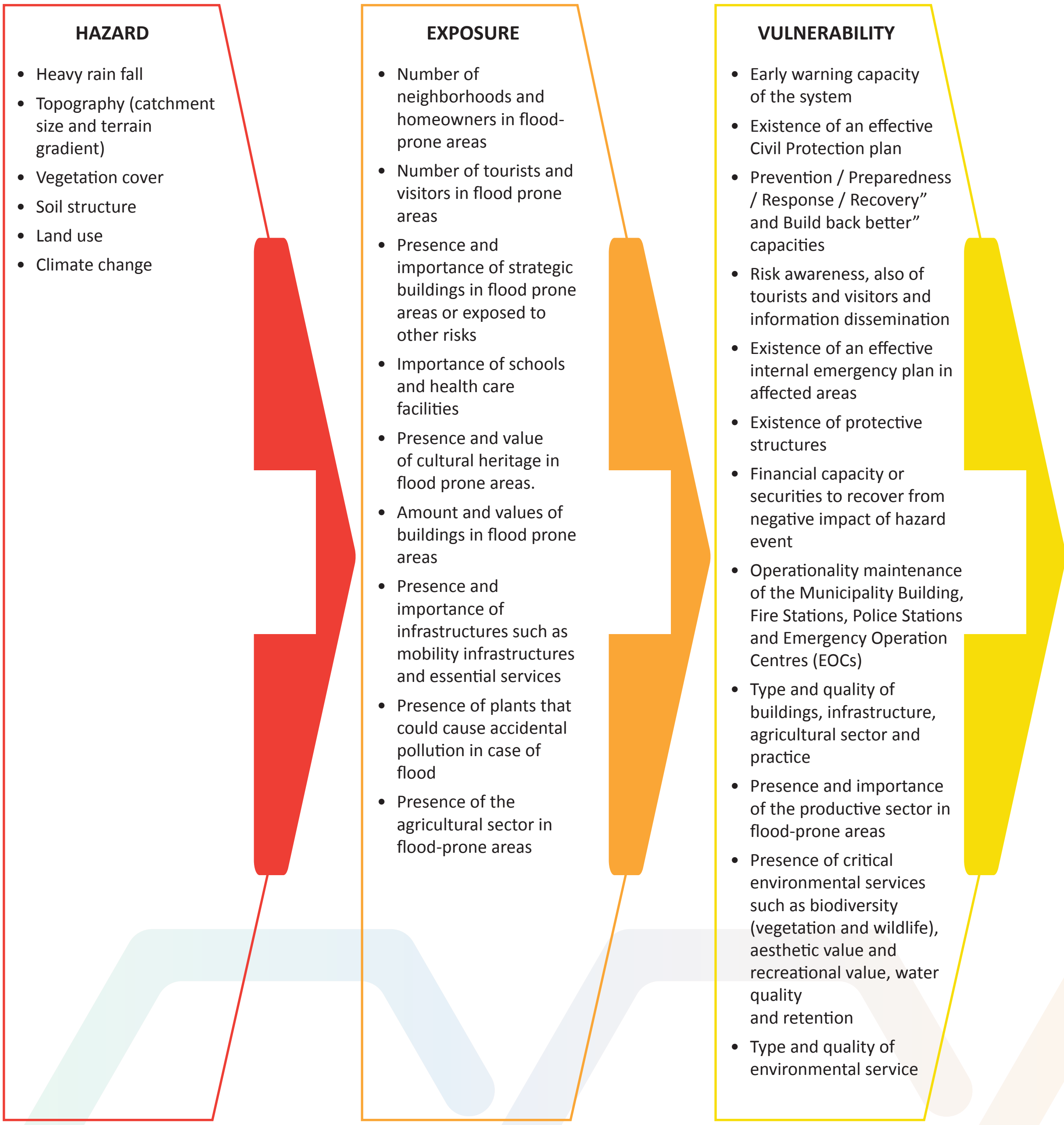


Figure 2. Flash flood risk driver factors.

How projections of climate change may influence flash flood regime

According to the EEA (2017), because of the projected increase of the extreme weather and climate-related events, pluvial floods and flash floods, which are triggered by intense local precipitation events, are likely to become more frequent throughout Europe, while in regions with projected reduced snow accumulation during winter, the risk of early spring flooding could decrease.

For the end of the 21st century (Alfieri et al., 2015) the greatest increase in 100-year floods (Q100) is projected for the British Isles, north-west and south-east France, northern Italy and some regions in south-east Spain, the Balkans and the Carpathians. Mild increases are projected for central Europe, the upper section of the Danube and its main tributaries. In contrast, decreased Q100 floods are projected in large parts of north-eastern Europe owing to a reduction in snow accumulation, and hence melt-associated floods, under milder winter temperatures (Madsen, 2014). These results are consistent with earlier studies (Dankers and Feyen, 2008; Ciscar et al., 2011; Rojas et al., 2012).

Moreover, in northern Europe, rainfall-dominated floods in smaller rivers may increase because of projected increases in precipitation amounts, even where snowmelt-dominated floods in large rivers are projected to decrease (Vormoor et al., 2016).

There are some evidences that the change in frequency of discharge extremes is likely to have a larger impact on the overall flood hazard as compared to the change in their magnitude. On average, in Europe, flood peaks with return periods above 100 years are projected to double in frequency within 3 decades.

In a study (Sassi et al., 2019) related to the impact of precipitation change on European average winter and summer financial losses due to flooding, it is showed that for both raw and bias-corrected statistics, the average flood loss in Europe generally tend to increase in winter and decrease in summer for the future scenario, and consistent with that change, the average flood losses have increased (decreased) for winter (summer) from pre-industrial conditions to the current day.

Finally, according to a Review of trend analysis and climate change projections of extreme precipitation and floods in Europe (Madsen et al., 2014) peak flows are expected to occur earlier. These projections are consistent with the observed trend towards earlier snowmelt peaks and decreases in spring peak flows.

Implications of climate change for flash flood risk management

For better dealing with climate change, the flood risk management should involve primarily the preparedness and prevention phases.

In particular, for the preparedness phase it could be useful:

- Spreading a participatory approach or bottom-up approach also for integrating the different expertise and competences in the risk management and so implementing a more coordinated and comprehensive actions,
- carrying out the Early Warning Systems (EWS) and risk communication system more understandable and local, developing a well-functioning cross-institutional horizontal and vertical communication,
- improving governance capacity and developing a clear transparent and comprehensive division of responsibilities, and
- strengthening the monitoring activity, favouring the shifting from reactive mode of responding to anticipatory approaches, with special reference to carry out early actions or dedicated actions.

For the prevention phase it could be useful:

- Increasing data sharing and increasing awareness,
- developing bottom-up approach for risk assessment,
- integrating potential and new scenarios in risk assessment and addressing the uncertainty,
- reinforcing the spread of nature-based solutions, maximising co-benefits,
- changing the scale of the actions - optimized at the level of river basins, rather than

through independent actions over selected river reaches,

- developing insurance schemes,
- providing enough flexibility to enable tailored approaches and adaptive pathways whereby a change in course is possible if dynamics require it (e.g., due to urbanization or climate change patterns), also combining the flood risk management within long-term strategic planning and approaches and climate change adaptation policies,
- favouring a diversified portfolio of flood risk management approaches and actions, on the basis of physical and institutional features,
- overcoming the fragmentation developing a synergy and coordination between different actions and actors and enhancing the connectivity between policy sectors and administrative levels, and
- developing consistent and complementary knowledge and coordination platforms at EU, national and regional level.

According to the Italian National Adaptation Strategy (2017), it is possible to identify some challenges for coping capacity in face of climate change. The most important are:

- Strengthening of alert systems,
- strengthening of monitoring activity,
- strengthening of the territorial coverage during floods,
- improvement of weather-climatic forcing predictive capabilities,
- improvement of alert systems (homogenization of messages on the national territory, more effective and timely communication, preparation of administrators) and of the related civil protection plans (preparation, dissemination to the population, exercises at local level involving the population),
- training of the "Flood preparedness" of the population, and
- ensure continuous effective risk communication actions, aimed at the population and administrators, to reduce the impact of hydro-meteorological events and spread awareness of the "residual risk".

1.3. STORMS

Key drivers

Storm events can have severe ecological, economic, and social consequences. Within RECIPE, we focus on winter storm events and resulting wind throw on roads that pose a threat to human lives and infrastructure.

Storms can evolve as a result of various meteorological conditions. Here, the focus is predominantly on winter storms resulting from extratropical low-pressure systems at mid-latitude level. This type of storm occurs almost exclusively during the winter months (October – March) due to high temperature gradients between the subtropics and polar regions. In the area where both warm and cold air masses collide, a so-called polar front emerges, and more or less extreme low-pressure systems form that are moved by westwards currents over the North Atlantic onto Central Europe. Under certain circumstances (e.g., very large horizontal differences of air temperature and water vapour content) intense cyclones can form resulting in hurricane like wind speeds. Characteristically, winter storms have a vast geographic spread (diameter of 1000 km or more), distinguishing them from other, smaller scale storm events.

The risk of storm-related hazards is determined by natural conditions in any given forest site, including topography, soil structure, degree of usual exposure to wind, forest composition and tree health, and characteristics of the meteorological event (i.e., critical wind speed and precipitation prior to the event).

In combination with other weather phenomena, winter storms can lead to cascading effects or lead to feedback events. A phenomenon observed in recent years is relatively sudden temperature changes during winter in conjunction with high wind speeds resulting in flooding and landslides. An approaching storm front often leads to quick temperature rise and brings along high levels of precipitation. The resulting rapid snowmelt fills streams that may be blocked with fallen trees (fallen due to lower root anchoring capacities) and provoking landslides on steep slopes. In proximity to human dwellings this can lead to overwhelming situations for local emergency bodies and case severe damage.

Storm damaged forests, combined with drier and hotter summer months lead to increased biotic threats for trees and forests (e.g., bark beetle infestation, pathogens spread). That way, even small and per se non-severe storm damage in forests provide ideal conditions for pest and pathogen populations to build up and spread to other unaffected parts of a forest. In the years 2018 and 2019 the described combination of hazards has led to unprecedented situations in the German forestry sector: dead trees need to be left standing in the forest, as forest managers and private forest owners are lacking transportation capacities or economically it is not viable. This leads to an additional threat to people, as dead trunks can fall.

At the same time, the proliferation of pests and diseases has an impact on wind exposure (e.g., insect disturbances increase canopy roughness), soil anchorage (e.g., pathogens decrease rooting stability) and resistance to stem breakage (e.g., pathogens decrease stability).

Meanwhile, there is an increase in the occurrence of local extreme weather events with smaller geographical extension, such as heavy precipitation, hailstorms, and tornados. However, compared to the impact of winter storms, the potential threat of these events on forests is substantially smaller. Nevertheless, the local devastation of these types of new weather events makes them worth to be considered.

How projections of climate change may influence storm regime

The most influential climate variable determining wind disturbance remains the frequency and intensity of strong winds, for which current and future trends remain inconclusive (Seidl et al., 2017). There are indications that climate change influences the duration and severity (i.e., peak wind speeds) of winter storms across Europe (Donat et al., 2011; Temperli et al., 2013 in Seidl et al., 2017). Projected changes in extreme wind speeds are indicated to rise in Central and Northern Europe, while slightly declining over the Mediterranean region. Likely, there is a poleward shift of mid-latitude storm tracks. Consequently, areas that were previously untouched by severe windstorms will have to face a new hazard situation.

In addition to greater intensity, a number of related indirect climate change impacts are expected to affect the overall impact of future wind disturbance on forest ecosystems in Europe. These include changes in tree anchorage (e.g., less soil frost) (Usbeck et al., 2010 in Seidl et al. 2017), wind exposure (e.g. tree growth) (Moore and Watt 2015 in Seidl et al., 2017) and overall wind resistance of stands (e.g. tree species composition) (Panferov et al., 2009 in Seidl et al., 2017).

Forest management decisions to address climate change induced challenges may also impact future wind disturbance impacts on forests. For example, the desire to move from single-species dominated, even-aged stands to forests with diverse species, ages and structures (Gardiner et al., 2019). The exact effect may vary depending on context. Recent research suggest, natural mixed forests are more resilient to wind disturbance when compared to monoculture forests (Jactel et al., 2017; Morimoto et al., 2019).

Finally, there is evidence for a strong interaction between disturbances: summer drought reduces tree's overall resilience, and facilitates the activity of other disturbance agents, such as insects and fire. At the same time, storm damage in forests in combination with drier and hotter summer months can result in increased biotic threats for trees and forests (e.g., bark beetle infestation, pathogens spread). That way, even small and per se non-severe storm damage in forests provide ideal conditions for pest and pathogen populations to build up and spread to other unaffected parts of a forest. The proliferation of pests and diseases in turn has an impact on wind exposure (e.g., insect disturbances increase canopy roughness), can affect soil anchorage (e.g. pathogens decrease rooting stability) and reduce resistance to stem breakage (e.g. pathogens decrease stability). On the other hand, climate induced changes in vegetation composition and structure can reduce the forest's sensitivity to different disturbances, particularly wind (Seidl et al., 2017; Temperli et al., 2013 in Seidl et al., 2017).

Implications of climate change for storm risk management

Managing storm risks involves primarily technical measures related to preventative silvicultural and forest management measures; either by reducing exposure, e.g., by closing off forest roads and limiting peoples' access to the forest or by excluding the hazard e.g., by creating tree free buffer strips along highly frequented roads.

Non-forest management related measures are more diverse and take place during all phases of the crisis management cycle, except the recovery phase. They reach from media dissemination and official declaration of early warning (risk culture and communication & emergency management and response capacity), storm damage insurance (technical measures), identification and rating of critical infrastructure (risk assessment, mapping and planning tools), to regulations and building codes (risk governance and policy).

Climate change is expected to result in multi-hazard interactions and thus in new hazard scenarios, which go beyond familiar hazard scenarios. The variability in potential hazard scenarios makes specific preparation for distinct scenarios impossible. Instead, emergency bodies are advised to develop adaptability to new situations, and a general crisis preparedness.

The main challenge for emergency authorities is thus to increase overall adaptability to an increasing number of potential and new scenarios. Uncertainty needs to be addressed and incorporated into emergency planning. Well-functioning cross-institutional horizontal and vertical communication is crucial to ensure coping capacity during a crisis event. It can be trained and should be part of the preparation phase prior to a natural disaster.

1.4. AVALANCHES

Key drivers

Snow avalanches are a natural phenomenon that can affect people, villages, facilities, mountain resorts, properties, the environment, economic services, and infrastructure. Therefore, this natural risk must be evaluated and analyzed for a better understanding of the phenomenon at the spatial and temporal level that allows effective risk management.

Image 2. Major avalanche arriving to the bottom of the valley and blocks a river (©ICGC).

Image 3. Snowpack profile to measure the properties of the different snow layers, searching for instability conditions (©ICGC).

The types of driver factors that influence the danger of snow avalanches are those described in the following order of importance: snowpack structure (snow strength, weak layers, internal instability, crystalline bonds, friction between layers among others), terrain (topography, steepness, altitude, aspect, geomorphology, rugosity and vegetation), overloads (people, animals, wind drift, snowfalls, rain, etc.), weather conditions (precipitation type and intensity, air temperature, wind direction and speed, humidity, sky cover and solar radiation.) and climate change impacts.

How projections of climate change may influence avalanche regime

Climate change can affect the three spheres conditioning the avalanche activity: snowpack, terrain and weather.

- **Snowpack:** climate change is expected to affect the duration (days) and thickness (cm) of the snowpack during future winter season. In both cases, a diminishing of days and snow depth is expected. Moreover, typical internal conditions are varying due to the increase of the variability of the winter weather.

Image 4. Wet avalanches are occurring also in the coldest part of the winter, affecting socioeconomic activities (©ICGC).

- **Terrain:** in a context of global warming, some variations on the prone terrain to avalanches are expected to appear in future. Vegetation helps to fix the snowpack and a more homogeneous distribution, and roughness. In this sense a greater number of forest fires would increase the erosion of the terrain and thus increase the probability of avalanche triggering.

Image 5. The increment of temperature accelerates processes of terrain warming and humidification that trigger gliding avalanches (©ICGC).

Furthermore, the natural forest growth could affect the altitudinal zonation of vegetation and the type of forest. Some species have different behaviour concerning avalanche triggering: some recovers more rapidly than others, some are more flexible when are affected by avalanches while other breaks and "die" and are difficult to grow again.

- **Weather:** in the context of climate change both the intensity of precipitation and the increase of temperatures affect the probability of extreme events (different return period) and the type of avalanche problems (wet snow and avalanche glides). Other weather driver factors must be also considered and their role in the climate change context, such as the atmospheric circulation; in this sense, changes in the frequency of the atmospheric patterns leading major avalanche cycles have been recently observed in the Pyrenees.

Image 6. Recording weather and snow data in high mountain areas is essential to understand the consequences of the climate change in this sensitive ecosystem (©ICGC).

