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Networking for the European Forest Risk Facility initiative

Report on transverse risk assessment on wildfires, storms, floods and avalanches, and crosslink risk interactions in a climate change context

Deliverable nº 6

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1. Introduction

Under several climate change scenarios, all European countries seems undergo increased risk of different natural disasters. This expected trend, will affect areas that historically have not experienced significant impact from a specific natural hazard; a large proportion of damage is likely to be related not only with high-severity events but also with new hazards interactions (new risks coming up and influencing existing ones as wildfires affecting mountain forests increasing avalanche risk). Actions encouraging the sharing of knowledge and good practices among natural hazards and local/regional expertise should improve the disaster risk reduction strategies, preparing the national civil protection systems to cope with the impact of climate change.

Nevertheless, Pan-European exchange of experiences, lessons learnt and good practices guidance of forest risk management are also often lacking or may not be accessible or tailored to the needs of different operational actors. Numerous initiative as the EU Disaster Risk Management Knowledge Centre (DRMKC) seek for more transfer of scientific knowledge into practice, as well as an increased cooperation of risk assessment and disturbance management. Research knowledge is also required as input to policy development and implementation. In order to ensure effective interaction between research, policy and practice at European, national and local levels it is essential to base collaboration on mutual understanding while allowing for a continuous and open exchange on corresponding needs.

NET RISK WORK (Networking for the European Forest Risk Facility Initiative) is a two-year Project (2017-2018) co-funded by the EU Civil Protection Mechanism, which wants to promote knowledge and lessons learned exchange and networking around risk management of four major European natural hazards and their interactions; wildfires, storms, floods and avalanches. Along the project, best practices capitalization, tools for assessing risk evolution under climate change scenarios and knowledge exchange with experts across Europe has been carried out. The Project is also giving continuity to the Risk Facility Initiative started in 2014 (www.friskgo.org) encouraging networking under informal and permanent multi-actor platforms seeking for a better transfer of knowledge into practices and policy making. All information and deliverables about the project are free-access: http://netriskwork.ctfc.cat/.

This report describes the outcomes from the lessons learned exchange among natural hazards risk reduction strategies - assessing what has been learned and what could be learned from other risks planning and management experiences – as well as crosslink natural hazards risks assessment with the interactions identified in the changing climate context affecting Europe. The document capitalizes contents and reflections figured out during the “Natural Hazards Risks Management” Workshops (deliverables nº 8 and nº 9), as well as the single risk and risks interaction and assessment matrix developed within the project (a total of 23 single risk and 26 risk interaction matrixes were conducted. They can be downloaded at the project web site, interaction tools section).

For all the forest risks; i.e. wildfire, storm, flood and avalanche, information is organized and presented homogeneously according to 3 thematic blocks: (i) A general review of the specific risk and it’s tendencies in a climate change context, (ii) Detailed description of the challenges and gaps on risk management organized by cross-sectoral components (see below), and (iii) Key highlights related with Sendai Framework for Disaster Risk Reduction and Disaster Risk Management phases and domains. This structure aims to facilitate the comparisons in-between each risks and to understand the multiple dimension of risk management and its current challenges.

Regarding cross-sectoral components of risk management, although a unique frame listing them does not exist, they can be pre-defined according the most common issues dealing with disaster risk reduction strategies. NET RISK WORK project has established the following ones:

i) Risk and vulnerability assessment and mitigation: related to the assessment of the level of risk (from modelling, mapping or qualitative surveys) and the underlying causes driving hazard, exposure, vulnerability and results of related mitigation measures.
ii) Cost-effectiveness assessment: related to the positive effects of risk mitigation measures in comparison with avoided costs due to the risk reduction.
iii) Risk planning, governance and policy framework: mainstreaming of previous ones to preventive risk planning figures and protocols, within the corresponding normative and public-private multi-actor governance frame under regional/national disaster risk reduction strategies.
iv) Community involvement and risk communication: referred to those actions promoting risk awareness and participation of exposed population in mitigating risk under the general frame of risk culture.
v) Civil protection, emergency and post-disaster management: considering all those actions once natural hazard happens related to protection of people, goods and emergency services organisation. Recovery and post-disaster management is also included as far after a disaster several initiatives are developed in a reactive manner (e.g., from lessons learned assessment to recovery plans or changes in risk management policies or resources).

Finally, into the last thematic block a summary of main ideas of each risk are figured out, following the same structure of risk components used during the best practices and tools on risk planning and management identification action (see deliverable nº 4), according to the SENDAI Framework for Disaster Risk Reduction and the Disaster Risk Management framework.

Report do not takes into account the RescEU initiative (Strengthening EU Disaster Management: RescEU Solidarity with Responsibility), as the NET RISK WORK project was in the middle of their lifetime when RescEU was approved and presented.

This report is not intended to be scientific document. Scientific facts that are mentioned have been thoroughly described based on experiences and knowledge of all experts involved, however further details on some mentioned topics and can be easily found in a scientific paper database. The document is addressed to provide ideas and guidance for all risk managers, aims at address future challenge to increase forest landscapes resilience and civil protection.

2. Wildfire risk

2.1 General review and tendencies in the context of climate change

2.1.1 General review

Both components of global change - climate change and land use changes due to socioeconomic scenarios, such as rural depopulation - make wildfire risk evolve in many European territories. For instance, in the Mediterranean, a combination of more intensive heat waves and droughts together with an increase of fuel biomass from land abandonment is increasing the severity of wildfire events. On the other hand, climate change leads to an increase of fire risk in unusual regions as the alpine areas or Northern Europe. Enlargement of territories affected by fires as well as the duration of fire season (as observed, extreme events outside the summer period) and, an increase of fire severity and intensity are expected. Since there is a high potential of wildfires impacting on citizens and urban areas, extra efforts are necessary in terms of civil protection and emergency response services (resources, training, protocols, etc.). Due to this evolving context, fire suppression system has to deal with unprecedented fire behaviours, and this is affecting both, fire-prone areas and new risky regions at their relative scale levels.

Land use changes play a crucial role on wildfire risk evolution. In the first place, the forest recolonization over former crops and grasslands, has increased the forest surface and its continuity at landscape level. Secondly, due to the lack of wood and firewood removal or forest grazing, a continuous growth of forest vegetation between understory and trees canopies has led to an increase of fuel loads at stand level. Drought conditions allow this vegetation to burnt easily and more intensively. Therefore, without a modification on the fuel patterns at landscape level, the fire severity and intensity will keep at very high levels that overcome suppression and emergency management capacities. Consequently, there is a high potential of increasing the impact of destructive forest fires in wildland urban interface, threatening citizens and infrastructures as well.

In terms of forest recovery capacity after the fire event, even though most Mediterranean forests communities have natural post-fire recovery mechanisms (e.g. sprouting or pine nuts spread after head influences opening cones), this could be compromised by repeated high intensity events affecting the same location, or by increasing desertification indexes in poor soils. In the cases of Alpine and North-Central Europe, forests are changing as several species are not adapted to fire effects (in some cases, neither to low intensity fires which produce tree mortality as a result of heating its thin bark), jeopardizing forests recovery capacity. This situation can have relevant consequences in terms of preserve the forest protection function in mountain terrains.

Nevertheless, direct consequences of climate change on forests health and vulnerability to wildfire hazard, are not always visible at a short term, as different cascade effects can appear related with diseases or pest affectations, which provide huge amount of dead biomass and unhealthy forests increasing wildfire risk.

Therefore, wildfire risk management in the context of climate change, in addition to fire suppression and defensive prevention measures, is a matter of forests management at landscape level (influencing fuel loads distribution), avoiding dense and homogeneous wooded lands, as well as enhancing spatial planning, reducing exposure and vulnerability of urban areas and infrastructures to wildfires.

Beyond physical changes of structural factors, wildfire risk under climate change context will also have important repercussions over the social sphere. In terms of risk culture, (1) due to the increasingly exposed population to unrecorded extreme events; even in traditional fire-prone areas, or (2) because new unknown phenomena have to be faced; e.g. wildfire risk in Alpine regions. In both cases, population will have to deal with uncertainty regarding how to act and react to face those type of events. Consequently, efforts invested in risk awareness and communication are becoming crucial for wildfire risk DRR practices. The responsible social behaviour in areas at risk aiming to reduce fire ignitions, enhancing public awareness on prevention, self-protection measures of properties in wildland urban interfaces and ensuring a safety preparedness and response during wildfires events in terms of population confinement or evacuation.

Indistinctly of the increase of fire severity and the unprecedented fire behaviour given by climate change scenarios, it is necessary to update risk management protocols from prevention and preparedness to response phases. At prevention and protection level internal procedures and resources accordingly to the coming fire hazard characteristics should be updated and redesigned into disaster risk reduction strategies according to the extreme events occurrence. The high weather variability at local/regional level jointly with the slow evolution of the process until becoming tangible results, add difficulties when building up more resilient systems to the changing risk scenarios.

In summary, the increasing of wildfire severity and/or frequency are threatening large amounts of public values and communities. This includes the appearance of potential wildfire risks in areas that were traditionally considered safe or threatened by low-disturbance fire regimes. Without reducing the vulnerability of the landscapes to burnt in high intensity, preparedness and response actions have to be able to deal with the impacts of severe wildfire events to urban areas, and to react consequently.

2.1.2 How other natural hazards are affecting wildfire risk management

With regards wildfires and other natural hazards interactions, a major concern about risk cascade effects is related to the loss of existing forest cover, especially in the case of forest with protection function which prevent snow avalanches, flash floods, landslides or rock fall risks among others. These situations have a high relevance on mountain forests from Alps or Pyrenees, which are growing on hilly terrain instead of on old crop terraces as in many Mediterranean forests. In those Alpine areas, the potential damage of low intensity fires to tree species non adapted to heat and fire impact effects, i.e. thin bark species such as Spruce, it can be initiate a process of forest degradation resulting in an exacerbating of the cascade effects.

Once the natural disturbance regime changes, interaction between hazards could, on the one hand, magnify the intensity of a specific risk when acting simultaneously; e.g. in October 2017, high wind speeds of Ophelia's storm interacted with a wildfire event in the North-East of Spain (Galicia), exacerbating fire behaviour with extreme spread rates making its control and suppression more difficult. On the other hand, risk interaction could generate additional or unexpected damages and raise concerns when acting as cascade effects (one after another); e.g. a wildfire in Borjomi's Georgia forest after a wind throw event, have experienced high fire intensities due to the fallen trees and fuels overloading, in comparison with surrounding trees non windstorm affected, where only low intensity fire took place.

Consequently, there is a special need to consider multi-risks assessment protocols, aiming to manage, adapt and enhance forest resilience for new risk scenarios. For instance, considering together fire and avalanche risk in mountain areas, or storm and wildfire risk in central Europe. These interactions make

also recommendable moving towards cross-sectoral cooperation protocols among the corresponding administration and agencies' segments dealing with the several risks involved, helping to optimise forestry management guidelines.

2.2 Risk management achievements and challenges

2.2.1 Risk and vulnerability assessment and mitigation

I) Achievements

During last decades, forest fire science has widely evolved allowing to better understand wildfire phenomenon and its interaction with the environment. There has been a notorious improvement on risk and vulnerability assessments. From the first fire theory models; e.g. modelling surface fire's spread to the ultimate forest fire's simulators and forecasters models; e.g. fire area and behaviour simulator (FARSITE) and Fire Weather Index respectively, a broad knowledge on how diverse environmental conditions; i.e. how forests fuels type, topography and meteorology conditions interact and influence fire behaviour.

On the one hand, the daily fire risk assessment is based on complex indexes which evaluate the present and coming weather conditions together with fuels availability to burn in terms of moisture. This allows to spatialize fire ignition and spread capacity across a region, and allows to regulate specific activities of high fire risk initiation such us machinery works on wooded lands, and to alert the population about a dangerous situation in order to increase their awareness and preparedness.

On the other hand, dynamic and static fire behaviour models allow to estimate specific wildfire shape and characteristics across a terrain, according to particular fuels load and weather conditions; it is mainly based on fire behaviour estimation in terms of flame length, rate of spread and fire intensity according to forest fuel model (dense vs open canopy forest, with or without shrubs, etc.). These models allow to better understand the factors from a landscape that have a higher influence on wildfire, being able to prioritize adapted mitigation measures. In this sense, fire types concept has recently appeared, which assumes that in similar conditions of topography and weather similar fire behaviour shall be expected, being more or less intense according to the present vegetation type[1]. Fire intensity will vary according to fuel loads and distribution, being of high severity in those dense forests without any discontinuity between understory and tree canopy.

The approach allows to design the specific prevention and protection measures at landscape level to efficiently suppress wildfires, evaluating different landscape patterns and climate change scenarios.

II) Challenges

New conditions allowing extreme wildfire events and the technological limitations of fire services to face them are highlighting that null risk does not exist. Paradoxically, success suppression of most of medium and low intensity fires allows forest fuels accumulation. Those fuels remain available for future wildfire events out of suppression capacity given the necessary vegetation drought and weather conditions. In

[1] Costa, P.; Castellnou, M.; Larrañaga, A.; Miralles, M. and Kraus, P.D. 2011. Prevention of Large Wildfires using the Fire Types Concept. (U GRAF, ed.). Outcomes of the European Project Fire Paradox, Bombers de la Generalitat de Catalunya. Barcelona. 87p.

summary, recurrent extreme events show the limitations of response stage into risk cycle and the need of enhancing the assessment and mitigation landscape vulnerability to high intensity fire behaviour.

As far as fire intensity is directly related with fuel loads, wildfire risk is highly influenced by human behaviour. Consequently, fire assessment should consider both prevention-response capacity together as communication vessels. In most areas with high exposure and vulnerability, prevention, preparedness and response efforts run simultaneously, temporarily demanding huge amount of resources. Reducing the hazard of extreme fire behaviours through fuel management, will ultimately require less efforts on suppression.

As wildfires with the potential of affecting citizens and infrastructures increase, it is necessary to include into risk assessment the forest vulnerability and also goods and services vulnerability. In this sense, the integration of fire risk into spatial planning domain, as it is already done with other natural hazards such as floods or avalanches, becomes a major issue. The legal frame and planning process would require updating, and adapting fire risk assessment to land planning process requirements (that may not answer the same operational needs of fire service). By doing so, the vulnerability of social and economic exposed elements could be pre-identified, and consequently apply prescribe prevention and self-protection measures for an urban planning compatible with wildfire risk.

All in all, once the hazard strikes, prevention and preparedness actions become crucial for minimizing impacts and reducing risk. In such an interconnected system, the more efforts are put on preparing infrastructures against fire impacts, the less efforts are necessary during the response phase to protect them.