Implications of climate change for avalanche risk management

Avalanches risk management could adapt to climate change by strengthening the phase of preparedness. The main aspects to achieve are:

- Uncertainty: new snow scenarios are occurring and the experience in forecasting them is low. It is needing to enhance the flexibility of the usual processes to take decisions.
- Monitoring: there is the need of implanting early warning systems to detect the increase of unstable conditions and get ready for a response.
- Operational tools: new developments are required to focus not only on the predictability of the threatening phenomena but on the probability of affecting vulnerable items.

1.5. ROCKFALLS AND LANDSLIDES

Key drivers

Within the RECIPE project, the focus is on spontaneous, rapid landslides in loose material (soil, debris) and rockfalls with a volume below 100 m³ and negligible interaction between rocks.

Rockfall occurs preferably in terrain above 45° and endangers assets through the impact energy of the moving rocks (see Image 7 left). They are rarely predictable as their triggering depends on a complex interaction of many parameters (freeze-thaw-change, contraction, permafrost melt, micro earthquakes, water pressure in cracks, storms, vegetation growth, etc.).

Landslides may affect people, buildings and infrastructure through erosion in the release area (see Image 7 right), impact pressure during the fast mass movement and burring in the transmission and deposition zone.

Image 7. Rockfall (left, © Liebl) and Landslide event (right, © Plörer).

The main driver factors of landslides (in Austria) are heavy precipitation events which lead to high soil moisture contents, reduced internal friction angles and high porewater pressures. Landslides usually occur between 20° and 45° slope inclination. Geological conditions, soil properties and vegetation influence the probability of the landslide-occurrence as well.

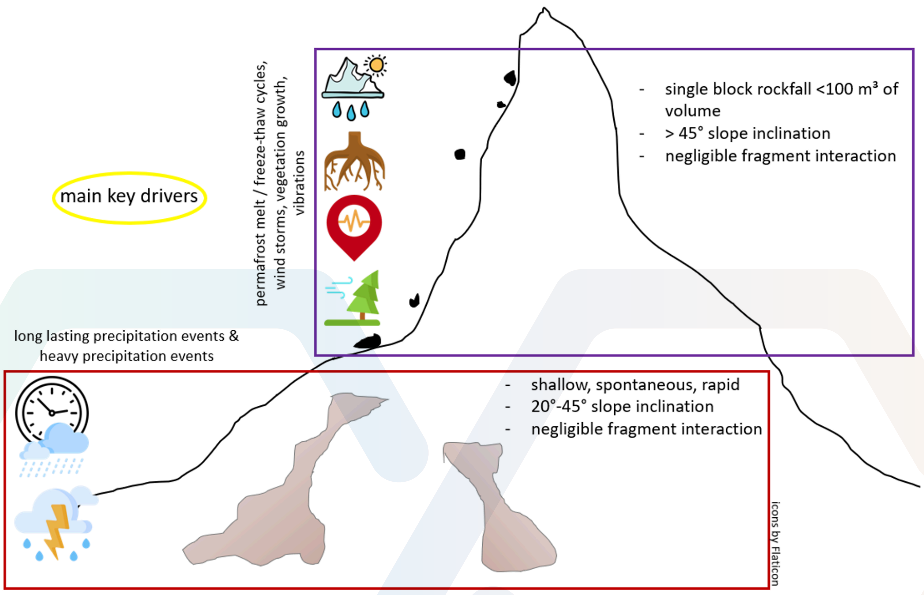


Figure 3. Key drivers of rockfall and landslides.

How projections of climate change may influence rockfall and landslide regimes

Rockfall: the degree of change of several climatic parameters and the related effects on rockfall are insecure. Anyhow, the rise of temperature and the accompanying shift of the permafrost border line is a fact and causes increased rockfall frequencies in high altitudes. In addition, the main rockfall activities will occur earlier in the year. Apart from high alpine terrain, cascade effects triggered by climate change (forest fires, wind throws, bark beetle calamities) may increase the rockfall frequency as well.

Landslides: in high altitudes also the landslide frequency may increase due to thawing permafrost areas. At lower altitudes of Central and North Europe an increase of landslide frequencies, caused by increased precipitation intensities is to expect, as well as a shift of events to the winter half-year.

More frequent sudden deforestations (wildfires, windthrows, avalanches) or gradual damage of forests caused by droughts and/or by bark beetle infestations lead to loss of root reinforcement and missing tree trunks as obstacles which may increases landslide probability and decreases forest protection effects against rockfall.

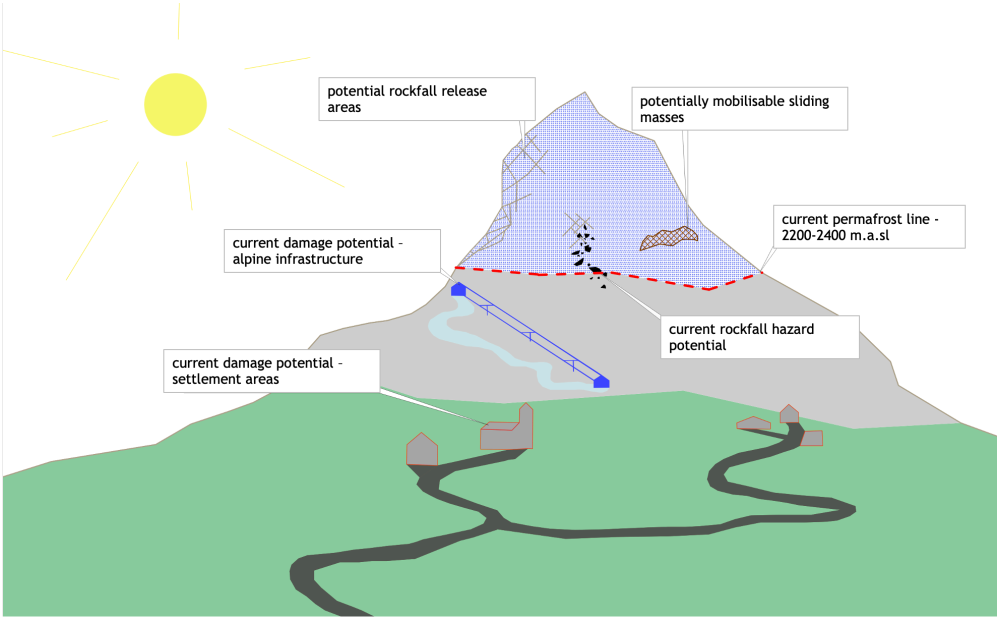


Figure 4. Example: Pre climate change impact scenario, current landscape and risk situation in an alpine terrain.

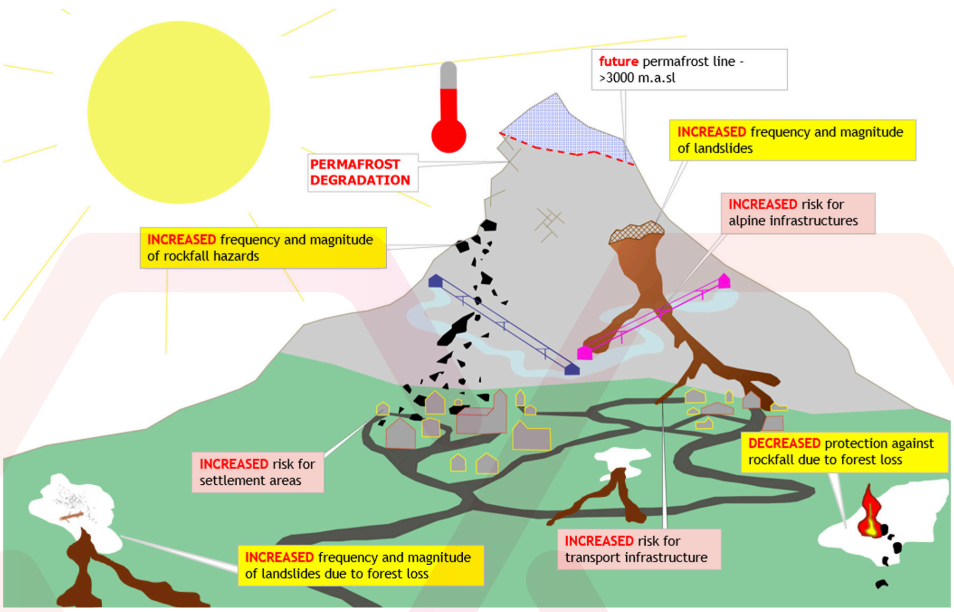


Figure 5. Example: Post climate change impact scenario, future landscape and risk situation in an alpine terrain.

Implications of climate change for rockfall and landslide risk management

The intensity (magnitude) and frequency of rockfall and landslides will change due to climate change in the coming decades. Thus, damage events experienced so far can be significantly exceeded. At the same time the ongoing (regional) exploitation of alpine areas causes an increased potential of damages. Thus, an improved interaction of structural, organizational and spatial planning especially in the preparation phase of the risk cycle is needed. The approach of risk governance by involving all actors in the interaction and decision-making process might also be necessary. Scenarios considering potential impacts of climate change have to be taken into account for any measures.

In the context of prevention, spatial planning is important, since restrictions on land use keeping endangered areas free and requirements for targeted land use can reduce risks significant. However, this requires risk based, standardized protection goals, harmonized design events and uniform safety levels as basis for any protection measures. In addition to the established static spatial planning tools, dynamic modules are needed to extend the maps by risk assessment and climate change scenarios.

In Austria, hazard index maps and hazard maps for landslides and rockfall are only available for regions, they are incomplete and inconsistent, risk aspects are not considered so far. The compilation of nationally uniform planning documents considering risk components as exposure and vulnerability is recommended to overcome future challenges. Information on infrastructure is available area-wide, however at the current level they enable only a limited assessment of exposure and vulnerability.

Several institutions are involved in the management of rockfall and landslide impacts (fire brigades, road maintenance departments, geological services of the federal states, torrent and avalanche control, etc.). However, with increasing event magnitudes, the communication and clear division of competences is crucial. A standardized area-wide event-documentation and the exchange of data between different institutions is required.

Adequate, risk-oriented spatial planning reduce the required resources for technical protections and recovery measures. It should focus also on non-structural measures (e.g., choice of climate change-adapted tree species, mixed forests). To enhance the preparedness, early warning systems (for landslides) may be sometimes cost-efficient measures to alternative structural protection measures, which is easily adaptable to changed frame conditions.

Unclearly regulated framework conditions (e.g., where should / can / may landslide material be deposited?) and insufficient insurance coverage for homeowners are further weak points in the recovery process.

1.6. EXAMPLES OF MULTI-RISK INTERACTIONS

Box 1. Storm-Wildfire multi-risk interaction.

Storm - Wildfire

Climate change is expected to increase the frequency of storm and fire events, including in areas that have thus far had little exposure to forest fires. In addition to the particular challenges of managing for forests for each of the two natural hazards, a forest facing both storm and fire events within a short period of time (e.g. winter storm – summer fire or vice versa) poses particular challenges:

Key issues to consider due to multi-risk situation – storm (winter) followed by fire (summer):

- Deadwood = amount of fuel increases, horizontal and vertical fuel continuity increases following the storm (natural hazard risk).
- Safety concerns limit active work in stands with standing deadwood such as creating fuel breaks etc. (natural hazard risk).
- WUI context – fire might affect properties not affected by the initial disturbance (storm) (exposure risk, vulnerability risk).

Key issues to consider due to multi-risk situation – fire (summer) followed by storm (winter):

- Burned forest stands are more susceptible to wind and likely to fall in a storm event.
- New forest edges created by the fire are also more susceptible to wind disturbance as the trees have not adapted to the mechanical forces of wind.
- Danger of working in burned areas due to falling branches or trees.

The interaction of wind and fire disturbance increases all dimensions of risk associated with forest fires; the **natural hazard risk** increases as large amounts of dead wood, interspersed in the stand provide ample fuel for potential forest fires. This effect is exacerbated by potential insect or pathogen outbreaks, which can spread into neighbouring stands, thus providing more fuel in the future. In some cases, options to proactively reduce fire risk are limited as damaged forest stands do not permit for safe working conditions to e.g., reduce fuel loads, bring down hanging trees (ladder fuel) or install fuel breaks.

Exposure risk increases as fire may spread to areas unaffected by prior wind disturbance and associated damage. Fires may spread beyond the area damaged by wind, including properties in the wildland urban-interface (WUI), or areas subject to subsequent insect outbreak.

Vulnerability risk also increases – in part because infrastructure in the WUI is potentially impacted by fire. Given that forests are a hotspot for recreational activities, and fire is a fairly new phenomena in some areas of Europe, there is a risk of injury or harm to individuals. Furthermore, important forest ecosystem services can be negatively impacted by a fire following a wind event.

To address such a multi-risk scenario requires the close collaboration of multiple entities throughout all phases of the risk management process. Key actors include forest owners and managers/forest management agencies, fire department, local authorities, and civil protection organizations.

Box 2. Wildfire-Flash flood multi-risk interaction.

Wildfire - Flash flood

Climate change is expected to increase the frequency of wildfire events and flash floods, including in areas that have thus far had little exposure to forest fires. Moreover, wildfires can considerably change hydrological processes and the landscape's vulnerability to major flooding and erosion events (Shakesby and Doerr, 2006; Stoof et al., 2012).

Key issues to consider due to multi-risk situation

- Vegetation cover is an important factor in determining runoff and erosion risk (Nunes, 2011). Its removal by fire increases the raindrop impact on the bare soil and reduces the storage of rainfall in the canopy and the roots, thus increasing the amount of effective rainfall.
- As reported by Lourenço et al., (2012) burned catchments are at increased hydrological risk and respond faster to rainfall than unburned catchments (Meyer et al., 1995; Cannon et al., 1998; Wilson, 1999; Stoof et al., 2012). Wildfires also affect the hydrogeological response of catchments by altering certain physical and chemical characteristics of the soils, including their water repellent conditions (Conedera et al., 1998; DeBano et al., 1998; Letey, 2001; Martin and Moody, 2001; Shakesby and Doerr, 2006).
- Increased runoff can lower the intensity threshold and the amount of precipitation needed to cause a flood event and also exacerbate the impact of precipitation. Combined with steep slopes, this can create the potential for flash floods.

Measures/Actions to cope with multi-risk situation

- Strategic forest management.
- Long-term (strategic) planning and integrated planning.
- New risk maps.
- Tools and methods for collecting past data events.
- Improvement of EWS - Forecasting and monitoring capacities and systems able to include climate change.
- Improvement of EWS – Dissemination of early warnings.
- Improvement of the civil protection planning and updated knowledge considering the uncertainty.
- Enhance the level of preparation of stakeholders and authorities for these intense and concentrated events, also in terms of civil protection.
- Define smart recovery protocols between events.
- Operational tools able to collect information in real time from the territory and, by combining static and dynamic information, to provide scenarios evolution.
- Inclusion of multi-risk interactions in civil protection planning, risk analysis and forecast systems.
- Communication with the population and awareness.
- Increase the resilience of the society.

Box 3. Wildfire-Avalanche multi-risk interaction.

Wildfire - Avalanche

This scheme is based on the practical assumption (based on Climate Change trends for the Catalan Pyrenees and land uses changes in the territory) that a large wildfire occurs at the end of summer in the Pyrenees, affecting several valleys (large surface) and, in addition, that a heavy snowfall is foreseen at the beginning of the winter season (October-November) in those areas affected by the large wildfire where potentially forest cover is lost.

What should we do in this case? How to proceed in terms of risk assessment and planning?

This exercise is based on a Table-Top scheme.

- STEP 1: Risk analysis. Expert Working Group

Time triggering assessment after the wildfire to size possible response capacity in case of avalanche.

Assessment of affected space (burned area) into the avalanche hazard map to analyze the effects on the forest protection function.

Exposure and vulnerability assessment (from the cross-links between burnt area and potential avalanche areas) to prioritize areas/elements where to act.

Proposed actions to reduce the risk on those areas prioritized.

Assessment of simultaneity or very short-term triggering related to other risks (e.g., landslides or rockfalls).

- STEP 2: Identify preventive measures to eliminate or mitigate the chain effect. Creation of an executive committee

Measure 1.- Develop a protocol for action in the event of a large wildfire in avalanche paths.

Measure 2.- Avalanche Terrain Assessment.

Measure 3.- Assess the state (after the wildfire) of the vegetation and forest cover.

Measure 4.- Burnt area forest cover restoration.

Measure 5.- Check and restore avalanche protective structures.

Measure 6.- Update the Intervention plans for avalanche triggering (PIDA) according to new multi-risk situation.

- STEP 3: Emergency Planning

Measure 7.- Close the access to potential avalanche zones where it has not been possible to restore forest protection function.

Measure 8.- Extend the preventive triggering of avalanches in new risk areas.