Therefore, risk management strategies must be based on an appropriate understanding of the wildfire risk, focusing on the underlying factors of the “hazard build-up process”. Nevertheless, as was mentioned, in highly intense events, suppression capacity is limited meanwhile latent existing risk of spread of high intensity fires remains in the land. Therefore, technological solutions to cope with emergency response are necessary; even though they operate with high levels of vulnerability.

In the specific case of wildland urban interface where the collaboration of citizens in mitigation risk is crucial, social awareness on risk exposure could motivate prevention and preparedness actions, which will improve response efficiency in case of fire. On that sense, risk assessment and planning process, through participatory approaches, can be used to involve local communities on understanding the risks situation they have, giving them a role as part of the solution. This could be complemented with trainings and fire drills to stablish a safe confinement and/or evacuation manoeuvres. Putting together civil protection, fire services, land planners, local administration and neighbours identifying risks and the necessary mitigation measures should enhance risk planning and improve citizen protection and emergency management during wildfire.

From a cross-border and European perspective, common standards in terms of risk assessment (for instance, common wildland urban interface fire risk index) and their inclusion into emergency operational information should make the international cooperation more efficient.

In parallel, the exchange of knowledge and experts across Europe is a key practice to help developing comprehensive and integrated strategies that will help facing forthcoming wildfire risk challenges derived from climate change. Since wildfire risk is being extended through EU, lessons learned exchange among regions can accelerate the learning process about how to face wildfire risk. For instance, even if there has been a generalised and exponential evolution of fire suppression efficiency during the past 50 years,

some specific wildfire events (e.g. 2017 fire season worldwide) demonstrates that emergency services can be widely surpassed by the incident. Through the exchanges of knowledge and experts many countries that are less used to forest fires can adopt a more focused preventive land management approach to minimise and mitigate climate change effects, rather than keep observing to fail. The strategies that are applied in different risks and/or different regions, can help getting a broader perspective of risk management approaches and provide lessons learned from other risks that can be applied to wildfire risk.

With regards to risk information dissemination, wildfire risk assessment and mapping are mostly based on the calculation of complex hazard indexes. Typical outputs on maps, indicating colours according to the danger level have to be strongly rigorous, as information must be credible and trustworthy for building up confidence between risk managers and end users.

The risk management community is important concerned about the extensive use of the risk colours rating and its inflexible and unpractical consequences; e.g. limiting activities associated with a high economic impact at regional level such as restricting mountain access to the public given a red danger level. In this case, if no fires occur, people's risk perception diminishes and the focus moves to the activities' limitation and the associate opportunity costs. At the end, risk prevention actions are often affecting societal/individual rights and duties. As the risk increases during the summer, the restriction of activities should be well identified, and alternatives should be defined in order to make safety compatible with the development of economic activities. Moving from restricting access to increasing individual and collective risk management capacity during high wildfire risk days will be key to success.

Methodologically, forest fire risk assessment is limitated to a regional stochastic distribution or probability of fire ignition and spread in a certain site. Potential burnt areas are defined by fuel distribution, and fire ignition points is highly influenced by human factor and random natural distribution of lightings. The methodological limitations to statistically define the level of risk are adding difficulties for integrating wildfire risk into spatial planning, as happens with the return period of floods and avalanches.

Alternatively, the potential fire severity intensity in each situation and fuel distribution can be estimated according to the current knowledge on fire behaviour patterns. This could help defining the required mitigation measures for each hazard (e.g. perimeter fuel load reduction) instead of applying same rules in all situations, that in many circumstances can be inefficient or even unnecessary. Moving towards specific impact of fire on buildings and settlements based on common and homogeneous criterions should facilitate the effective integration of wildfire risk into urban planning as well the involvement of private sector such as insurances in promoting self-prevention measures.

According to all the above mentioned, wildfire risk assessment should identify gaps towards providing mitigation measures covering all risk domains into a common and coordinated strategy. A risk assessment under a cross-sectoral and a short-medium-long term perspective able to connect the socioeconomic and land use pattern drivers that are generating hazards and able to mitigate them.

In summary, risk assessment has the challenge of measuring risk level from different perspectives;

- The more traditional about protection of forests functionality (provision of wood, provision of soil protection, etc., e.g. fire can be a problem at a short term for wood provision but not necessarily in terms of forest conservation at medium and long term);

- Since the potential of wildfires to impact on urban areas increases, evaluation of exposure and vulnerability of citizens-infrastructures should be undertaken, and;
- According to the knowledge on fire behaviour patterns, identifying fire suppression opportunities and strategic fuel management points.

Each objective can have different criteria and priorities, and risk assessment should integrate all them from different disciplines-competences - i.e. from forest managers, emergency services to land planners or even sociologist, defining common standards to be shared among fields of expertise.

2.2.2 Cost-effectiveness assessment

I) Achievements

More and more there is a social recognition about the contribution of forests to social welfare in economical, aesthetic, environmental or recreational terms among others. This helps to get societal support to prevention and suppression efforts towards reducing wildfire risk. Economical investments to protect forests from wildfires are being complemented as far wildfires are increasing potential impact on citizens and infrastructures. In that sense, huge amounts of resources are being used on prevention, preparedness or suppression systems under a stable political commitment along time.

In some cases, owners from highly productive planted forest, invest in prevention and suppression systems, under public-private collaboration frames. In other cases, owners are organised on voluntary associations of forest defence to join efforts to economically contribute to prevention and suppression systems.

As far as underlying causes of forest fires are socially understood, more easily is linked the consumption of forest and agricultural products to fire prevention, as they are removing fuels (e.g., local cheese from goats grazing forests, wine from vineyards providing mosaic landscape or biomass coming from surrounding forest contributing to forests thinning for domestic or district heating). The strong link between bioeconomy and wildfire prevention at landscape level, offers interesting opportunities for rural development.

Prevention starts playing a role on wildfire risk management strategies once the suppression capacity of high intensity fires (given fuel overloading) is overwhelmed. This underpins the interconnections between prevention/suppression capacity and how investing more in prevention and preparedness, means less efforts on response.

Potential losses in burnt areas increases when forest functionality plays an important role at economical level, e.g. protection forests against avalanches in mountain areas, scenic beauty provision in touristic areas or water provision in wooded watersheds. Although, traditionally, emergency systems are sustained by public resources, the direct impact of fires on private interests should help to motivate beneficiaries of forest services to be involved in financing forest functionality conservation.

In that sense, in an increasing risk scenario due to the global change, more and more economic activities mobilising citizens into forest lands (e.g. touristic resorts in many coastal areas along the Mediterranean) should be aware of the need of having the corresponding prevention actions properly executed and the civil protection and emergency plans ready, to ensure the sustainability of their activity along time.

II) Challenges

Main challenges from a cost-effectiveness approach when discussing risk management alternatives are the difficulties of quantifying the economic benefits of forest conservation. Beyond direct benefits from products with market price (e.g. firewood, non-wood forest products or cost of opportunity of activities developed into wooded lands with a market price), most of the other forest services, such as biodiversity conservation, water and air regulation, landscape beauty provision and recreation (technically defined as externalities) are usually out of the market. Therefore, there are methodological limitations to undertake cost-benefit assessment comparing the cost of prevention with the avoided cost of the risk mitigated[2].

Another important limitation is the random distribution of fires. Ignition points are heavily influenced by human factors, and the potential burnt area is related not only with the fuel distribution and weather/orographic conditions, but also with the efficiency of the suppression systems. Contrary to snow avalanches or floods that follows known paths and impacts can be measured by return periods, stochastics approaches have heavy limitations in case of wildfires (similar happens in case of storms).

However, according to the fire behaviour pattern concept, it is feasible to predict how a territory is going to burn, according to a specific weather conditions, type of vegetation and its physic characteristics. Knowing how fire behaviour change according to fuel distribution offers the opportunity of highlight the benefits of wood and other forest biomass mobilisation on wildfire risk mitigation.

With this knowledge, mix of quantitative and qualitative assessments defining levels of exposure and vulnerability in terms of economic impact can be developed. This shall be integrated into risk management strategies as the criterion for development of mitigation measures and allowing the allocation of resources in a cost-efficient manner. In the case of protection forests it is clear the cost effectiveness of maintain a forest cover to minimize the underlying hazard (e.g. landslides, avalanches), than any artificial mitigation measures in case of forest cover loss. In this sense, the concept of natural capital could fit perfectly. This way of accounting natural values makes the contribution to the economy and societal wellbeing visible and allows for effective decision making.

Beyond forests as a threat in terms of wildfire risk, wooded lands with a proper fuel distribution can play a role to reduce fire intensity and prevent wildfires propagation. This “fire protection function” of biomass mobilisation and proper distribution into forest could be recognised as has been done with other protection functions against other risks as rock falls and avalanches. For this, it is necessary that all wooded lands (understood as a fundamental DRR infrastructure) have a coherent legal status to enhance forest management, oriented to preserve the protection function against large fires. For long, traditional and sustainable forest management has indirectly taken the lead of maintenance of protection functions. The economic feasibility of forest management is determined by the global market, especially in the Mediterranean or mountain areas, where wood mobilisation is expensive. From a financial point of view, a cash-flow between the forests’ protection function and the avoided costs of risk prevention should be established.

In summary, the three risk components (hazard, vulnerability, exposure) should be always taken into account in risk assessment and mapping and from an integrative approach. This can be a long and expensive process that is not easily updatable. However, the visualisation of trade-off efforts between prevention, preparedness, response and recovery improves technical and social acceptability in decision making processes, while offering better cost-efficient solutions. Even more, not all preventive efforts

[2] Plana, E., Font, M. 2015. Wildfire risk mitigation: Protocol for a cost effective assessment on fuel treatments at landscape level. FIREfficient Project (Deliverable 14), 31pp

have direct reliable and visible results at short term, as forest management and transformation action needs time to reach the desired prevention status. This situation hinders to maintain high levels of investments towards vulnerability reduction achievement at medium-long term, compared with investing at response level which offers, apparently, immediate results. Some potential solutions could be based on reinforcing long term prevention actions into the legal frame by means of economic incentives or payments for environmental services. Insurance sector can play a role motivating social awareness and own responsibility in managing risk, having different insurance policies according the level of exposure and vulnerability.

2.2.3 Risk planning, governance and policy framework

I) Achievements

In fire prone areas, wildfire prevention plans are usually defined by a legal frame and developed at different geographic (e.g. massifs) and/or administrative (e.g. municipalities, counties) levels. This risk planning includes the identification of exposed and vulnerable elements and the corresponding prevention measures (water points, fuel breaks, access roads, etc.) as well as the protocols in case of fire following civil protection plans. Globally, they are offering a good point of departure from where to integrate the structural wildfire risk causality, as, for instance:

- Facilitate the planning process, giving the corresponding role to the local administration as they are closer to citizens.
- Assessing the fuel distribution and dynamics at landscape level, even beyond the administrative limits, integrating those forestry and agricultural activities related to fuel management as a prevention measure.
- , Identifying needed preventive fuel treatments, according to fire behavior patterns, beyond the administrative limits and sharing it with the surrounding areas, facilitating to build-up a common prevention strategy.
- Considering confinement and evacuation opportunities given the increasing potential of wildfires impacting on wildland urban areas.
- Promoting coordination among public agencies with competences in landscape management (i.e. civil protection, fire suppression and urban planning), from prevention-preparedness and response integrated perspective.
- Building a shared vision (hazard-exposure-vulnerability) with society through a participatory approach, defining roles between public and private actors, and promoting risk awareness among citizens.

In many regions, special attention is given to the wildland urban interface, with complementary plans and measure towards firewise planning that aim at creating defendable spaces around houses and infrastructures. In South of France, for instance, specific plans for wildfire risk at the WUI are elaborated. They are developed by the prefect authorities. A weak point is that there are several methods applied and lack homogeneity. Moreover, they are quite generic and do not always fit to the different realities. Other examples are in Catalonia, some local administrations have developed their own programs giving economic and technical support to firewise planning and fuel treatments. In some cases, a specific tax system at municipality levels addresses the maintenance of the fuel breaks. Depending on the site, the costs of fuel treatments is covered by homeowners, forest owners, public bodies or mix situations. These programs are, in parallel, promoting risk awareness among homeowners and, in many cases, municipalities are directly leading the initiative, being aware about the wildfire risk.

National/regional wildfire risk management strategies describe ignition and spread risks and related mitigation measures separately. Corresponding actions usually include a set of measures on the prevention, preparedness and response stages. The approach based on landscape management is getting more common across fire prone regions. Therefore, new risk scenarios posed by climate change and land use changes could easily be integrated into the existing strategies. Especially on those actions related to fuel distribution at landscape level proving patterns able to keep wildfire within suppression and emergency management capacity.

National/regional strategies allow developing a cross-sectoral wildfire risk management, where different sectoral policies are involved (forestry and agricultural policies, spatial and urban planning, fire prevention and suppression policies, etc.) and should be coordinated. Some initiatives reinforcing the link between bioeconomy promotion (biomass sector, grazing, forestry, etc.) and wildfires prevention are more and more recognized at social and decision-making spheres. Under a common cross-sectoral strategy, multi-agencies governance models ensuring the proper institutional coordination, beyond some administrative segmentation inertias, should be easily implemented.

II) Challenges

High rates of uncertainty and complexity posed by climate change, combined with land use changes, are a main concern for efficient risk planning and forest management, and make the implementation of proactive prevention measures more difficult. In principle, there is more capacity to reduce unknown effects of land use changes, than improving ecosystem resilience towards climate change consequences. Including these high rates of complexity and uncertainty into decision support tools through different scenarios could help to increase the robustness of decision making processes. All in all, helping on establishing a dialog between risk managers and society based on values that can realistically be protected.

Since the interaction of forests and society is increasing (urbanisation close or inside forest areas, infrastructure, recreational uses, etc.), the necessary role of urban and spatial planning to reduce exposure and vulnerability becomes more and more crucial. Risk planning should integrate not only the existing risks but considering the upcoming ones under climate and land use changes scenarios. In this sense, new disturbance regimes can overcome existing prevention measures giving a false sense of safety, or let new areas become exposed to previously non-existent and unknown risks. Once again, efforts dealing with physical vulnerability should run together with initiatives promoting an updated risk culture. To do so, it is necessary to extend the traditional wildfire risk community; mainly integrated by forest and firefighters Departments, to other disciplines such as civil protection, spatial planning and multiple private actors involved/affected by the risk – e.g. land owner associations, exposed economic activities clusters, cultural/natural associations, etc. According to the human-influence on wildfire risk, putting together actors involved in prevention-preparedness and response phases, should also result in identifying the best cost-efficient solution, as well as better connecting the communication vessels among them.