- STEP 4: Implementation of new procedures - operational information (to operatives)

Measure 9.- Update the Civil Protection and Self-protection Municipality Plans according to the new multi-risk situation.

Measure 10.- Update the ALLAUCAT plan (Civil Protection Emergency Plan for Avalanches in Catalonia) in the burnt area according to the new multi-risk situation.

- STEP 5: Assessment of citizen collaboration and information measures

Measure 11.- Increase population awareness towards new risk situations.

To know more about all the multi-risk interactions analysed within RECIPE project and the climate change impacts expected on natural hazards, see *Report on impacts of climate change projections on wildfires, floods, storms, avalanches, rockfalls, landslides and multi-hazard risk management*, online available.

SECTION II.

HOW TO REINFORCE CIVIL PROTECTION CAPABILITIES AND EMERGENCY MANAGEMENT TO FACE EXTENDED, MORE SEVERE, UNPRECEDENTED, OR EXTREME NATURAL HAZARD EVENTS IN A CHANGING CONTEXT

II.1 CIVIL PROTECTION AND EMERGENCY REQUIREMENTS TO FACE NATURAL HAZARDS

In order to identify needs and gaps of the civil protection and emergency management systems which able to improve capabilities to face extreme natural hazards it was conducted a series of interviews to different actors. It included an integrated view of all parts of the risk management cycle, from prevention to recovery.

With around 50 interviews, it covered a wide range of organizations of 5 countries (Germany, Austria, Italy, Spain and Portugal) from the national to the local level, considering civil protection and firefighter staff, but also decision makers and risk management and prevention agencies. It takes into account different hazards: storms, forest fires, floods, landslides, rockfalls and avalanches. Therefore, it is considered to be representative of a wide vision of the entire system.

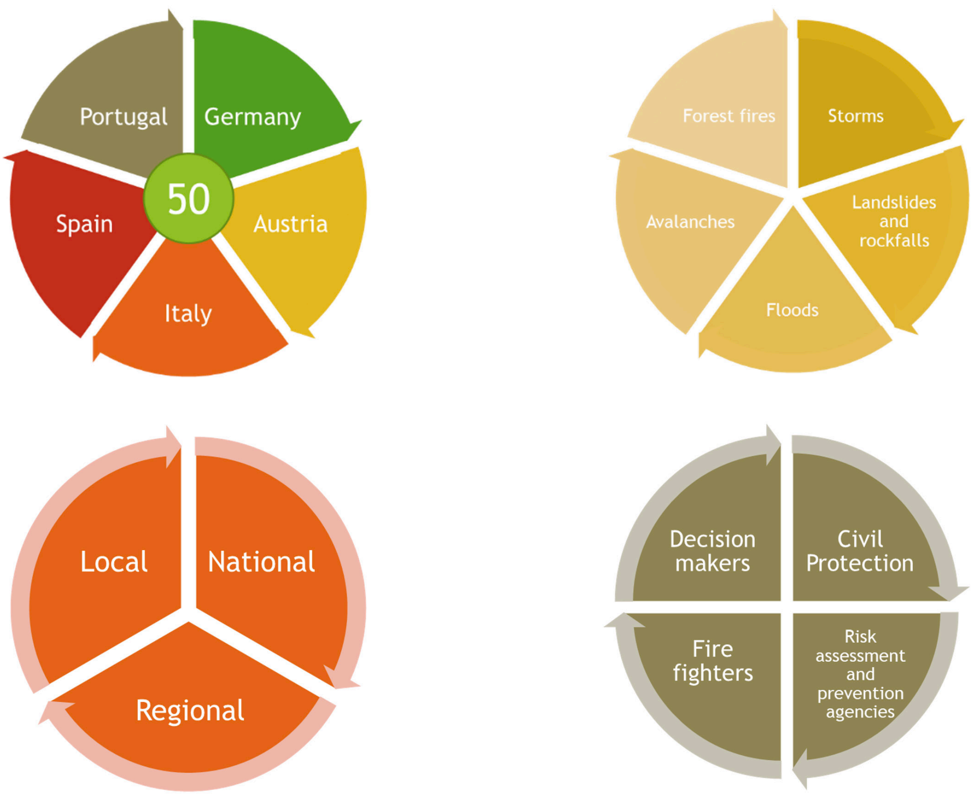


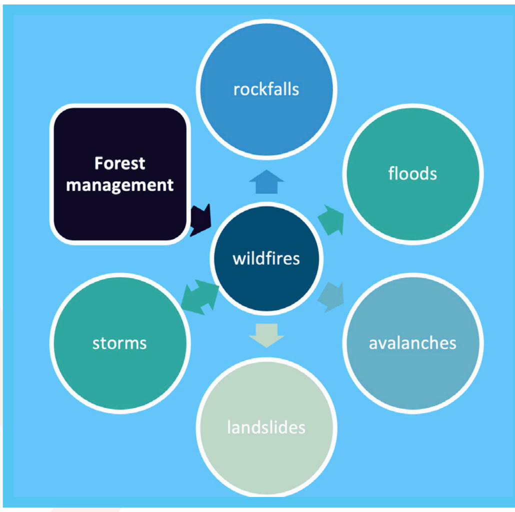
Figure 6. Nationalities, risks, levels and profiles covered by the emergency-response interviews.

Interviews were divided in two parts: to identify the current needs (1) and to identify the possible future needs in a climate change context (2). This information was crossed and grouped to have different perspectives. The results are shown in the next paragraphs.

Current needs

To solve all the identified needs and requirements is obviously important political and financial support, and it also needs a long-term planning and engagement. Moreover, this support is important to cope with overloading of the system and the need for more resources and staff.

Civil Protection in urban planning	The inclusion and strengthening of **civil protection requirements in the urban planning** may avoid the exposure of vulnerable elements, especially the most vulnerable like hospitals and schools.
Support local scale	As many of the extreme phenomena are mainly local, a strong **support to the local management** is essential to improve. It implies different issues, from assessment to planning, but especially to **increase the tools resolution**. **Consider tourist and visitors** as they have different characteristics.
Early warning systems	**Early warning systems**, **assessment, better forecast** and **monitoring** (all these parts are linked) will be a solution to increase the reaction time.
Practical training and drills	Practical **training** as well as **drills** are considered important as it reduces the reaction time, ensures effectivity and helps to improve plans.
Coordination and cooperation	As different administrative levels and organizations interacts, it is very important to improve the **coordination** and **cooperation** (between institutions at different levels but also between offices of the same agency during all phases), together with the assurance of **efficient communication processes** and **clear established responsibilities.**
Integrated platforms	**Integrated platforms** are a technical measure that will help to have a **global vision** of all the event, especially if it has a large extension or it is a multi-risk emergency. It should be able to **manage large amounts of data** and **include visual tools, monitoring tools and Decision Support Systems (DSS)**.
Reliability of communication and power supply	All technical tools may be useless if **reliability of communications and power supply** are not guaranteed (may be with redundant systems).
Enhance participation and communication	**The participation of the population** improves their engagement and risk awareness. **Improve the communication with the population** to increase their knowledge on their **exposition** and **self-protection** measures in case of an emergency, but also to be warned with efficient tools. It is deeply related to the awareness of **self-responsibility** and the promotion of **resilience**.
Lessons learned protocols during the after-event stage	Although many actors have some kind of **lessons learned** system it is highly recommendable to give them a form of written and standard protocol.



Forest fires: In some regions, the abandonment of crop lands opens the way for young forest and an extension of the biomass continuity, which in turns increases the forest fire hazard. The amount of biomass of the forest, the type of vegetation and other factors have a direct impact on this hazard. So, one of the most important improvements in prevention should be to promote sustainable systems of **forest management** to keep a healthy forest. Moreover, it helps to reduce other risks, like floods and avalanches, in a domino effect.

Figure 7. Example of a risk management need with a domino effect to other hazards.

New future needs in a climate change context

These collected needs are referred to all the phases of the Risk Management Cycle (RMC), and especially to prevention and preparedness. Certainly, this result does not mean that efforts on response are not necessary, but – according to the interviews - the emphasis in a climate change context is shifted more in these two phases.

Additionally, it is worth of reminding that climate change and its impacts on the risks are affected by high level of uncertainty.

This is something that could have some important implications for Disaster Risk Management (DRM) actions and policies in a climate change context, and should be addressed among others by maintaining flexibility, developing improvements even in absence of climate change or within a range of climate impacts.

So, current risk management policies and practices have been challenged by new risk scenarios related to climate change and also by development processes and claim for a new approach that moves towards:

Knowledge of climate change new risk scenarios and their uncertainties	A greater knowledge of climate change new risk scenarios and of their uncertainties is essential to orient more effectively the disaster risk management.
From "protect all" to "live with"	It is important to innovate the approach of the disaster risk management, moving from the paradigm of protecting all to learning how to live with disaster risk, so defining policies able to more efficiently adapt to the climate change.
Integrate CC impacts in risk analysis and mapping	Inclusion of climate change impacts in risk analysis and mapping can lead to take into account the change of exposure and vulnerability originated by change in hazard extension, frequency and severity and so can enhance preparedness and response actions, as well as prevention.
Integrate territorial, urban planning, forest and agricultural policies in DRR	The territorial and urban planning and agricultural and forest policies should be informed by the territorial risk information deriving from DRR planning, so avoiding creating new risk scenarios and favouring a sustainable development.
understand and Manage current exposure and vulnerabilities	Managing current exposure and vulnerability means reducing current risk and preventing and mitigating future risk situations that could be aggravated if the risk areas are not properly managed.
Integrate climate change scenarios in multi-hazard assessment and planning	Multi-risk situations imply a response to a previous emergency situation (e.g. forest fires, storms with intense winds, etc.) that has affected/modified a risk territory. This major impact implies an increase in the frequency and intensity of other natural hazards.

To know more about Civil Protection, emergency and risk managers needs, see *Report on Civil Protection and emergency management requirements to face natural hazards*, online available.

II.2 HOW TO REINFORCE DECISION SUPPORT SYSTEMS (DSS)

In the framework of RECIPE project, a DSS refers to any information tool that enhance the decision process made by an emergency body during any of the risk phases. A DSS can improve the management, operations and planning levels of a civil protection by giving information and reducing uncertainty to risks that may be in constant change. DSS can be either:

- Fully computerized or human-based.
- Dynamic or static.
- Commercialized or specifically made for an organization.
- Local, regional, national or international.
- Single risk or multi risk.

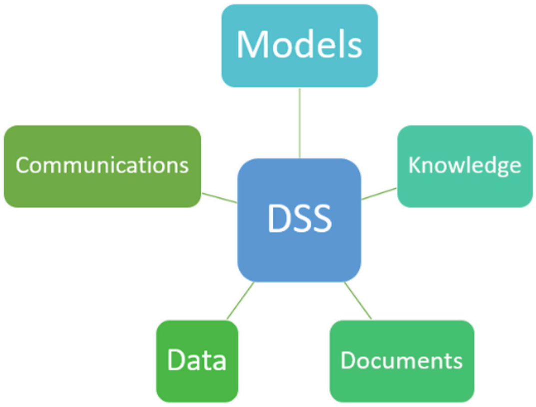


Figure 8. DSS components.

Knowing that climate change will influence Disaster Risk Reduction methods, it is clear that DSS should make a step forward and provide new functionalities to face new scenarios posed by climate change. The following table summarize DSS requirements that civil protection agencies would like to work on to improve risk management in the coming years, according the interviews done during the project (18 DSS assessed).

DATA

DSS Data organized in Emergency phases: More accurate treatment of data and address required actions according to the phase. Under climate change context, it is important to rethink how hazards evolve and their impact on risk management. Future emergencies will force civil protection agencies to deal with more extreme events, which may mean more information to be processed.

Appropriate data gathering frequency: Static information is usually out of date since risks occur under a dynamic environment. Therefore, it is clear that static DSSs are in process of being replaced by dynamic and easily updated ones. However, DSS must include static and dynamic information. Some information is static by nature, or at least, static during some years. The process of updating this information is crucial as it has to be done in a proper frequency and in a proper scale, usually bottom-up, starting from municipalities.

Economic costs in all of the emergency phases: The idea is to be more cost-efficient when managing the risk. According to experts, despite some DSS include economic inputs, they are still far from having an integrated and detailed picture of the real cost of management actions and losses. It is especially important during the prevention stage because it shows that prevention is often more cost-efficient than other actions.

Impact on ecosystems: Impact on ecosystems can be measured through ecosystem services, that is why gathering Ecosystem Service information could serve to have a better-informed decision, when, for instance, leaving a piece of land to burn to find a better opportunity to control a fire.

Real-time positioning and health monitoring of First Responders: DSS are already offering this service and products, such as health belts or small GPS to deployed units. The challenge relies on two aspects: (1) the capacity to obtain positioning in areas with poor connectivity and (2) widely implement the available services into DSS.

MODELS

Climate projections: Firstly, climate change must be incorporated in emergency management, and lately, implemented into DSSs. DSSs should not only be able to add climate change projections and its impacts on risk, but also to include these projections to see their impacts on landscape and forest species. The reason is that the landscape offers both opportunities and weaknesses and modelling landscape changes under climate change will offer the capacity to identify future threats and opportunities.

Appropriate spatial scale and uncertainty management: While large scale resolution information seems to be more trustable but more generic, small-scale resolution usually offers a more detailed information, but with a higher level of uncertainty. There is the need to develop trustable high-resolution methods and technologies. Some agencies already use an uncertainty category to understand information reliability.

Scenario matching: Observing and studying major emergencies generated by natural hazards of other regions helps to understand the new challenges posed by climate change and to see how decision-making influence on the result of emergency management.

KNOWLEDGE

People engagement: The identification of land values, preventive measures, etc. This co-creation process has been demonstrated to be a good way to make sure that the planned management measures are executed, since all the involved stakeholders agree on them from the beginning.

Enhance knowledge at the recovery phase: Only a few DSS take recovery into consideration. It is necessary to include new functions to monitor the affected area of a given disaster, quantify the losses, analyse the effectiveness of the actions done during prevention and response and, finally, to find synergies between recovery and prevention.

COMMUNICATIONS

Early alerts: Emergency services are limited and, in most of the cases, they arrive later than citizens at the disaster area. It is necessary to find strategies to collect information from the people through quick systems such as a smartphone app.

Enhanced cross-border communications: Cross-border scenarios raise a set of challenges that could be solved through the implementation of common DSSs and command systems. Only a few DSS are ready to enhance coordination and communication between agencies of cross-border regions.

COMMUNICATIONS

Link DSS with land and urban planning: Need to integrate the information obtained from advanced DSS into land planning. Currently, most of European countries consider flood risk into land and urban planning through a return period analysis. However, other risks, like avalanches or forest fires do not seems to be considered when planning new urban areas. DSS, particularly those performing reliable simulations, have a great potential to become a basic tool for land and urban planners, that should include risk in their decision-making process.

To know more about all DSS analysed and the main conclusions within the RECIPE project, see *Guidelines to incorporate projected climate change impacts into Decision Support Systems and platforms*, online available.

II.3 RECIPE SUPPORT TOOLS

II.3.1 GUIDELINES FOR FLOOD CIVIL PROTECTION PLANNING WITH PARTICIPATORY APPROACH WITH A PROTOTYPE TOOL FOR MONITORING PARTICIPATORY PROCESS

By Chiara Franciosi and Marta Giambelli (CIMA)

The following outlines a methodology to develop a civil protection planning process (with specific reference to flood risk), able to integrate climate change impacts in the civil protection system acitivities, and thus to reinforce civil protection capacity in the changing context. The metholodgy is based on a participated and integrated approach for civil protection planning:

- The **participatory approach** fosters a "governance" process that favours stakeholders' engagement and the codesign of civil protection measures. It raises risk knowledge and risk awareness, promotes civil protection actions more adapted to the territory and finally a greater sharing of responsibility between administrators and technicians at different territorial levels.
- The **integrated approach** can be seen as a system-based approach. It provides a way of understanding how the different territory elements interact and, on that basis, defining the way in which disaster risk should be managed on the ground (Máttar and Cuervo, 2017). It encourages the exchange of information between planning and supports horizontal and vertical coordination and cooperation. Moreover, this methodology, if intersected with a participatory process involving citizens or specific stakeholders, can become a place for identification and definition of in-depth policies, targeted and accepted by the community, defined as constituted by the administration and citizenship.

This methodology is usually managed in person. Because of the pandemcic situation, the process could be carried out remotely. So, beside the main steps of the process, the following describes an IT tool that allows developing and monitoring this process remotely. This tool should consist of an IT environment with differentiated functions (Rooms) and with targeted access but open to all users for consultation of the results. Therefore, it should perform the tasks of encouraging co-planning and proposal, but also observation and consultation.

The overall description of this operational process (operational tool) mainly derives from a pilot case study developed by CIMA Research Foundation in the territory of the 5 Terre in the Liguria Region. The area is characterized by the presence of a very high tourist flow due to the exceptional nature of its landscape nominated a UNESCO World Heritage Site and National Park, by a high hydrogeological fragility due to very small hydraulic basins prone to flash floods, and by a territorial management not very attentive to hydrogeological risks (terraces abandonment, presence of buried canals, etc.).