An adequate risk planning shall take into account all the key actors in a territory and shall aim to create safe scenarios for the citizens and the emergency services to operate during forest fire emergencies. An effective risk planning will also contribute to reduce uncertainty during the emergency response, creating safety, certain scenarios of resolution and allowing emergency responders to include values such as landscape management in the final result.

Since natural hazards follow physical criteria (topography, fuels distribution, winds direction, slope exposition, etc.), more cooperation at all administrative levels, nationally and internationally, for data sharing and homogeneous risk assessment, as well as mapping procedures based on geographic limits instead of administrative boundaries is needed.

As wildfire risk increases and response resources are limited, the impossibility to protect everything becomes a fact and prioritisation is required. In this sense, planning of forest fire risk should be developed linked to the main management objectives (recreation use, biodiversity conservation, civilian and strategic infrastructure protection, income source, etc.) under societal agreement to grant a certain value to specific services.

Willingness from authorities to raise wildfire risk awareness is key for a joint decision-making process between researchers, practitioners and authorities. Rotations into policy cycle can be compensated by interacting at the intermediate public servants' level, and developing robust national/regional strategies to help defining dedicated public policies. Well oriented wildfire risk management strategies should include cross-sectoral approaches, which require a high political commitment. Spatial planning frame gives some consistent advantages as they are defined to integrate different strategic planning requirements at medium-long term perspective.

Actions to address fuel load distribution along the landscape takes time. Therefore, decisions that are made now regarding bioeconomy and prevention/suppression strategies shape the future landscapes, and define the mid and long-term wildfire risk. This long timescale makes necessary to include the future of landscapes in wildfire risk management strategies.

With all, risk management in a climate and land use change context has to deal with high levels of uncertainties. This makes relevant to consider how to approach "what we don't know" from a legal perspective and how flexible should law be to accommodate "what we don't know". Climate and land use change context poses the need of planning with future wildfires in mind. As fire behaviour is expected to worsen, it arises an important question at prevention planning level; wildfire prevention planning has to focus in all type of wildfires events, from those low-medium intensity events (controllable), to those extreme events (uncontrollable). Prevention planning shall prepare society to learn how to coexist with wildfire risk.

The recurrence of wildfire events facilitates the innovation at a policy-making level accordingly to the stated reactive behaviour on risk management policies after event occurrences. This is specially reinforced due to a high social awareness towards forest conservation. To make the most of this momentum, technical proposals and advice need to come quickly after the event and, therefore, should be prepared beforehand. In this sense, there is a need of a proactive attitude to take advantage of the opportunity windows, according to a pre-defined strategy as agreed as possible among all involved stakeholders.

Existing knowledge developed in some regions about wildfire behaviour patterns offers a good chance for an effective integration of wildfire risk into urban and spatial planning, from the perspective of potential events affecting the area. Nevertheless, current risk assessment and indexes are designed for fire suppression and prevention services and little adapted to the requirements of land planning. For this reason, specific work should be done in a collaborative way within public agencies. Dealing with operational and legal support to provide robustness to the risk information, that affects public/private rights and duties.

Based on the above, although spatial and urban planning processes have their own tempos and administrative processes, expertise on forest risks should be included in the initial stages of the planning phases. By doing so, it is easier to connect prevention – preparedness – response actions and to improve global system's resilience in a more effective and cost-effective manner.

Complementary to the quality of risk assessment information, a strong legal framework is necessary where conditions of risk planning development are fully recognized through mandatory rules. In this sense, the may be cases where there's no commitment of homeowners in wildland urban interface to cover fuel treatment costs. For this reason, wildfire strategic planning shall be supported by legal tools that bring societal needs of risk management before private interests. For instance, help getting permission from forest owners if a forest patch is identified for fuel treatments. Case law in which the risk assessment methods are criticized for not being robust enough can result in invalidating the urban planning decisions related to wildfire risk management. In these cases, a homogenization of the current risk assessment methods should be done, and forest fires managers shall work in close collaboration with the inhabitants and urban planners.

Under climate change scenarios and as far as wildfire risk is being extended across EU countries, knowledge and lessons learned exchange among regions with different experiences dealing with wildfires can offer significant advantages to face upcoming extreme events, probably not present at all in the current moment but possible in near future under the evolving fuelled landscape. In two side directions, knowledge about large fire events can be transferred south to north, and experience on social involvement/participation and urban risk planning of other natural hazards as floods or avalanches can be transferred from north to south.

2.2.4 Community involvement and risk communication

I) Achievements

Forest fires phenomenon is perceived by citizens as one of the worst environmental problems, at least in fire-prone areas. In several regions, research institutions, public bodies and environmental groups have been developing a common message on the need of preventing wildfires, reaching a certain level of consensus on the messages contents and inspiring more credibility and trust.

In that sense, recurrence of wildfire events helps to the evolution of narratives towards the causes of wildfires, related to land use change and fuel loading processes. This is allowing to create a connection between people and environmental challenges. In some regions, initiatives linking fire prevention with consumption of local products (wood and biomass promoting forest management, cheese from grazing, wine to provide mosaic landscape, etc.) are being developed.

Scientific consensus on the ecological role of fire in the ecosystem help recognizing prescribed fire as a tool for fuel control and wildfire suppression. Having environmental groups involved in the same message makes it stronger. A better social understanding of the role of natural fires allows to move from "risk zero" to "living with fire" scenarios. Social recognition of the technological limited capacity of suppression reinforces the need of reducing vulnerability and self-exposure to wildfires as main risk mitigation measures.

In terms of dissemination, risk communication has to be clear, precise and understandable and should avoid to over inform people. Different narratives and frames are needed according to the target audience. Information need to fit people's priorities. Being credible, inspiring and confident are core

elements of risk communication and awareness. Local institutions/administrations can help in making the message more effective in changing attitudes, as people feel closer to institutions if they get personalized meetings and face to face information exchange. This trust and credibility is fundamental for getting community involved and expect particular reactions and behaviours from citizens even if risk is not apparently visible or perceived. For instance, temporarily limiting individual rights in a specific risk circumstances such as forbidding the access to a forest massif due to high wildfire risk forecast.

Population exposed to wildfires should understand that, despite the efforts from the emergency services, there is a part of the risk from every emergency situation that they shall be individually assuming. Since resources to fight fires are limited, not all assets can be protected by the emergency services. There will be losses and as citizens, they are also responsible of preventive management of own properties. Raising risk awareness is helping citizens to understand the risk they have to live with fire and what preventive actions can be done as well as self-protection in case of fire. Emergency services cannot protect all, sharing responsibility is a way to build credibility and social commitment. This can be accelerated when citizens understand the risk they are facing individually.

To sum up, since wildfires are affecting more and more urban areas, risk culture level of exposed population is having more relevance into DRR strategies. In this sense, strategic communication is being identified as a crucial component of the wildfire risks management strategies, at the same level of importance as other technological solutions.

II) Challenges

Globally, there is a common consensus on the need to increase the social wildfire risk culture, in order to improve the understanding and applicability of the individual and collective roles and actions to deal with own exposure and vulnerability. Working in communication messages based on the community's solidarity and wellbeing, aiming to reach people's attention and understanding the need of collaborative responsibility should be promoted. The goal is to succeed in transferring the idea of: "my individual prevention measures, protects the rest of the community" or on the contrary "not doing my prevention duty, can carry dramatic consequences for my neighbours". This is especially relevant on the wildland urban interfaces, where population are mainly concerned by their own property without realising the importance of surroundings and neighbours risk situations which can have direct consequences to oneself.

In that sense, new vulnerability situations posed by climate or land use change should not be transferred exclusively and directly to individuals (homeowners in the case of wildland urban interface for instance, where urban planning has contributed in generating that exposed housing model). In all cases is necessary to empower citizens in self-protection and prevention capacities and responsibilities, transferring knowledge and tools to individuals.

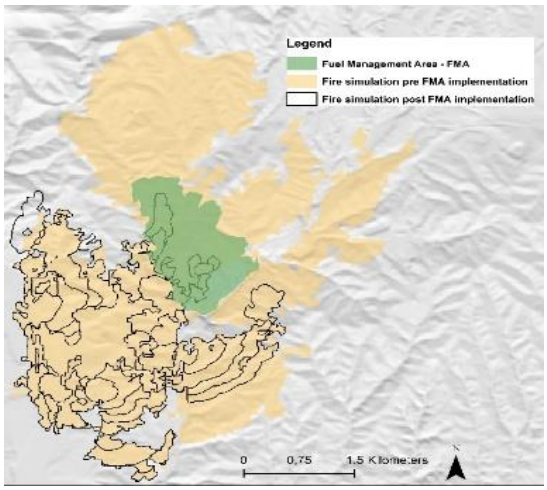
Due to social changes, people are less connected to the land and its dynamics (also natural hazards) than they used to be. A deep social process is necessary to reconnect population to their natural environment and, therefore, develop consciousness, knowledge and concern, and finally encourage accountability and responsibility. Social sciences are central in that respect and approaches to raise risk awareness and engage society on forest management shall be explored. For instance, CUIDAR project[3], has been analysing children's risk perception during different types of emergencies. One of the most relevant

[3] Project description available in Best Practice template (http://netriskwork.ctfc.cat/reports-tools-best-practices-risk-planning-management-fire-storms-floods-avalanches/)

outcomes of the project is that children want to be aware of the risk and the emergency management procedures that affect them. Children, like other citizens, want to be part of the decision-making process. Thus, for a successful bottom-up approach it will be necessary to provide enough information and knowledge to citizens so decisions can be made efficiently.

As risk will never disappear completely, the introduction of the "acceptable risk" concept is needed, which indicates the risk that people collectively and individually are willing to accept. Some technological solutions in the prevention/response phases can lead to the perception of a false sense of security based on the "technological myth", which at the end, leads to an even higher hazard exposure of people. Risk culture and communication have to be precise on identifying the threshold of risk level which cannot be reduced even with all available resources. This takes high relevance in case of wildfires as the success dealing with low-medium intensity fire reinforce the perception that all wildfires can be controlled.

To convince people about the need of taking prevention measures, it is useful to show the results, notably by using comparisons. This is especially effective when comparing fuel treatment's efficiency at landscape level. Wildfires simulations in different scenarios can show the results of different fuel treatment implementation. The result allows to see how the burned area is reduced when applying appropriate fuel treatments, and the related avoided costs, across the territory. This tool helps to visualise how fuel preventive measures works. Cost-benefit analysis is also a good way of convincing people, since the risk culture is more developed when property comes into play.



A continuous debate shall focus on defining the communication strategies and channels to use in order to carry out an effective dissemination of the information and knowledge to raise risk awareness. Are the appropriate channels being used to communicate risk awareness with society? New technologies evolve faster than the capacity to adapt the contents and knowledge for risk awareness communication. It is observed an increasing trend of behavior, where the population is quite well informed via social media. However, this information is not or very seldom translated into social behavioral change when a crisis (e.g. wildfire) happens. Most of the citizen involvement is reduced to participation on social media and smartphones. Across Europe, we can hardly observe the "responsible citizen" actively engaging in disaster risk mitigation, prevention and preparedness. The tendency to rely on others, namely the fire service is widespread despite the fact that, in a crisis situation, we all know that fire service resources are always on the limit of their operational capacity. In the medium and long run we therefore see a necessity to actively work on the "responsible citizen" concept, i.e. in the active role of supporting fire prevention or change of social behavior and consumerism to slow down the effects of climate change.

Fire prone areas in the South of Europe are highly touristic during the fire season; which supposes a specific challenge to raise awareness among "temporary" exposed communities; i.e. visitors and holiday tourists. This situation adds an extra difficulty to the risk managers and, in particular, to reach the desired risk awareness among the hole exposed population. Consequently, specific strategies targeting the visitor's communities should be designed. The role of specific actors (example of the tourism sector) which might suffer from an image of "risky" region and may, therefore, not be willing to convey the appropriate messages has to be take into account.

Globally, new climate and land use changes are posing new challenges for risk management and communication in the cultural sphere, since new fire risk scenarios are arising faster than the necessary cultural processes to adapt social resilience. For instance, significant barriers can be found in the rural areas where population traditionally are more familiar with fire; either as a management tool or in form of forest fire. Nevertheless, they are aware about past fire behaviours and solutions, but in front of mega fires this knowledge is not sufficient anymore to ensure safety and awareness. At administration level, updating knowledge to intermediate technical stages in charge of civil protection and risk management should help to cope with changing risk scenarios.

Extreme events beyond the "normal" patterns are usually understood as extraordinary and infrequent. Nevertheless, in case of an event, social demands in terms of security and protection are the same, adding high pressure to civil protection and emergency services, up to political levels.

Additionally, it is also fundamental to foresee a lessons learned and knowledge exchange channel/mechanism to ensure the future reliability of crucial conclusions raised from extreme fire events. Future fire managers and stakeholders at risk could take advantage of already recorded experiences, since probably the same person will not experience two or more extreme fire events during the professional life.

Traditionally, risk emergency and civil protection have been exclusively managed by public actors, making citizens "receivers" of the regulations. As has been stated, in the face of new risk scenarios, individual responsibility and participation in land managing should be part of the DRR strategies. Education instead prohibition approaches should get social involvement easily. Typically, authorities and fire risk managers implement limitations when risk is high in order to minimize people exposure. However, if no incident appears many users feel uncomfortable with the regulations implemented and their trust with risk management is affected.

2.2.5 Civil protection, emergency and post-disaster management

I) Achievements

As it has mentioned, wildfire risk is evolving into unprecedented fire behaviours due to the land use changes together with climate change. This situation is posing the need to update the emergency management protocols, where civil protection, with civil evacuation or confinement procedures, becomes an essential component. In several fire-prone areas where suppression capacity is overwhelmed by recurrent extreme wildfire events, more attention is put on improving response capacity by means of reducing vulnerability and exposure, connecting prevention-preparedness and response to a unique emergency management stage.

Since wildfire risk is being extended across EU, advantage of cross-national cooperation and knowledge exchange from those countries with high occurrence of large and complex fires to those where the phenomenon is appearing, is being highlighted. On that sense, successful emergency collaboration protocols at local-regional-national and cross-border levels are being implemented. A special emphasis is put in the need of developing common protocols and mechanisms on the response stage across neighbouring regions, to address the extreme wildfire events from a multi-emergency point of view - e.g. suppression, evacuations, confinements, etc. At international level, it is also being developed common operational procedures to facilitate the exchange of human and technical resources to face severe wildfire events. Officially, this international cooperation is addressed by some initiatives such as the European system to tackle natural disasters - RescEU initiative, or the EU Civil Protection Mechanism

which has coordinated and facilitates exchanges of wildfire experts. With the same purpose but at research level, the issue is addressed by some projects such as the FIRE-IN or, MEFISTO amongst others.