The development of a participatory civil protection planning process with an integrated approach is characterized by two main phases: its design and its implementation. Each phase is realized through the development of different steps (see Figure 9).

Figure 9. Outline of the steps for the process development.

1. DESIGN PHASE

Institutional stakeholders mapping

In order to design an effective participatory process, it is essential to correctly map the stakeholders at different territorial levels, paying attention to include those who have a specific competence and those who have a more general competence, but which can affect or influence the choices covered by the path.

For this reason, in the context of civil protection planning with an integrated approach, it is necessary to identify institutional actors with specific Civil Protection competence and other institutional actors with territorial planning competence.

ELEMENTS THAT CAN BE UPLOADED TO THE IT TOOL: List of participating institutions.

Preliminary investigation and analysis of the context - and of the local civil protection system - and identification of weaknesses or critical elements (semi-structured interviews and literature analysis)

This step is accomplished through:

- a preliminary analysis conducted by experts,
- the realization of individual or group interviews - in the form of focus groups – with the aim of analyzing the weaknesses of the local civil protection system and identifying the challenges that the system will have to face in the context of climate change.

Both activities are useful for tracing the roles of institutional actors in the different risk management phases and identifying synergies that could be developed in an integrated civil protection planning, addressing an overall vision of the problems that have emerged and approaching to integrated and shared solutions.

ACTIONS THAT CAN BE SUPPORTED BY THE IT TOOL: Focus group and interviews.

ELEMENTS THAT CAN BE UPLOADED TO THE IT TOOL: Map of actual roles and responsibilities and collection of existing plans and procedures.

Definition of the general objective of the path (consultation and / or co-design with institutional actors) and updating of the mapping of institutional stakeholders

Before starting to implement a participatory process in general - and related to civil protection in particular - it is necessary to define the objectives and the type / level of participation.

The general objective of the process must be defined together with the institutional stakeholders, based on the context elements (results of the preliminary investigation process and context analysis) and on its feasibility, assessed by the stakeholders. It must be a clear and shared objective and this will favor the institutional actors to take charge of the process implementation. In the absence of such taking charge, the participatory process could be ineffective.

ACTIONS THAT CAN BE SUPPORTED BY THE IT TOOL: Discussion and co-planning between institutions and technicians/experts.

ELEMENTS THAT CAN BE UPLOADED TO THE IT TOOL: Systematization of Focus groups and description of the general objective of the process and definition of a methodology.

2. IMPLEMENTATION

Establishment of the interinstitutional working group and its formalization

The formal constitution of the interinstitutional working group is a very important step for the effectiveness of a participatory process and consists in identifying the individuals who undertake to follow the participatory process, ensuring its development. The formalization in fact initiates a process of greater empowerment of individuals who thus officially become part of the path.

ACTIONS THAT CAN BE SUPPORTED BY THE IT TOOL: Presentation of the commitment document and commitment document.

ELEMENTS THAT CAN BE UPLOADED TO THE IT TOOL: Commitment document.

Training

Another key element for the effectiveness of the process is the construction of a common and appropriate language on risk and its management by the interinstitutional working group. For this reason, once the working group has been formalized, it is important to deliver training sessions on the theme of risk management and civil protection.

ACTIONS THAT CAN BE SUPPORTED BY THE IT TOOL: Online lessons, workshops, and in-depth material.

ELEMENTS THAT CAN BE UPLOADED TO THE IT TOOL: Online lessons and in-depth material.

Participatory SWOT analysis on the general objective identified in the previous phase

The SWOT analysis is usually used in strategic planning to evaluate the strengths, weaknesses, opportunities and threats of a project and to carry out a systematic assessment of the status quo regarding the possible implementation of the project.

In the context of the participatory process for civil protection planning, this analysis has among its main objectives:

- to understand and contextualize which may be the critical issues for achieving the objective of the process,
- to map in a shared way the elements that can feed the process,
- share the opportunities that would exist in the area with the realization of the process.

Through this analysis, it becomes possible to plan the participatory process and its specific objectives in more detail.

Co-design / Identification of solutions to the problem identified within the interinstitutional working group

This is the step of the participatory process implementation in which the different information, exchanges and insights are systematized to identify the civil protection actions useful for achieving the specific objectives and therefore the general objective.

In particular, this phase is carried out through interinstitutional discussion tables around the realization of the specific objectives. These tables must be managed and animated by a facilitator.

Due to the complexity of the subject, given that civil protection actions always have an impact on the local civil protection capacity, but can also be effective in reducing vulnerability and exposure, the possible solutions identified can be clustered in macro- groups that have as a reference the risk component on which they mainly impact.

ACTIONS THAT CAN BE SUPPORTED BY THE IT TOOL: Discussion tables.

ELEMENTS THAT CAN BE UPLOADED TO THE IT TOOL: Final discussion table + Final decisions.

The above described guidelines can be adapted to prepare for other scenarios involving actors from multiple organizations or sectors, e.g. wildfire, and regional contexts. The process described is most suitable to be implemented at a local level.

To know more about this tool, see *Guidelines for flood civil protection planning with a participatory approach*, online available.

II.3.2 PROTOTYPE FOR IMPROVED DECISION MAKING IN LANDSLIDE AND ROCKFALL RISK MANAGEMENT

By Peter Andrecs, Karl Hagen and Matthias Plörer (BFW)

In Austria comprehensive information for risk management is basically available. Thus, intersections of hazard index maps and infrastructure information yield a rough identification of potential hotspots of risk. Anyhow, these approaches are static. However modern risk management and civil protection have a strong dynamic approach. Considering expected climate change impacts as permafrost degradation and deforestation as well, based on available relevant information is necessary. For example, the "Alpine Permafrost Index Map", which shows probable frozen underground conditions, or maps including specific silvicultural information are already existing.

Together with predicted climate change impacts they have to be implemented in specific approaches. In the case of permafrost degradation, former stable slopes can change their behavior. The intersection of the permafrost layer with an alpine infrastructure layer indicates areas at risk in the future (Figure 10).

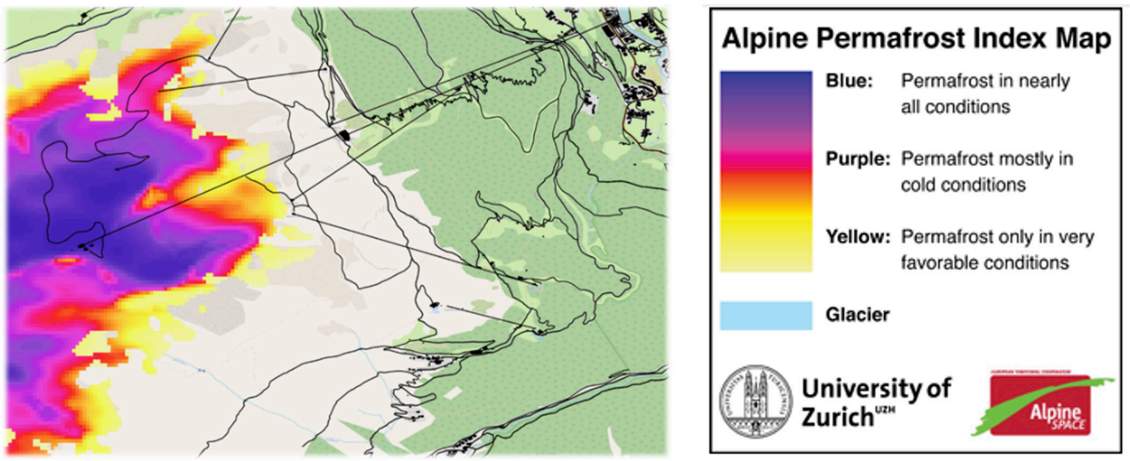


Figure 10. Overlay of the Alpine Permafrost Index Map with current alpine infrastructures.

To elaborate a real future risk scenario e.g., about the future rockfall or landslide propagation and their intersection with assets, existing data sets (DEM, infrastructure layer, Permafrost Index Map; Figure 11) need to be merged. Therefore, several applications are already available (commercial and open source software; e.g., Figure 12).

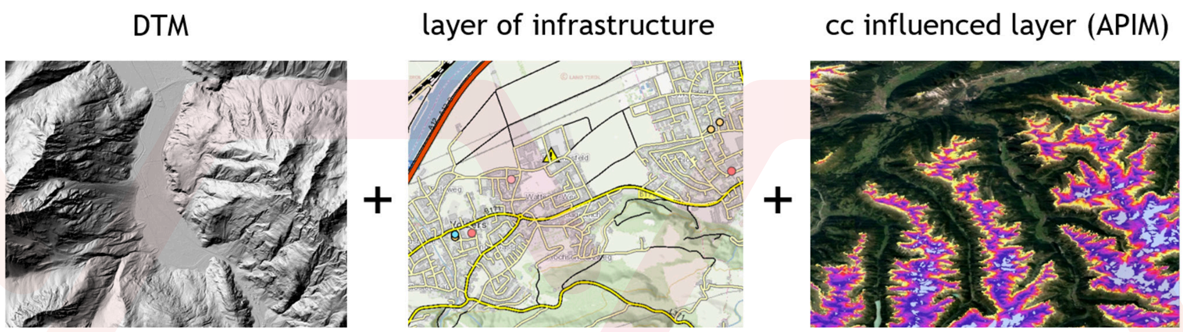


Figure 11. Existing free and online available data.

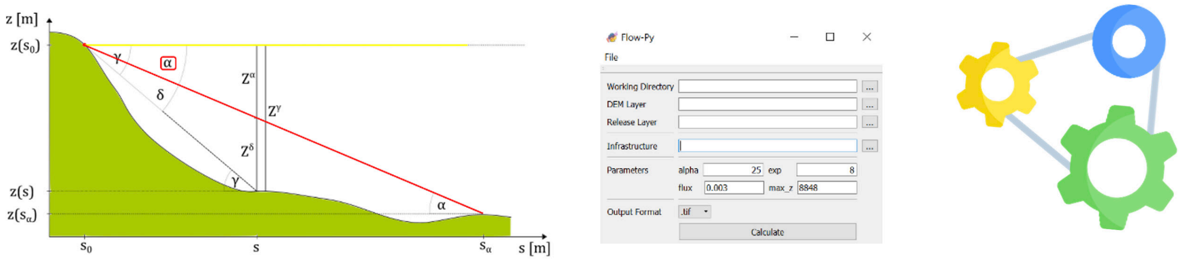


Figure 12. Existing software for e.g., rockfall simulations, downloadable online (© D'Amboise).

In a further step, rockfall release areas can be determined in a pre and a post permafrost degradation scenario. Release areas predominantely below the current permafrost border line (see blue pixels in Figure 13) represent the pre permafrost degradation scenario. Release areas also including rock faces above the current permafrost border line (see blue and red pixels in Figure 13) represent the post permafrost degradation scenario.

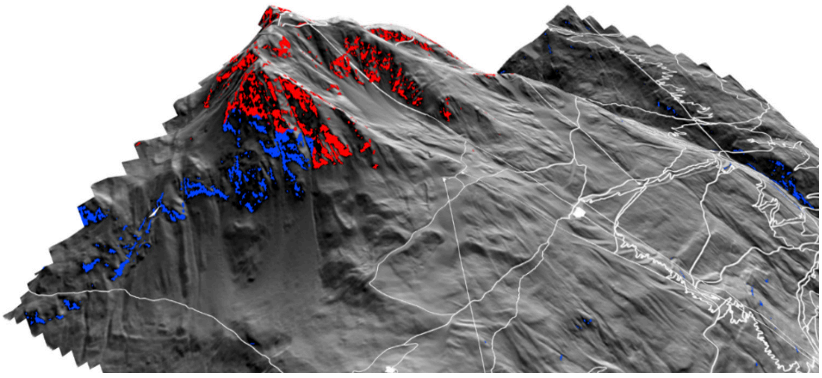


Figure 13. Main rockfall release areas without further permafrost degradation (blue pixels) and potential rockfall release areas with further permafrost degradation (blue AND red pixels). Terrain model: Land Tirol / Tiris.

The calculation of the range of rockfall or landslides provides a scetch of a pre- and post-climate change hazard scenario.

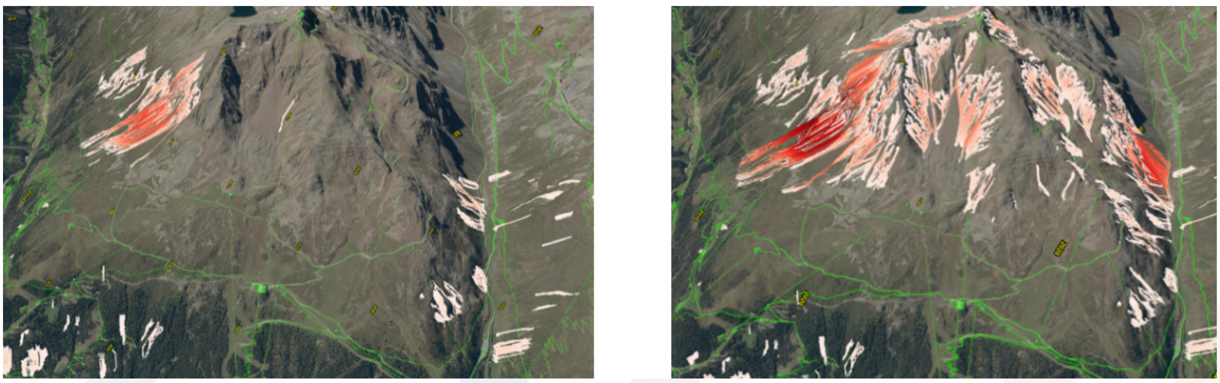


Figure 14. Left: rockfall propagation using only release areas below the current permafrost borderline; Right: rockfall propagation using also release areas above the current permafrost borderline. Orthofoto and terrain model: Land Tirol / Tiris.

The comparison of the two sceneries (e.g., rockfall, Figure 14) allows a rough estimation of changing further hazard conditions and by the intersection with infrastructure (green signatures) the risk situation due to global warming and related permafrost degradation.

A schematic overview of a DSS prototype is shown in Figure 15. In the left box providers of existing tools as well as potential receivers of new DSS are listed. The inner circle includes the main responders of civil protection, namely municipalities and their official bodies. They are the potential target group of new DSS. The upper right box shows the main environmental changes (with regard to rockfall and landslides) due to climate change (permafrost degradation and deforestation). The lower right box indicates the application of existing knowledge (data, tools) and the development of dynamic risk management tools.

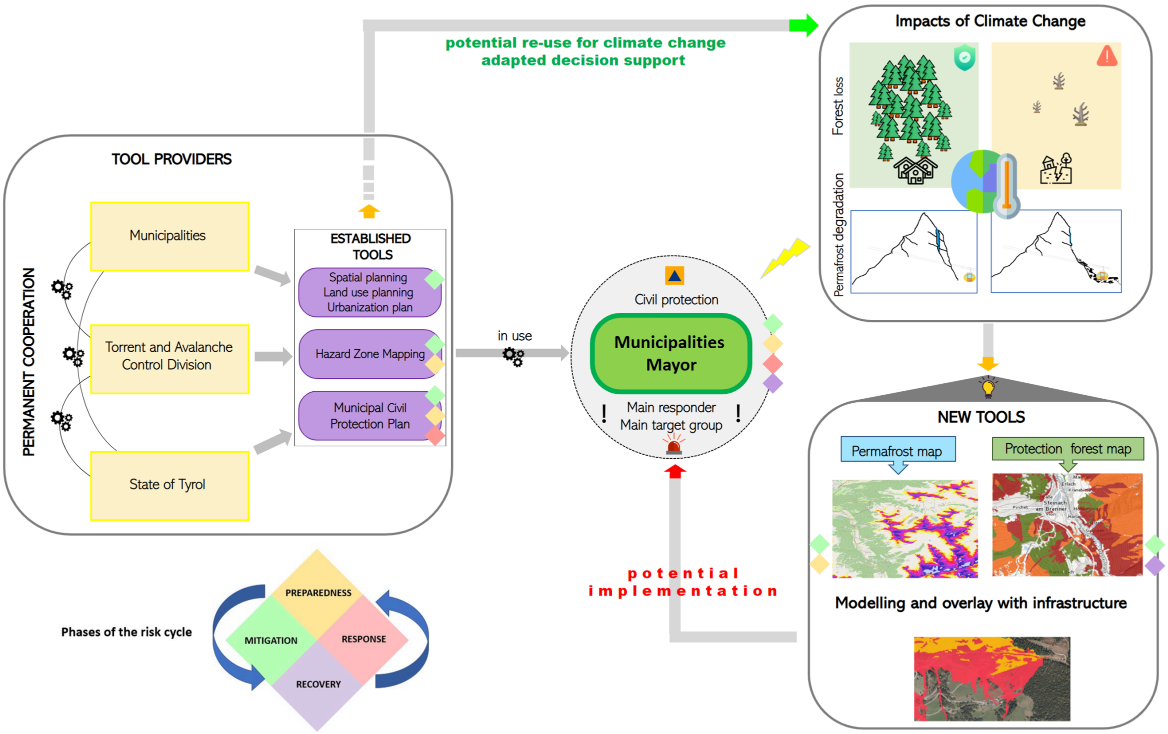


Figure 15. Sketch of the DSS for changing conditions (e.g., permafrost degradation, deforestation).