Recovery and post-disaster stages offer a chance to improve risk management as more political commitment can be reached taking advantage of the social concern after a wildfire event. As far as more consensus exist on the necessary updates of the DRR strategies, more easily they will be mainstreamed to the political system.

II) Challenges

In front of new risk scenarios, emergency agencies need to react to new challenges with updated approaches and strategies, as “old recipes” are not anymore functioning. As an example, it is a challenge to educate emergency systems on the “friendly fire” concept - i.e. low intensity fire, burning within suppression capacity rate and within a specific acceptable boundary, resulting on a decrease of forest fuel loads and minimizing future extreme wildfire events, which can be helpful for making the civil protection duties easier, more effective and first of all much safer.

To address new approaches, it is required a strong collaboration between involved actors in risk planning and emergency management. Leaving behind interagency competitiveness, as well as creating more flexible organization hierarchies to facilitate knowledge and resource sharing. There is a specific and generalized claim to build up the feeling of being working jointly on facing the wildfire problematic.

In parallel, some important changes are necessary at legislative and operational level in order to adapt the response and emergency capacity to upcoming risks scenarios. Given events with extreme fire behaviours, spreading through forests and wildland urban interface simultaneously, multi-emergencies prioritise protection of civilians, taking huge amounts of resources. Training on protocols of self-protection and emergency management (safe confinement or evacuation) and strong collaboration with local administrations with more close contact with local inhabitants, can help to better manage the situation. Special attention has to be given to citizens’ mobilisation in case of fire, regulating the transit to avoid entrapments. Prior identification and preparation of safety routes for evacuation or safety place for confinement could improve emergency management as, in extreme wildfire behaviours events, fire spread velocity overcome formal decision-making process.

Since climate change impacts will bring new fire behaviours and frequencies in areas that are not used to them, the interaction between fire services from across Europe should be promoted intensively in order to learn the best practices and lessons learnt from other fire services. Wildfire risk knowledge in Europe should build on the existing knowledge. This method can be achieved through an effective networking strategy that enhances exchange of practitioners.

Independently of the events’ magnitude, lessons learned analysis and post fire reflection can offer useful information for improving risk management. Collecting data of low impact hazard experiences, could help to ensure a better analysis of high magnitude and impact events, as in such situations there is normally no capacity to collect and analyse the experience. In the special case of extreme events, it becomes crucial to collect, analyse and share information and lessons learned, in order to ensure the capitalization of the success and failures experienced during the action, and being available for future intervention in similar events. This takes special relevance in case of extreme events, that will rarely happen in the same place (in a burnt area, some years are necessary to recover certain level of fuel loads to be on the same risk). Although region-wise is possible, even frequent. Consequently, the same individual; whether professional or civilian, will rarely experience two major wildfire events along the professional life, at

least in the same place. Therefore, little chances to implement the lessons learned on future occasions arise. Moreover, this knowledge could be useful for other operational crews across Europe, as climate change is increasing the likelihood of experiencing extreme events across all the continent.

In parallel, the post-emergency information capitalization has to be properly transferred to citizens, in order to increase stakeholders' active involvement, as an opportunity to build-up trust and raise risk awareness. One effective example on this knowledge sharing is the post fire "journal clubs"[4] carried out by the Pau Costa Foundation across Catalonia and Spain. These communication formats, help to empower vulnerable communities and to develop a solid historic memory on wildfire risk events in each affected region, facilitating the change of citizenship's mentalities and perspectives, as well as strengthening the definition of each role, duties and responsibilities. The lack of standardised European mechanisms to exchange knowledge, clearly leaves a gap in the process of European knowledge building on wildfire risk. This gap could be covered by a generalised implementation of some of these best practices across Europe.

Following large forest fire risk events, the focus tends to be on getting new plans and funding, but rarely on developing more integrative processes. This can be related to the "political cycle", which explains a preference of politicians for short-term actions with visible results, as well as structural measures being favoured instead of non-structural measures. In this sense, technological solutions have been a recurrent way to invest on better response capacity, as at short term it seems to have higher social revenues and acknowledgment. However, as fire risk increases and its structural problems are not addressed, technology lifespan becomes shorter. Therefore, more investments and efforts are needed on preventive and preparedness levels, aiming at increase resilience at medium and long term.

2.3 Sendai and Disaster Risk Management Framework

SENDAI	**WILDFIRE**
Priorities	
#1 Understanding disaster risk	Need of increase understanding of upcoming wildfire risk under climate change and land use changes scenarios, and its consequences at multiple social, economic, technical levels and decision-making arena. Spread the new challenges of wildfire risk management among fire community and all cross-sectoral actors involved in the vulnerability and exposition building up process, including exposed population. Promote the lessons exchange with the extension of extreme wildfire events risk.
#2 Strengthening disaster risk governance to manage disaster risk	Need to include all involved/affected actors in wildfire risk and emergency management to foster transectorial and bottom-up approaches for efficient risk governance, while defining roles, duties and responsibilities of each stakeholder.
#3 Investing in disaster risk reduction for resilience	Need of invest in long term risk reduction measures complementary to response resources, addressing together cross-links between exposure, social and physical vulnerability and response capacity. This means to adapt forest landscapes to wildfire risk by means of; promoting fuel loads distribution and forest structures that make extreme wildfires behaviours more difficult; moving towards fire management (prescribed burning, natural fires) instead of suppress all fires; integrating agriculture and forest policies into wildfire risk management promoting mosaic landscape and biomass removal; including wildfire risk into spatial and urban planning to

[4] Project description available in Best Practice template (http://netriskwork.ctfc.cat/reports-tools-best-practices-risk-planning-management-fire-storms-floods-avalanches/)

	make safer settlements and roads and increasing prevention and self-protection capacity of communities exposed to wildfires.
#4 Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction	Several actions can reduce wildfire impacts as; to reinforce and ensure the preparedness measures from the starting of the emergency, ensuring safety confinements or evacuations of vulnerable population; promoting cross-national/regional operational protocols for an efficient response, as well as international exchanges and cooperation sharing resources and best innovations; To promote lessons learned exchange after fire events, updating wildfire risk management strategies to face new challenges or using burnt areas recovery process to build-up fire prevention communities and to develop firewise planning.
Targets	
Reduce global disaster mortality	Prior preparation of the landscape ensuring safety site for evacuation and confinement is necessary. Increase early warning capacity and emergency communication to ensure social engagement, and update fire service protocols to new risks scenarios to ensure safety response of fire crew. Offer to exposed population tools and facilities for to enhance prevention and self-protection capabilities.
Reduce the number of affected people	Include wildfire risk into urban planning processes complemented with awareness raising mechanisms. Move towards the idea of living and adapt to wildfire risk, preparing the wooded lands to potential wildfire events and to create safety places and evacuation protocols.
Reduce the direct disaster economic loss	Assess wildfire impacts from the forest functionality perspective, considering avoided costs of prevention measures on forests goods and services with market prices as well as on forests environmental services, especially those sustaining other economic activities as, for instance, tourism (landscape beauty), settlements and road traffic communications protection (soil, floods and avalanches retention) or water supply (watersheds regulation). Special focus should be put on the wildland urban interface, implementing preventive and self-protection measures for reducing vulnerability.
Reduce disaster damage to critical infrastructure	Includes wildfire risk into the landscape planning processes, minimizing exposed locations of critical infrastructures, and reducing their vulnerability implementing self-protection measures according to the corresponding risk. Present and future risks, as well as multi-hazard cascade effects as fire and avalanche or flood risks should be considered.
Increase the number of national and local disaster risk reduction strategies	At local level, empower vulnerable communities by means of risk planning and governance mechanisms, enhancing bottom-up and participatory approaches to involve citizens in the risk reduction measures. At national level, promote transvers wildfire risk strategies, able to tackle cross-sectoral wildfire risk from an integrated prevention-preparedness-response approach. Risk changing scenarios due to climate change and land use changes, as well as multidisciplinary of multi-risks cascade effects should be fully considered.
Enhance international cooperation to developing countries	Strength the international networking through best practices and experience sharing, as well as supporting training and exchange programs for knowledge and resources transfer. Reinforce the international cooperation programmes and mechanisms as far as the territories under extreme fire events risk increase.
Increase availability of and access to multi-hazard early warning systems and disaster risk information and assessment	Reinforce early warning and emergency communication, overall in case of large wildfire events, to better inform population exposed to risk on how to ensure a safety confinement, evacuations and proper collaboration with emergency services.
DRM	
Cycle phase	