To know more about this tool, see *Prototype for improved decision making in landslide and rockfall risk management*, online available.

II.3.3 GUIDELINES FOR A PARTICIPATORY CRISIS MANAGEMENT PLAN TO MANAGE WIND THROW ALONG ROADS

By Carolin Mayer, Yvonne Hengst-Ehrhart and Christoph Hartebrodt (FVA)

The following outlines a way for individuals and organizations working in civil protection or the forest sector to develop a crisis management plan in a participatory manner. Its implementation is illustrated using the example of a participatory process that took place in the spring of 2021 in the forest district Oberkirch in Baden-Württemberg, in southwest Germany. The forest district is located at the edge of the Black Forest, crisscrossed by a number of high-traffic roads. With climate change, the region is expected to experience higher intensity winter storm, hence the need to prepare for such events.

The process outlined below helps structure collaboration through a participatory development of communication pathways and information exchange at the local level, addressing all phases of the crisis management cycle - prevention, preparation, response, recovery. The process of collaborating to develop a crisis management plan, as well as the plan itself can be the starting point for strengthening or building new networks across organizations. Ultimately, implementing the plan and maintaining these networks is up to local practitioners. These guidelines can also be adapted to prepare for other scenarios involving actors from multiple organizations or sectors, e.g., wildfire or heavy rainfall events.

Developing a crisis management plan involves several steps: 1) determining the plans' objective and scope, 2) contacting relevant actors, 3) interviewing relevant actors individually, 4) hold a workshop to develop process map further and discuss means of cross-organizational collaboration, 5) draft crisis management plan, 6) obtain feedback on the draft, and 7) finalize crisis management plan and distribute. It is recommended to have one person moderate the entire process.

Central in this process is the so-called 'process map' that is accompanied by 'process briefs' (see Figure 16 and Figure 17). A process map is a tool to visualize individual process elements in each of the four phases of crisis management: prevention, preparation, response, and recovery. For each of these phases, three layers are distinguished: (in our case) 'forests and roads', 'organizations' involved in crisis management (e.g., forest administration, fire departments), and 'environment', which refers to actors and organizations not directly involved in crisis management, in particular media, the general public, and in our case forest visitors and commuters.

Through the participatory process (outlined below), actors from different organizations work to develop a process map that outlines those crisis management activities that require some form of collaboration across organizational boundaries, such as up-front information exchange, or direct communication during a crisis event. As such, the map visualizes the interconnectedness of different organizations and facilitates a structured, participatory analysis of necessary steps to take in order to make the most of available knowledge, resources, and experience. Since the map serves primarily as an illustration and overview, it is accompanied by process briefs that describe in more detail what each process element entails, how is in charge, who is involved and in what form, and what needs to be done to realize this process in real life. Together, the map and briefs form a basic crisis management plan.

1) **Determining the plans' objective and scope**

The very first step is defining the crisis management plan's objective and scope. Outlining clearly the scenario to plan for, its geographical scope, as well as its focus on those processes that involve multiple organizations is key. It brings focus to all subsequent steps and helps keep participants' expectations toward the crisis management plan realistic.

In this case study in the forest district Oberkirch, Germany, the declared aim was to develop a crisis management plan for a winter storm event with wind throw along roads for a specific forest district; the objective was to structure communication and collaboration among actors from different organizations in all phases of the crisis management cycle (prevention, preparation, intervention, recovery). Hence, it did not aim to display all processes going on in each organization related to a winter storm event, nor did it aim to address managing wind throw damage in the forest away from the road.

2) **Contacting relevant actors**

First, actors relevant to the envisioned scenario have to be identified and contacted. Starting out with the most obvious candidates, each contacted person is asked who else/which other organizations should be included. The exact position an interviewee has in his/her respective organization is not of fundamental importance as long as he/she can speak to the organization's internal processes and resources. The individuals participating in the crisis management development process may later serve a point of contact for inquiries by other participants from other organizations.

In this case study, we started out by contacting the forest management, as well as road management agencies responsible for the Oberkirch forest district. Were also contacted the fire department, the county's integrated emergency services control center, private forest owner associations, forestry businesses, as well as local units of the federal agency for technical relief and armed forces reserve. Some organizations were represented by more than employees to represented different perspectives within their organization. The example, both a district supervisor and a forest ranger participated in the process.

3) **Individual interviews**

Individual interviews with all relevant actors – the future workshop participants - serve to gain an understanding of the different perceptions regarding the challenges associated with winter storm events, as well as the resources and capabilities various actors and organizations can contribute to managing winter storm events.

The interviews also serve as preparation for the subsequent workshop; it is an opportunity to familiarize interviewees with the concept of dividing crisis management into four phases and distinguish processes that take place in the forest, in the respective organization(s), and in relation to the environment (e.g.. media, the general public). The input received through individual interviews serves to build a first draft version of a process map, which will be central to guide workshop discussions.

In this case, the moderator interviewed 11 individuals - due to COVID-19 related travel restrictions - by phone. Each interview lasted between 30 and 45 minutes and covered the following topics: prior experience with winter storm events and wind throw on roads, and associated collaboration with other organizations, challenges associated with such events, resources to contribute to the prevention, preparation, intervention and recovery phases in the context of winter storms, and suggestions for future improvements. Based on the interviews, the moderator drafted a first process map (see Figure 16).

4) **Workshop**

The workshop serves two main purposes: it is an opportunity for participants from different organizations to meet (ideally in person). To facilitate network building, it is recommended to plan sufficient amounts of time for each participant to introduce him or herself, as well as for informal exchanges, e.g., during coffee breaks. In addition, the workshop serves to discuss the first process map draft which illustrates points of interactions among different organizations. A such, the process map allows participants to form a common understanding of all phases of the crisis management cycle and facilitates a discussion on how to organize the inter-organizational exchange. The suggestions are collected and documented by the moderator and later included in the first crisis management plan draft.

Due to COVID-19, the workshop for the forest district Oberkirch had to be held online. At the core of the workshop was the process map draft which reflected the insights gained from the interviews. Participants had the chance to voice additions and corrections, before discussing suggestions for future improvements. Most of the suggestions made revolve around improved facilitation of information exchange in the prevention and preparation phases. For example, participants agreed on the benefit of establishing a system of exchanging contact information as well as maps that indicate responsibilities by forest rangers, road management agency, as well as fire departments.

5) **Drafting the crisis management plan**

Based on the input provided in the workshop, the moderator drafts the first version of the crisis management plan. It consists of the process map and a text document containing 'process briefs' (Figure 17); these outline the individual processes in more detail, including a process description, who is in charge and who participates in the respective process. The brief also lists 'to dos' if a process requires any initial action or new routines to be implemented. This is the case particularly with new processes or altered process elements, e.g., the implementation of a regular exchange of contact information among different organizations.

6) **Obtaining feedback on the draft**

Workshop participants are given the opportunity to read and comment on the draft plan. Their feedback is integrated into the final version of the crisis management plan and ensures it addresses local level needs and concerns.

7) **Final crisis management plan**

After incorporating participant's feedback, the crisis management plant can be finalized and distributed to all participants and interested third parties. A less tangible, though just as important output are the networks built across organizations.

The above described guidelines can be adapted to prepare for other scenarios involving actors from multiple organizations or sectors, e.g., wildfire or heavy rainfall events, and regional contexts. The process described is most suitable to be implemented at a local or regional level.

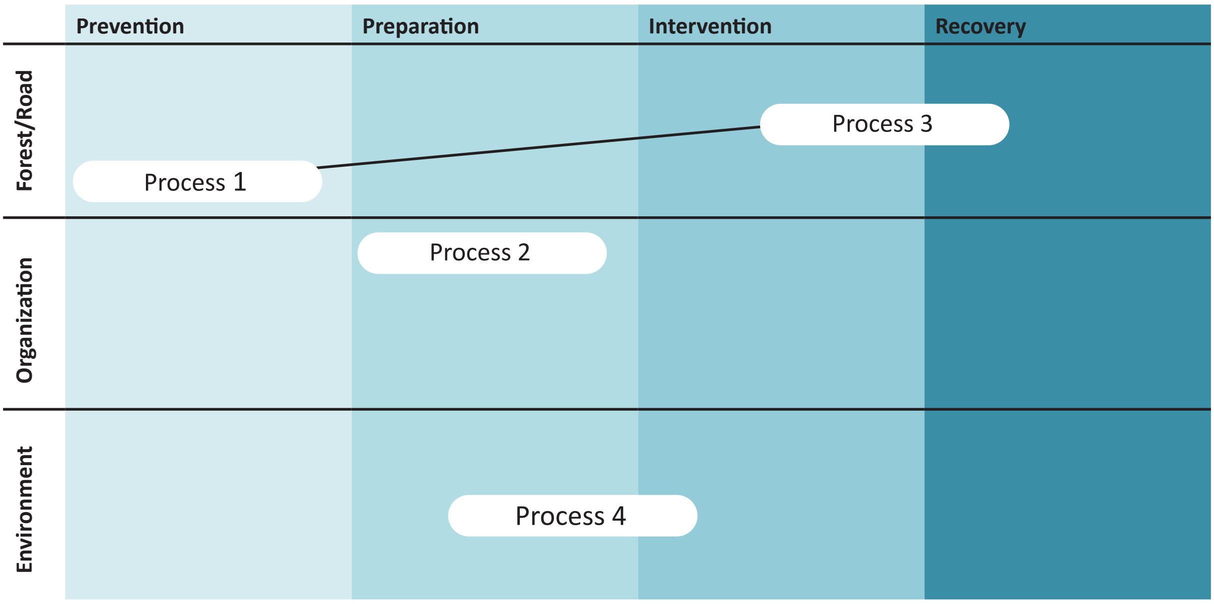


Figure 16. Template for a process map; the columns indicate the phases of the crisis management cycle, the lines represent the different levels.

Process Title	Color code – indicates the organizations involved in this processes
Short description of the process	
Who’s in charge	Who/which organization is in charge of implementing this process?
Who’s participating/informed?	Which organizations are participating in the implementation or are informed about it?
To do	What has to happen in order for the process to be realized?

Figure 17. Template for a process ‘brief‘. For each process displayed in the process map, the crisis management plan includes a ‘brief’.

To know more about this tool, see *Guidelines for a participatory crisis management plan to manage wind throw along roads*, online available.

II.3.4 SUPPORT TOOL AND GUIDELINES FOR INTEGRATED WILDFIRE RISK ASSESSMENT, PLANNING AND AWARENESS

In a global change context, wildfire risk management is achieving high levels of complexity and this is where integrated and participatory approaches may offer advantages in terms of multi-agency cooperation, the smart use of risk mitigation resources and stakeholders' engagement. Based on the above, within the RECIPE project, three actions at pilot site level in Spain and Portugal were developed as follows:

i) A novel method for integrated wildfire risk assessment and planning with a specific focus on Civil Protection requirements (pilot site in the municipality of El Bruc, Spain, led by CTFC).

ii) Tools for enhancing wildfire risk culture and awareness in children and wild-land urban interface communities (El Bruc, led by PCF).

iii) A decision support system for prioritizing fuel management at wild-land urban interfaces (municipality of Mafra, Portugal, led by ISA).

II.3.4.1 Integrated wildfire risk assessment and planning method including stakeholder engagement for resilient communities at local level

By Eduard Plana and Marta Serra (CTFC)

This chapter describes a novel methodology of risk assessment and planning (RA&P) to address integrated prevention-preparedness-response-recovery approaches developed and implemented at local level. The method approaches wildfire risk in a systemic way, aiming to enhance a smart use of (limited) resources for risk mitigation, promoting synergies across agencies and local communities, and to enhance policy coherence on risk reduction from the perspective of Civil Protection and landscape resilience.

For the implementation, a pilot site at local level was selected to explore the concordance between most risk and land planning tools deployed throughout the municipalities. The chosen municipality of El Bruc (situated in the limit of the metropolitan area of Barcelona, Catalonia) has a high diversity of risk situations (wild-land urban interface (WUI), natural protected areas, critical infrastructures such as oil station and highways, tourist activities and large forests). El Bruc also represents the situation of many small municipalities (2202 inhabitants in 2020) with limited resources and a significant surface to be managed (47.2 km^2).

Image 8. (Above) Meeting with the mayor of El Bruc, analysing the risk factors and overview of the Montserrat foothills sector (Below). Field visits were conducted with different stakeholders, aimed at understanding each other's perspective and, in the case of emergency bodies, meeting each other's operational requirement (©Plana).

A methodological flow from HEV analysis to integrated RMC planning

The RA&P method developed conducts a three-step process (Figure 18) for addressing integrated wildfire risk management (IWRM), where the protection of the exposed population, infrastructures and ecosystem service is focused according to the potential impact of pre-defined wildfire risk scenarios. In the first step, main hazard, exposure and vulnerability components (HEV) are identified. The H factor analysis states the risk scenarios according to potential wildfire events in the territory. Subsequently, corresponding risk mitigation measures are proposed for each factor and related stakeholders and tools are identified. Finally, pre-defined risk scenarios and related mitigation measures are organised within the risk management cycle (RMC) stages, as well as the corresponding planning tools. This is achieved in a coherent and synergic manner, effectively integrating the emergency management requirements to enhance Civil Protection capabilities and included them in the corresponding sectoral tool planning.

Within this method, risk mitigation is approached as an Ecosystem Service. Accordingly, the map of stakeholders is comprehensive, including those related to risk-generating activities as well as those helping to reduce it. Therefore, risk reduction "providers" and the corresponding "beneficiaries" are identified. This way, in the last stage, the process allows stakeholders to be engaged on a very operational level (answering questions like what the measures are, what is my role and to which planning tool the measures should refer), involving them across the definition of risk scenarios and mitigation alternatives, and simultaneously promoting risk awareness and a sense of community.

The definition of risk mitigation measures includes **the sequence of HEV factors** in terms of risk management (Box 5). Consequently, mitigation measures are balanced according to the level of risk, "starting" with measures able to reduce the H, then, looking for options to reduce E and, finally, defining actions for V reduction. This way, trade-offs among HEV mitigation measures are established, giving visibility in a practical way to the consequences of acting or not, and tracing alternative risk reduction pathways in each case.

At the end of the process, synergies among risk mitigation measures and activities on the ground are identified more clearly and are strengthened, therefore enhancing policy coherence and the cost-efficiency of IWRM by getting stakeholders involved on an operational basis (Box 4).

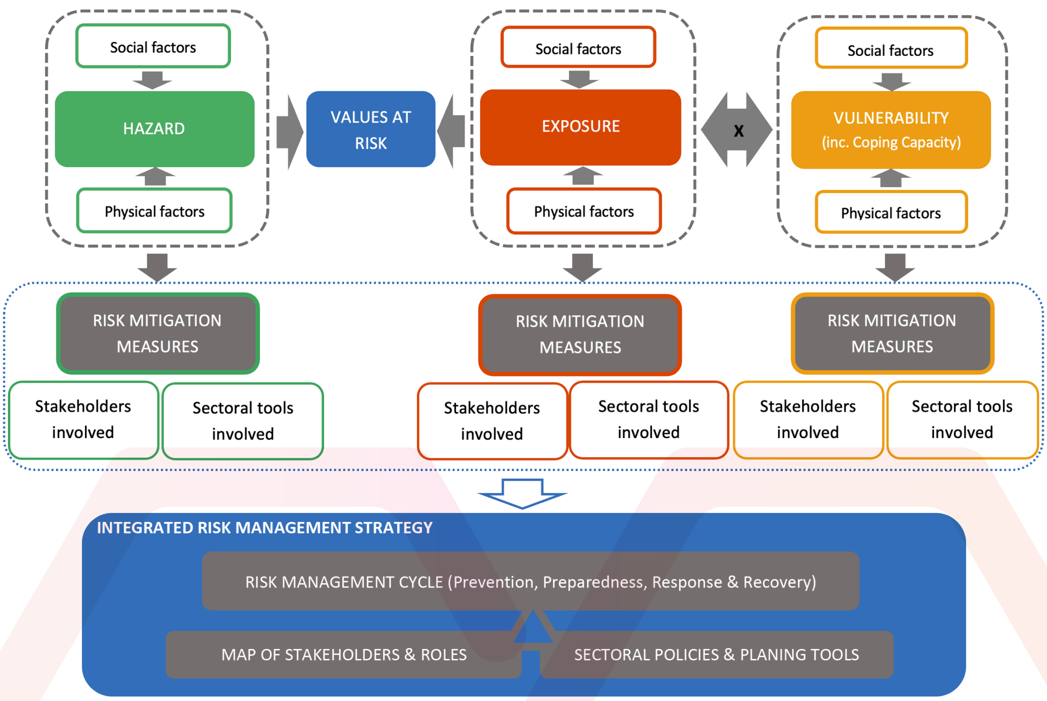


Figure 18. Risk assessment and planning sequence towards integrated, cost-efficient and synergic risk management strategies.

Box 4. *Example of RA&P results in terms of policy coherence.*

- **Promoting the idea of strategic crops and managed wooded lands to reduce the capacity for spreading wildfire** and including it in spatial and urban planning and corresponding sectoral policies, with incentives defined to support them as a Civil Protection infrastructure.
- Establishing **coordination mechanisms with neighbouring municipalities and regional initiatives to up-scale risk mitigation measures** across administrative limits (e.g., evacuation/confinement facilities or fuel treatment areas), including them in local/regional planning, and simultaneously using the process to reinforce the risk community.
- **Including proactively related stakeholders** in the Civil Protection mechanism (such as tourist resort managers who may play a role in the first early warning signs vis-à-vis clients, and manage pre-defined and trained emergency protocols).
- **Reviewing the legal mechanisms to look for the most efficient use of limited resources** to reduce risks (e.g., allowing expenses to be reallocated for fuel treatments in WUI perimeter strips so as to reduce V to grazing or forestry promotion in adjacent areas and reduce E).
- Make the **trade-off among HEV factors visible,** creating operational, technical, legal and financial measures (e.g., through payment for the risk reduction ecosystem service) to counteract those actions that generate risk, and to compensate those that reduce it across stakeholders.

Image 9. (Left) Visiting a grazing area promoted by LIFE+Montserrat providing large fire prevention to the area and simultaneously promoting the local economy, and (right) fuel treatments executed by the Natural Park in the entrance paths used for hikers and climbers, therefore reducing vulnerability and also ignition hazard from visitors (©Plana).

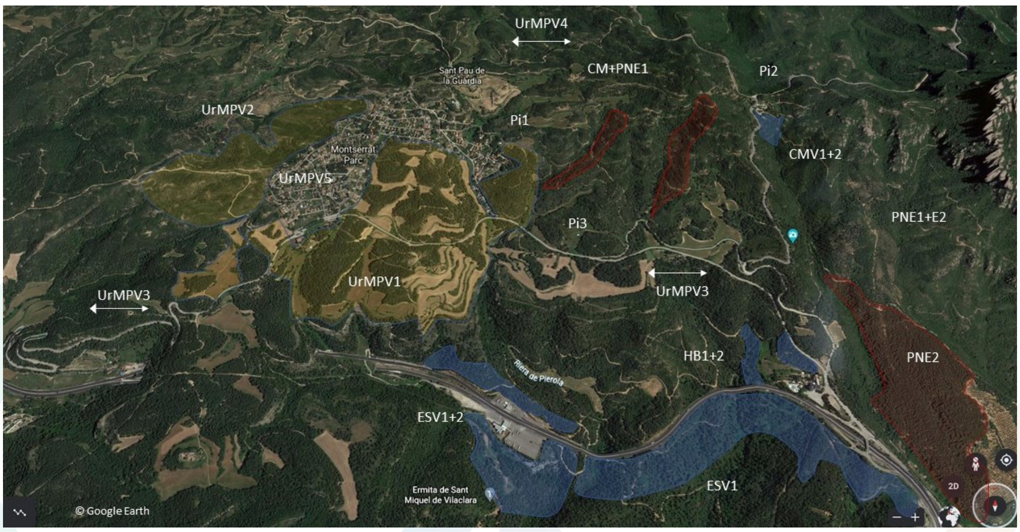


Figure 19. Example of figure representing risk mitigation measures in Montserrat Parc sector.

Lessons learned, main achievements and further developments

The method in place is highly influenced by a proper, in-depth understanding of the risk process (expressed through HEV factors and their trade-offs). In terms of the H factor, the better potential wildfire events in the area are known, the more precise the risk scenarios definition will be, and it will be easier to consistently engage stakeholders in risk mitigation routes.

Wildfire event scenarios offer the advantage of relating the operational needs for fire suppression and prevention, Civil protection and urban planning. Sharing this information becomes a crucial point for advancing towards to IWRM. On the contrary, if information on wildfire patterns is not accessible, risk management is planned from a segmented RMC competency perspective (at institutional and spatial levels) and resources are used in a less efficient way.

Therefore, the method shows to what extent pre-defined and validated risk scenarios under an impact-oriented approach may serve as a common baseline for all risk management agencies. This should help to deploy the different mitigation measures in a coordinated manner, embedding them into the corresponding sectoral plans from active (strategic fuel management) and passive (forestry, grazing, etc.) prevention to response, framing a shared multi-agency risk reduction strategy.

Moreover, the methodology's comprehensive approach helps to combine several cross-sectoral components of risk management in one single process, from those referred to risk assessment, mapping, and planning to risk governance and culture. Moreover, within the RA&P process, emergency management requirements may easily fit within the prevention stages (including, for instance, urban planning), therefore improving the copying capacity in the case of wildfire.

The stakeholders' involvement in RA&P process permits socialising the balance of risk situations and the levels of implementation of risk mitigation measures, therefore establishing the corresponding commitments, collaborations, and protocols, and promoting risk awareness and a sense of community. The method connects exposed economic sectors and citizens to the stakeholders who provide risk mitigation (e.g., making local populations aware of how local olive oil farmers or local cheese consumption are "protecting" them from wildfires).

As for **further steps**, potentially, the developed approach can be included among the existing tools for risk and land planning. It also connects the economy of risk mitigation with the economy of the territory and frames a sense of community risk. The pilot site has demonstrated the crucial role of local authorities in the implementation of risk management and stakeholders' engagement. For this reason, existing and additional tools and resources for risk reduction should be able to articulate and implement IWRM strategies both across and with local authorities.

Box 5. *Understanding HEV & RMC sequence of wildfire risk management.*

Wildfire risk management must deal with a changing risk context where policies addressing fire ignition and spread risk, potential impact of high-intensity fires to exposed population and infrastructures, safety and efficient response capacity and recovery strategies to mitigate cascading wildfire risk effects meet. A more detailed analysis of risk factors shows how risk mitigation measures, on one hand, are distributed in different stages of the Risk Management Cycle (RMC, from prevention to recovery) and, on the other, how these measures involve different public and private stakeholders, both as "providers" of risk mitigation ecosystem service (e.g., managed forest avoiding high intensity fire behaviours) and "beneficiaries" of it (e.g., urban developments or tourist resorts less vulnerable to wildfire impact).

In terms of risk components, normally the higher the hazard (H) the greater the exposure (E), and increased efforts to decrease vulnerability (V) are needed. By reducing H, there is less E, and less V reduction is needed. This sequence is particularly relevant in the case of wildfires, where H is highly human influenced since fuelled landscapes are one of the main wildfire risk drivers: reducing fuel and modifying its distribution in the landscape permits mitigating the presence of high intensity fires that overwhelm the suppression capacity and have an impact on the exposed elements. Moreover, fire-smart urban planning may also play a crucial role in reducing risk, contributing to the "building" process of E (e.g., promoting the dissemination settlement housing model into forest fire-prone landscapes). Even when H and E cannot be reduced, building codes and norms can allow us to reduce V to below consistent risk thresholds adapted to the copying capacity of each territory. Therefore, resulting risk is the sum of actions increasing/reducing H, E and V. Consequently, high levels of HEV may collapse the system and collapse the socially assumed risk threshold.

This cross-link between HEV factors can also be explained through the RMC stages. Prevention actions can help to reduce the H, limiting high intensity wildfire risk behaviours through managed forest, mosaic landscape or ignition control. Within Prevention, E and V can be reduced through integrating wildfire risk into urban and spatial planning and standardized and compulsory building codes to be applied in the case of wildfire risk. In terms of Preparedness, the copying capacity (V) may be reinforced by defining Civil Protection protocols for confinement or evacuation in the case of wildfire, preparing the territory infrastructure according to these protocols (e.g., reducing fuel along the pre-selected roads to be used as evacuation infrastructure or to the selected sites for safety confinement) or developing early warning systems (EWS). In some regions such as in Catalonia, due to the high level of H (fuelled landscapes) access to natural areas is controlled in high fire risk index periods, seeking the reduction of the E of visitors in the case of wildfire (which will jeopardize suppression capacity as well), the reduction of H in the form of ignitions, and the increase of copying capacity (V) by reducing the probability of simultaneous events (less ignition risk). Highly efficient Response means wildfire expansion is reduced, especially when it is based on the knowledge of wildfire behaviour patterns (Costa et al. 2011). This approach permits anticipating the wildfire path before it happens and increase the control capacity by implementing fuel management in strategic areas that support the Fire Service manoeuvres in the case of wildfire. These strategic areas, therefore, can be understood as infrastructures and resources to support fire suppression, such as water points or equipment. At the same time, the more trained, efficient, and equipped the Fire Service is, the greater its coping capacity. Nevertheless, extreme wildfire events everywhere show how often the suppression capacity is overwhelmed in many countries, and how in that situation, basically a defensive strategy is adopted to protect lives and infrastructures, limiting the capacity to control the fire spread in the forest.

Therefore, in a high HEV context, Response is offering a limited capacity to reduce the risk. This helps to understand the far-reaching connection among risk factors and mitigation measures within the RMC, in a similar sequence as in the case of HEV: the more Prevention actions adopted, the fewer the Preparedness and Response efforts needed, and lower Recovery impacts may be expected.

Consequently, in terms of risk management, there is a correlation among the level of the risk factors, the strategy to follow in case of wildfire and its potential impact on the values at risk. The assumption (or not) of risk reduction measures will influence how to manage the emergency and the final impact of the event on citizens, infrastructures, and the landscape ecosystem services. Indeed, there is not just one risk scenario, and how to manage wildfire risk can be balanced according to the level of risk, together with each territory's coping capacity and the values at risk to be protected. What extreme wildfire events are showing in the Mediterranean is that, in most cases, Response complemented by standard Prevention (fire breaks, ignition controls, etc) and Preparedness (Civil Protection plans) actions can deal with most wildfires, but a small proportion of wildfires burning with high intensity collapse the system and affect hundreds or thousands of hectares. This means that the Response capacity, in those risk scenarios, should be complemented by additional Prevention and Preparedness actions that can reduce the HEV factors. In this respect, predefined objectives should be stated according to the risk management strategy adopted, for instance: to ensure population safety but not being able to ensure forest protection, versus aiming for both objectives, will require different resources and mitigation action. In this regard, since fuelled landscapes become an H factor, win-win strategies can be adopted through high intensity fire-resistant landscapes, promoting forest structures capable of protecting the values at risk. The increasing risk context due to the land and climate change is stressing suppression-focused strategies and that is when a better balance among HEV factors and RMC measures is needed more and more. Stakeholders' engagement in these alternative risk management discussions should help to articulate the necessary contributions from individuals and private and public bodies, in a more synergic, cost-efficient and policy-coherent manner so as to protect fuel-laden communities from firestorms.

II.3.4.2 Tools for enhancing wildfire risk culture and awareness of children and wildland urban interface communities

By Guillem Canaleta and Jordi Vendrell (PCF)

Raising risk awareness among communities exposed and vulnerable to fire risk is still a challenge. For this reason, a specific door to door activity was tested in El Bruc municipality. A Wildfire Preparedness Day[2] was organized with the aim to boost the engagement of exposed population, making them understand the risk and to facilitate that they become a proactive stakeholder in the Disaster Risk Reduction strategies of their municipality. The activity was possible thanks to the involvement of the local city council as well as risk management agencies (Fire Service, Regional council, Police and Civil Protection).

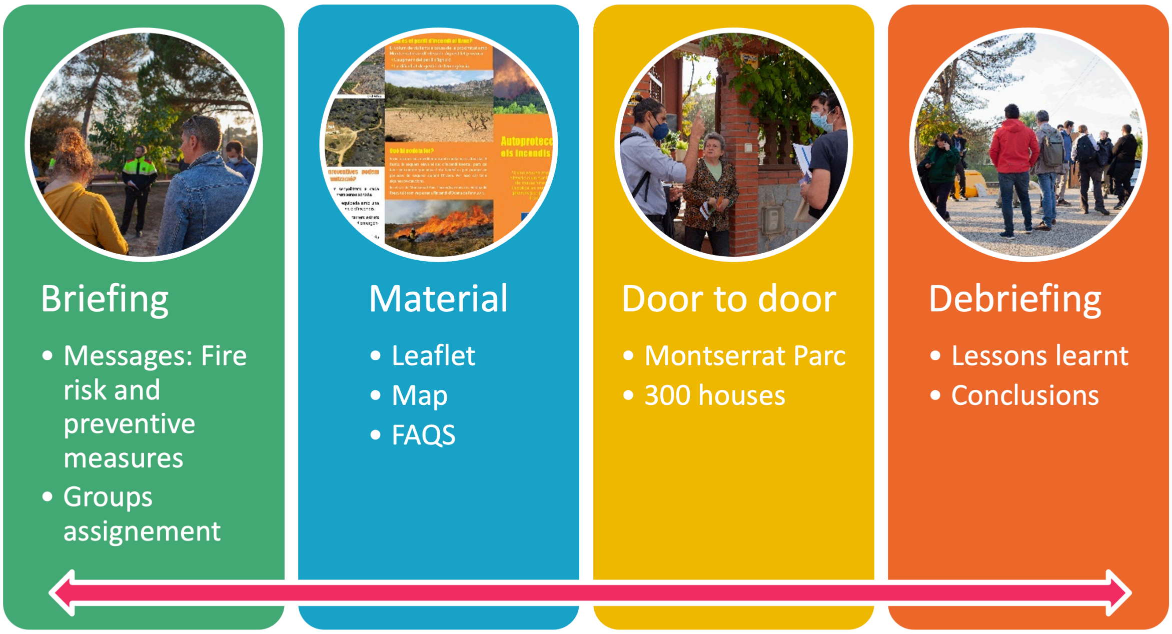


Figure 20. Wildfire Preparedness Day steps.

Main conclusions were:

- It is important that neighbors have experienced a previous fire to be aware of their exposure to risk and to be more receptive to messages.
- The involvement of different organizations is considered key and the impact that the joint work of different emergency bodies causes in the neighborhood is perceived.
- The involvement of the city council is key to facilitate that the activity takes place and to undertake future actions.
- It is necessary to follow up the community after the activity and continue implementing awareness strategies.
- It has been seen how a simple message reaches residents more easily. It is not necessary to get into specific topics or complex concepts unless the neighbor show curiosity.
- The message must be simple and in a positive tone. It is important to make people feel comfortable. The objective must be to make people reflect after the conversation and get it to be the neighbor himself who decides to act (Bottom-up Perspective).

In addition, an activity targeted to primary school children was carried out to make them understand the role of fire in Mediterranean Ecosystems and to present forest management as a key tool for risk reduction. The activity was divided into 3 main parts.

[2] https://www.nfpa.org/Events/Events/National-Wildfire-Community-Preparedness-Day

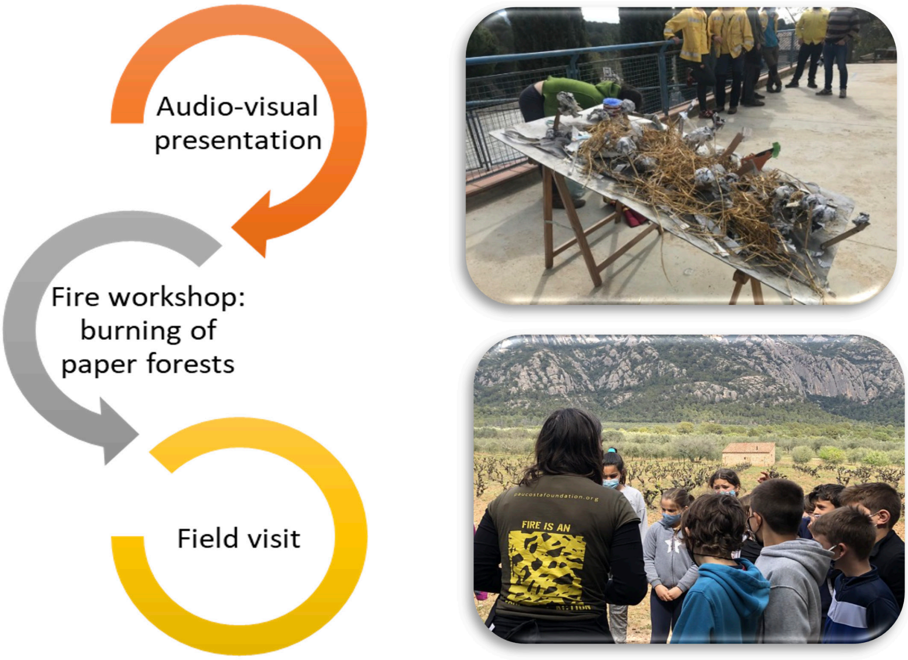


Figure 21. MEFITU activity steps.

At the end of the day, children understood that (I) zero risk does not exist, that (II) we have to learn to live with fire, that (III) fire has always been here, and it has helped to shape the landscape, and finally, that (IV) management models require investing in prevention (sustainable forest management) and self-protection.

II.3.4.3 DSS Module for prioritizing fuel management at wildland urban interfaces

By Ana Catarina Sequeira, Iryna Skulska, Vanda Acácio, Madalena Ferreira and Maria Conceição Colaço (ISA)

In Portugal, each municipality defines a municipal plan to protect forests from fires (PMDFCI), for a 10-year period, according to a technical guide provided by the Institute for Nature Conservation and Forests (AFN-ICNF, 2012). One of the actions included in the PMDFCI is the fuel management bands around infrastructures and houses on the Wildland Urban Interface.

RECIPE DSS Module is focused on defining critical areas for fuel management, within the fuel management bands, based on the priority for fuel management to prevent wildfires. RECIPE DSS Module emphasizes both civil protection needs and communities-on-site needs, from a technical point of view. The resulting database is a map and a detailed list of plots ranked by priority for fuel management. It is helpful both for authorities to plan the inspections according to assign priorities for fuel treatments and to increase communities' preparedness, by means of showing them and educate them about vulnerabilities of their property. This DSS is a Module to be inserted (in blue boxes) in the roadmap of PREVAIL (Sequeira et al., 2021) as it is shown in Figure 22.

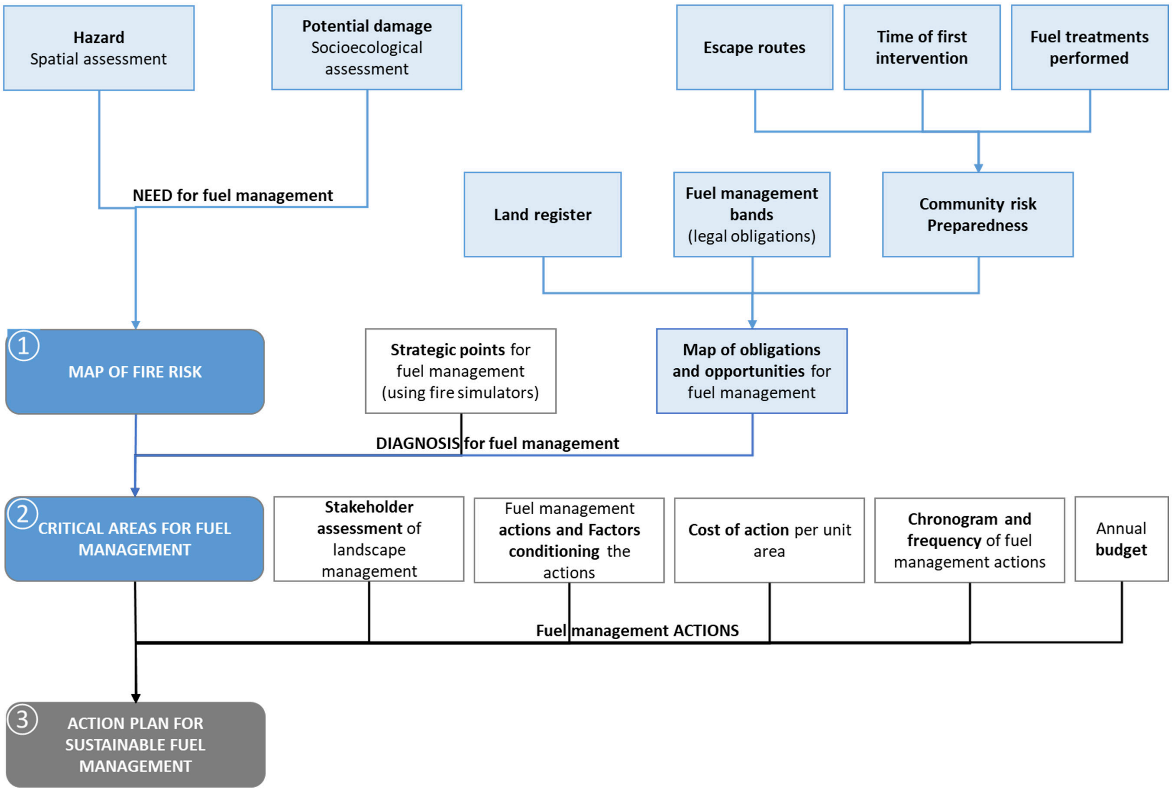


Figure 22. RECIPE DSS Module for prioritizing fuel management at WUI (in blue), inserted in PREVAIL DSS for fuel management.

Priority will be given to (1) areas that show lower community risk preparedness and (2) areas that present a higher fire risk, considering territorial hazard and potential damage. Materials used are available in every municipality in Portugal as it is mandatory to produce the PMDFCI. The process is based on a simple binary matrix, where value 1 stands for "need to prioritize", and value 0 "no need to prioritize". This binary classification is to be applied to every box of the module (shapefile raster or polygon format), according to Table 1, and then combined following Figure 22, using sums and/or intersection operations.

Objective	Topic		Value = 1	Value = 0
Map of obligations and opportunities for fuel management	Legal obligations for fuel management		If the fuel management band if of 1st, 2nd, or 3rd order	If the fuel management band is not of 1st, 2nd, or 3rd order
	Community risk preparedness	Time of first intervention	If the distance from fire station is ≥ 20 minutes	If the distance from fire station is < 20 minutes
		Fuel treatments performed	If no fuel treatments were performed in the past 4 years	If at least 1 fuel treatment was performed in the past 4 years
		Escape routes	If it is a no-exit road or If it is a one-way road or If the road in bad conditions	If it is, at least, a two-way road or If there are 2 roads in opposite directions
Map of fire risk	Hazard		In a classification 1 to 5: If hazard is 4 or 5	In a classification 1 to 5: If hazard is not 4 or 5
	Potential damage	Ecological	If there are ecological features	If there no ecological features
		Social	If there are social features in a 100 meters buffer	If there are no social features in a 100 meters buffer

Table 1. General binary classification.

To know more about this tool, see *Support tool and guidelines for integrated risk assessment and planning for landscape and wild-land urban interface*, online available.

II.3.5 PROTOCOL FOR WILDFIRE AND AVALANCHE RISK MANAGEMENT IN MOUNTAIN AREAS

By Eduard Plana, Marta Serra, Chiara Sabella (CTFC), Guillem Canaleta (PCF), Manuel Bertran, Glòria Martí and Carles García (ICGC)

New risk scenarios posed by climate change may result from the extension of natural hazards in new areas where other natural risks exist, driving novel multi-risk situations. In mountain areas, warmer environment could lead to favour the occurrence of wildfires (Resco de Dios et al., 2021, Müller et al., 2020), which could seriously threaten the forests protection role from avalanche or rockfalls for instance.

Consequently, wildfires in mountain areas can generate a cascade effect of unprecedented avalanche situation, which might require the implementation of costly structural defence/preventive measures until complete forest cover replacement is reached. Up to what extend this multi-risk scenario is it feasible in the Pyrenees? Is it possible to merge in a common risk assessment and planning protocol the wildfire and avalanche multi-hazard situation?

Along this tool avalanche-wildfire multi-risk situation has been analysed at two levels: massif and forest stand. In the first one, a practical exercise analysing the risk drivers of avalanche and wildfire risk has been carried out in the valley of Núria (Catalan side of the Pyrenees) conducting the sequence among hazard, exposure and vulnerability (HEV) factors.

MULTI-RISK INTERACTION WILDFIRE-AVALANCHES

WHAT?
Theoretical exercise which asses the possible interaction between wildfire and avalanche risk in mountain areas in a climate change context

HOW?
Biophysical risk analysis according to fire-environs and land use scenarios (see Figure 25).

WHY?
To know the magnitude of forest protection function affected by wildfires in a climate change context, and the consequent increase of avalanche risk in the area of interest.

WHERE?
Vall de Núria, Catalonia, Spain.
(Based on the avalanche "catchment area")

Figure 23. Wildfire and avalanche risk assessment in mountain areas: RECIPE case study procedure.

The methodology applied follow a 5 steps sequence (Figure 24):

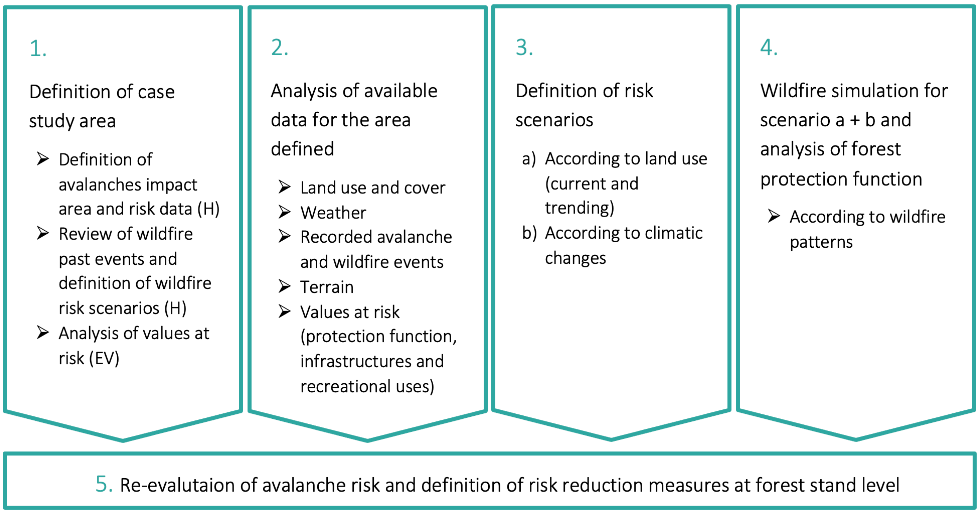


Figure 24. Multi-risk wildfire-avalanche exercise scheme.

The definition of a case study area serves to focus the exercise on a concrete territory and evaluate the data and knowledge availability to carry out the proposed methodology.

In this case, Núria valley was chosen due to different relevant attributes for testing the method:

- The area is within a Natural Park.
- An active touristic activity is promoted during winter.
- The range of altitudes (1.600m and 2.800m) representing potential wildfire-avalanche interactions.
- Presence of different elements at risk. Particularity, a railway to have access to the ski resort and to the Sanctuary, and the net hiking itineraries.
- A high intensity wildfire in December 2007, burning 60ha inside the study area.
- Recurrent large avalanches affecting the area.

According to the wildfire past event and known wildfire risk patterns in the area of study, two different weather synoptic scenarios were stated: north wind-drive wildfire and topographic south wind-drive wildfire (event of 2007) (Figure 25). These to wildfire patterns were combined with two different land use scenarios (current situation, increase of forest cover up to the tree line, due to natural reforestation).

In each scenario, wildfire simulations were carried out (using FlamMap and FARSITE) getting the total burnt area and those areas with crown fires. In this case, the main predominant tree specie is the Pinus nigra, adapted to low intensity fires. Nevertheless, since this specie cannot resprout after the fire, it is assumed that those areas where crown fire are indicated, the tree cover is jeopardized.

Current weather and land use scenario
- South pattern: heat wave scenario (using meteorological data from 2015 heat wave in Núria valley).
- North pattern: winter scenario with high wind intensity and low humidity (common meteorological situation in the area).

Climate change weather and land use scenario
- For both patterns, same conditions as previous, but increasing temperatures in 2ºC, and reducing 5% the relative humidity.
- Adding land use change according to land abandonment (decrease of traditional pastures) and natural reforestation up to tree line limit.

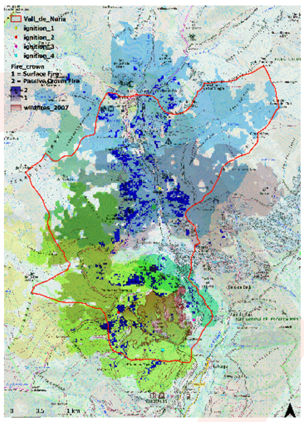
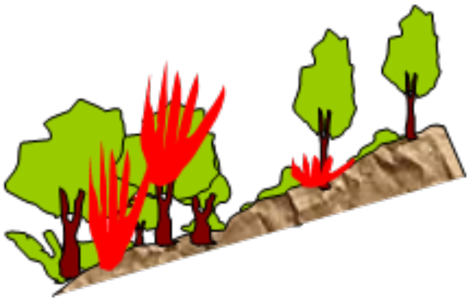


Figure 25. Scenarios defined and example of map showing the areas affected by crown fires according to the simulation.

Therefore, the identification and delimitation of the areas affected by crown fires allows to focus new avalanche risk situations due to the loss of forest protection function. Re-evaluation of avalanche risk should identify the increase of risk areas in those slopes over 28º due to the potential loss of forest protection.

Consequently, from avalanche risk management point of view, to identify "Susceptible avalanche starting zones due to wildfire" on those areas with values at risk become a priority. In those areas, forest management practices should be oriented to achieve forest stands resistant to crown-fire impact (see forest stand level analysis).

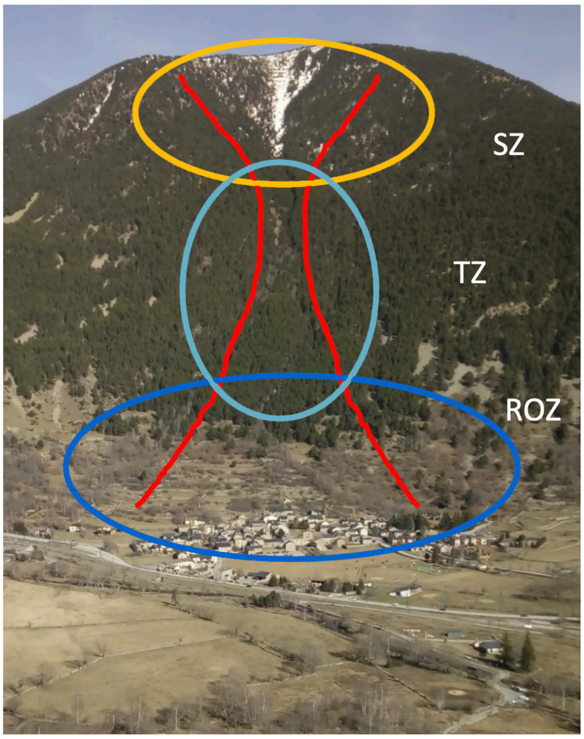
Moreover, wildfire influence on avalanche risk is not only the appearance of "new avalanches" but may also increase the level of avalanche event severity. Depending in which part is located the loss of protection function (e.g., track or run-out avalanche zone), the burnt forest can exacerbate the destructive effects of avalanches (e.g., died trees dragged by the avalanche).



Crown fires in dense and continuous fuel layers from the surface of the ground to the top of the trees (left) and surface fires (right) in open forest stands. Wind, slope and the preheating of fuels are the major forces influencing speed and intensity of fires. Typically, from bottom to mountain top, aligned with topographic ascending winds, may generate the worst situation.

Related to this, at **forest stand level,** forest management practices should help to address jointly the reduction of wildfire risk with the maintenance of forest protection function (both, from avalanches, but also from rockfalls). Open forest stands with low vegetation in the understory, which normally will suffer surface forests avoiding crown fires, may involve an increase of rockfall risks on steep terrain.

The proposed forest management guidelines for multi-risk avalanche and wildfire reduction is based in approaching different fuel treatments (and the consequent forest structure) according to the physical situation of the forest cover along the slope and avalanche zones (Figure 26). The main objective is to reduce crown fires risk to the forest situated in the avalanche starting point. For this reason, an open forest stands should be provided with some distance to down fire from canopies to the surface, in the case a wildfire is spreading form the bottom. In the middle slope, dense forest structures should be ensured to reduce rockfalls risk and, consequently, crown fires are possible. Moreover, in the bottom part, open forest stands should be provided to help first attack fire control but also reduce the biomass in the run-out avalanche zone.



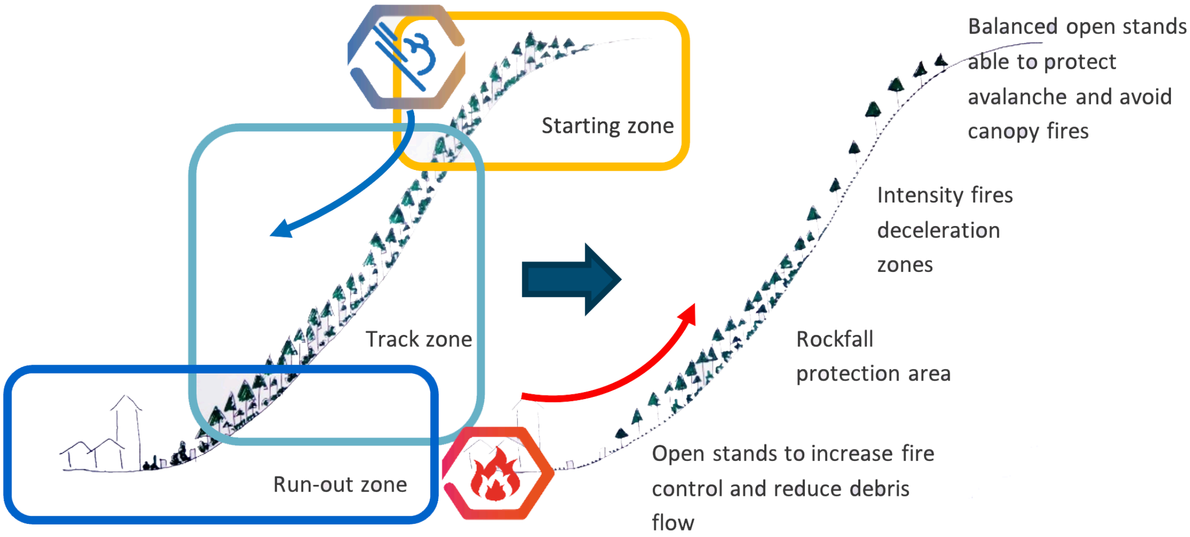


Figure 26. Scheme of forest management prescriptions towards common wildfire-avalanche risk mitigation approach at forest stand level.

The avalanche-wildfire risk analysis is completed with a practical exercise of cascading wildfire event followed by a fresh snow event at the beginning of the winter season. The corresponding steps for risk management are defined in Box 3.

To know more about this tool, see *Protocol for wildfire and avalanche risk management in mountain areas*, online available.

II.3.6 VISUALIZER TOOL FOR MANAGING EMERGENCY SITUATIONS IN CASE OF HIGH AVALANCHE RISK

By Glòria Martí, Manuel Bertran and Carles García (ICGC)

It has developed a visualizer tool that let Civil Protection get ready in advance to facing to snow avalanche emergencies. The typical warning issued by the ICGC when avalanche danger is high or very high (levels 4 and 5, according to the Unified European Avalanche Danger Scale) is now enhanced by probabilistic information about which vulnerable areas are most likely to be hit by major avalanches.

So, regional forecasting is improved with detailed information at local scale and priorities can be defined when plans of defensive measures such as evacuation, confining or closures must be executed.

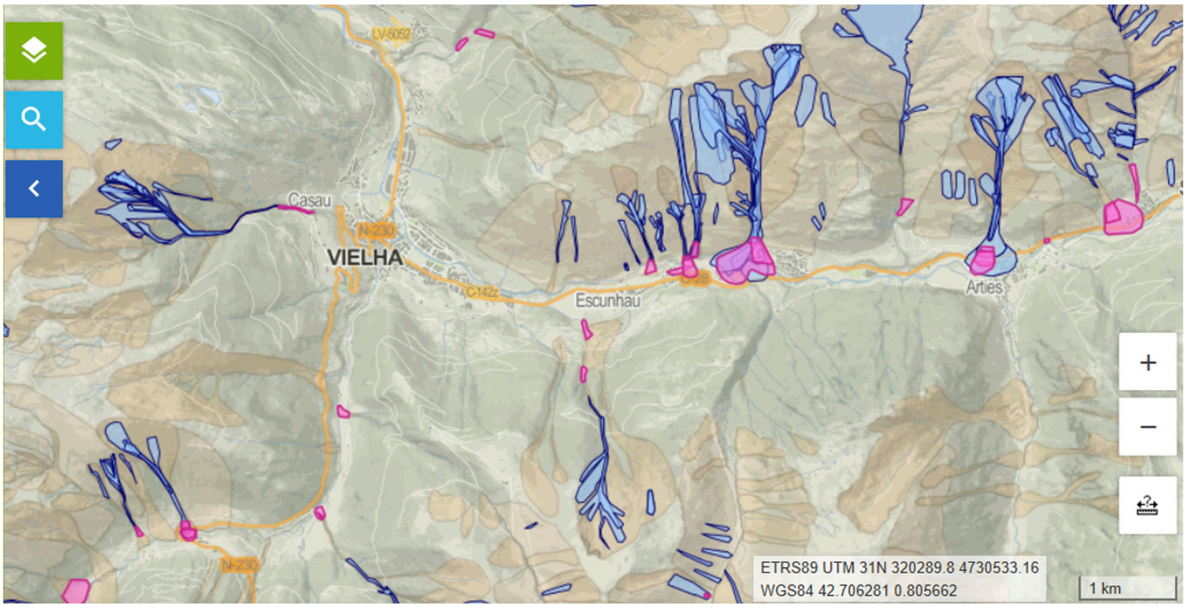


Figure 27. Avalanche map showing the recently observed events in blue colour and the historical observations in magenta colour.

In this case, results of scientific research on avalanches and weather conditions by the ICGC have been applied in the praxis of emergencies management by Civil Protection. Major avalanche activity has been observed to be linked to the atmospheric conditions at mid-level troposphere, such as 500 hPa geopotential topography. This level controls the weather on surface, mainly the storm profile (evolution of temperature, precipitation and wind), which defines the avalanche problem (new snow, wind drifted snow, wet snow, persistent weak layers, gliding avalanches).

Once atmospheric patterns leading major avalanches have been obtained by means of statistical techniques, it is possible to forecast at mid term (48h to 72h) both which are the most endangered regions and which are the most likely avalanche paths prone to fall down. Buildings, infrastructures and transportation corridors in exposed terrain are identified. Avalanche paths and specially runout zones are evaluated in function of their vulnerability.

For a given day classified in an atmospheric pattern leading major avalanches, Civil Protection can observe over a cartography where are the most vulnerable exposed terrain to the avalanches. This exposed terrain is classified as very likely to be affected or just possible to be affected according to the documented and historical information of the past events.

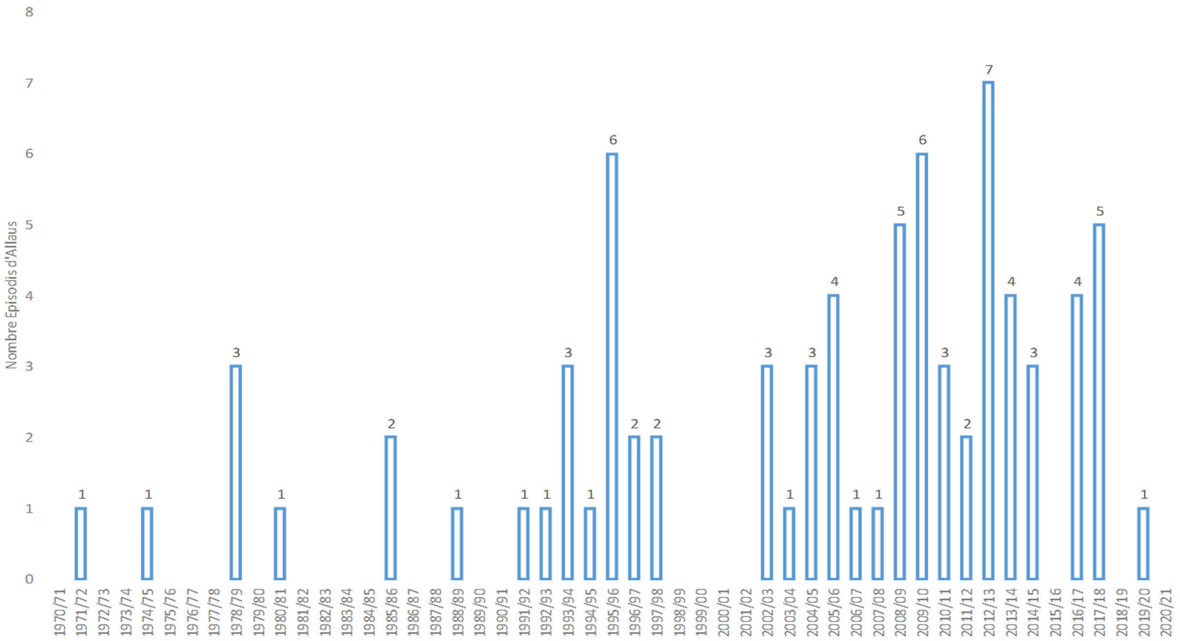


Figure 28. Number of major avalanche cycles observed from 1970 to 2021 (April) that have been dated at daily scale.

Developing this tool, a main reflection that has arisen is the importance of collecting data base information on natural hazards under the same homogeneity criteria along the time. This is not so obvious when recording tasks and mapping of avalanche activity is in charge of different institutions, territorial administrations, digital formats and spatial scales along the decades.

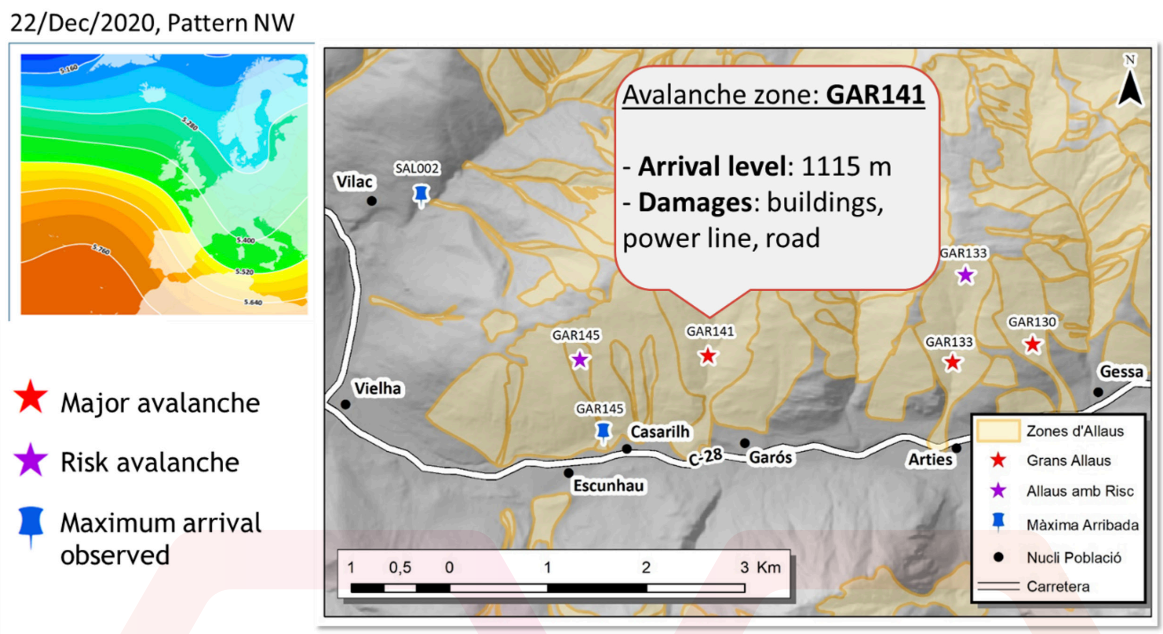


Figure 29. Likely major avalanches prone to fall for a given day classified in a category of atmospheric pattern leading avalanches (NW pattern) can be observed in the visualizer tool. Smaller avalanches but affecting vulnerable areas are also shown (risk avalanches).

To know more about this tool, see *Visualizer tool for managing emergency situations in case of high avalanche risk*, online available.

FINAL REMARKS

FINAL REMARKS

√ The **increasingly hazardous** and **uncertain environ** posed by **climate change** is adding new complexities to risk management. In this context, additional technical, procedural, knowledge exchange and financial resources become necessary since the **severity of events is increasing** and **unprecedented** (or very rare) **risk situations** are extending into new territories.

√ In terms of natural hazard behaviours, environ conditions posed by climate change will have a significant influence. Regarding **wildfires**, the global average increase in temperatures and droughts will facilitate more intense and frequent wildfires, increasing the potential of extreme events exacerbated by the expansion of biomass fuels due to land use changes. Moreover, the number of annual fire risk days will prolong the fire season. Flash **flood** and pluvial flood events are also expected to increase in frequency and intensity throughout Europe. **Windstorm** scenarios show events becoming more frequent, intense and longer lasting. As for **avalanches**, an increase in the frequency and magnitude of wet snow avalanche situations is expected, as well as potential changes in snowfall patterns during the season. The degradation of permafrost due to global warming will favour an increase in the frequency of **rockfall** above the permafrost limit. Moreover, the expected increase in torrential rainfall may lead to a higher frequency of **landslides**.

√ Moreover, since some natural hazards are expanding (e.g., wildfires in mountain areas affecting the forest protection function in avalanche risk prone areas), **multi-risk situations** will be more frequent, generating **new risk management scenarios**, where combining different natural hazard expertise will become fundamental. Protocols, risk mapping and risk planning should be adapted to this potential multi-hazard cascading or accumulative events.

√ Within this changing risk context, **Civil Protection and emergency management capabilities** may be reinforced within **integrated risk management approaches** by means of:

- Effectively integrating and engaging Civil Protection requirements into the initial stages of risk assessment and planning, strengthening the link between protection and prevention within the risk management cycle (RMC). For example, inserting operational response needs (e.g., predefined confinement and evacuation facilities and requirements) into urban and spatial planning.

- Enhancing the exchange of information between different sectors and agencies, favouring interinstitutional cooperation towards more aware territorial planning capable of considering current and future disaster risks. It is important to effectively integrate spatial, urban planning, forest, nature conservation and agricultural policies into disaster risk reduction, by enhancing policy coherence and highlighting risk-reducing activities and their beneficiaries (e.g., integrating protection forests as a Civil Protection infrastructure).

- Reinforcing the synergies among the different responsibilities and roles within the RMC, favouring cost-efficient trade-offs among the actions addressing hazards, exposure and vulnerability (including copying capacity), reduction along the prevention-preparedness-response and recovery stages. For instance, in the case of wildfires, bioeconomy and forest management as a nature-based solution may promote a landscape that is less vulnerable to the spread of high intensity fires, where risk management efforts to reduce exposure and vulnerability will become less costly.

- Promoting greater collaboration between stakeholders, and also more engagement in disaster risk management (DRM) and early warning systems (EWS) by the various agents, including the exposed population, private sectors and political actors. For instance, addressing tourist sector risk management as an opportunity to improve territorial resilience (considering the particularities of the occasional visitors).

- Developing and implementing improved tools for (disaster) risk assessment and planning, which can approach risk management comprehensively in a systemic way, facing both physical and social vulnerabilities. Risk planning should integrate the above-mentioned co-ordination among agencies, local authorities and stakeholders as well as efficient trade-offs across RMC measures, while simultaneously promoting better risk governance. In this respect, local authorities are key agents for promoting synergies with stakeholders, as well as for pre-planning and response and they will be supported specifically to carry out such integrated risk management approaches, in coherence with regional strategies.

- Achieving consistent financial support, strengthening the link between risk transfer, insurances and risk reduction, investing in current resilience to avoid the future cost of response and DRM. Obtaining political support to achieve successful risk reduction policies in the mid-long term is fundamental. Moreover, additional resources should be allocated in the corresponding agencies to face extreme events and related emergency situations.

√ To ensure a **faster and more efficient response**, reinforced cooperation and coordination among and across agencies must be achieved by means of sharing data, expertise, common and efficient decision-making procedures, enabling integrated platforms, promoting joint drills and practical exercises and ensuring efficient and reliable communication and basic supplies. In the case of emergency, the response can be supported by the capacity to compile information from citizens and to send and receive alerts. In this increasing risk context, the challenging need to advance towards cross-border data sharing and protocols under common emergency management strategies becomes more imperative.

√ As for the **Decision support system**, this should include updated monitoring of exposed and vulnerable elements according to risk scenarios, including the projections of climate change (and cross-links with existing trends of land use changes) and its expected impacts (such us flood levels according return period that may lead urban planning). This should be reinforced by integrating economic costs and environmental impacts (e.g., loss of the forest protection function and possible cascading effects). Moreover, the involvement of exposed populations and economic sectors within data collection and sharing may offer a frame to promote risk awareness.

√ In terms of an enhanced **risk culture**, improving the participation and engagement of citizens in risk planning may promote risk awareness and the co-creation of risk management processes. However, self-exposure should be addressed properly, offering the necessary resources and tools to improve the copying-capacity in carrying out those risk mitigation and self-protection measures according to everyone's own predefined responsibility. This can be achieved by means of coherent guidelines, agreements and commitments vis-à-vis individuals and the private sector.

√ Within the **recovery stage**, quantifying losses, evaluating prevention and response measures and synergies between restoration and adaptation may support further resilient approaches. In this respect, it is suggested establishing a protocol of lessons learned after the event, involving related agencies, local authorities, private actors and individuals, and even non-affected areas that can learn from the past events.

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