Prevention	Efforts done in reducing ignition risk have to be complemented with reducing wildfire spread risk, which is mostly related to fuel loads and distribution at landscape level. Forests' structures unable to sustain high intensity fires' behaviours, with very special attention at the wildland urban interface areas, together with specific housing constructive materials and gardening considerations should be take into account.
Preparedness	Increase risk awareness and self-protection procedures and plans to all exposed and vulnerable populations, in order to minimize or avoid the emergency system collapse and such be able to focus all efforts on containing/suppressing the fire propagation. Regular training programs for and with communities, all risk and emergency managers and related actors such as voluntaries should be part of the preparedness targets.
Response	Strength the cooperation and training with all different emergency bodies (fire service, security, health, etc.) to face the multi-emergencies running within an extreme wildfire event, affecting thousands of hectares, even more when wildland urban interfaces are involved. Increase efficient risk communication to society during an event, building up trust, credibility and social acceptance of official alerts and recommendations. Involve media and journalists under communication alliances frames towards information process to population. Integrate those fire suppression opportunities identified based on fire behaviour pattern concept and territory characteristic, in fire prevention plans, developing the corresponding preventive fuel treatments and accessibility facilities. Promote cooperation among fire services at regional/national and international levels.
Recovery	Assessment and reporting of the wildfire events, in order to share all the experience and lessons learned capitalized with other risk/emergency managers and the communities. Implement all the necessary improvements according to the lessons learned in order to minimize/avoid future similar situations. At local site burnt area, take the opportunity for building-up more societal awareness with regards wildfire risk mitigation measures.
Domain	
Policy making	Traditionally, wildfire risk policy frameworks tackle fire ignition control, direct wildfire prevention measures and wildfire suppression system. More recently, protection of wildland urban interface is being included. All this should be complemented with the necessary transverse approach dealing with social and physical vulnerability, including new spheres of policy-making regarding effective integration of wildfire risk into spatial and urban planning, or how to improve risk governance and societal involvement into DRR strategies.
Early warning system	Forest fires risk forecast at national/regional level offers a powerful tool for preventing risky situations. The necessary steps to update changing context of risk due to climate change and land use changes should be done. In case of extreme wildfire risk or event, communication and civil protection towards exposed populations is crucial to ensure their safety.
Disaster response	Changing context of risk are posing unprecedented wildfire behaviours in terms of intensity and velocity, which overcome existing suppression capacity and generate multi-emergencies, especially when forest fires interact with infrastructures and people. On that context, response has to be prepared to minimize the wildfire impacts, prioritising civil and societal goods and services protection, ensuring the safety of fire crews and the population exposed to risk. Increasing social awareness and individual self-protection capabilities, and reducing landscape vulnerability to extreme wildfire events are necessary steps linked to ensure an efficient response management. Lessons learned exchange and regular training can improve response efficiency at international level, moreover, when risk for wildfire extreme events is spreading in new areas across Europe.

3. Storm risk

3.1 General review and tendencies in the context of climate change

3.1.1 General review

Windstorms are a major disturbance factor for European forests. They originate from strong extratropical cyclones and most commonly occur in the autumn and winter months across the continent of Europe. The month with the most windstorms is January. On average, there are 4.6 windstorms per season.

The occurrence of windstorms cannot be prevented and their spatial distribution and intensity cannot be influenced. While the cycle of recurrence at a single location is long, the damages of major windstorm events affect large areas and can have disastrous environmental, economic, and social impacts. The disaster statistics of the European Forest Institute (EFI) attribute windstorms a 10%-share of overall forest related disasters, while these account for 75% of damaged timber volume. These high quantities of damaged timber volume have major implications for the forestry sector and downstream industries.

In a climate change context, the occurrence of storms is very likely to increase in frequency and severity across Europe. Projected changes in extreme wind speeds are indicated to rise in Central and Northern Europe, while slightly declining over the Mediterranean region. This is likely due to a poleward shift of mid latitude storm tracks. Consequently, areas that were previously untouched by severe windstorms will have to face this risk.

Additionally, there is an increase in the occurrence of local extreme weather events, such as heavy precipitation, hail storms, and tornados. However, compared to the impact of winter storms, the potential threat of these events for forests is substantially smaller. Nevertheless, the local devastation of these types of new weather events makes them worth to be considered. In the following, we concentrate on heavy winter storms as these are most relevant for the forestry sector.

The potential impacts of a storm event can be categorized in two groups: first, there is an immediate threat for human lives, objects, and infrastructure from falling trees during, or shortly after the storm event. This hazard is directly emerging from the forest. Second, there are long-term damages, notably from losses in timber value, as well as clean-up and recovery costs. In order to prevent damages, and better manage those that cannot be prevented, it is important to address storm hazard proactively and prior to the event. Therefore, efforts should be focussed on the preparedness and prevention phases within the risk management cycle to effectively mitigate impacts and avoid damage.

Increasing both, forest resistance and resilience capacity offers solutions at the stand - and forest level. Long-term silvicultural measures, such as forest conversion towards mixed forests with site-adapted tree species have proven useful to increase forest resistance to storms, while short-term technical prevention is impossible or not feasible.

Addressing storm risk at the enterprise and policy level is an even more effective risk reduction strategy. The integration of risk management into a forest enterprise's management and planning helps to proactively address storm risk and increase the preparedness. Coming up with clear procedures and a preliminary operation plan for the emergency case, as well as establishing a network of experts, who can be contacted, increases the overall resilience of the enterprise.

The rare appearance of catastrophic windstorm events makes it difficult to create constant awareness about this natural hazard and to establish a social risk culture among forest owners and citizens. Regularly, following a storm event, premature actions aiming at overcoming the most visible effects as soon as possible, causes injuries and casualties among forest workers and private forest owners. Consulting external experts and investing in proper planning and professional disaster management, can prevent common mistakes and ultimately avoid casualties and injuries. Once the emergency state is over, restoration management should focus on avoiding secondary direct effects, such as bark beetle outbreak.

3.1.2 How other natural hazards are affecting storm risk management

Depending on the type and intensity of the hazard event preceding the storm, various risk interaction effects emerge. Generally, the interaction of two hazard events largely depends on the intensity and time interval between both. Stands that have been previously affected by another hazard contain weakened or dead trees, which in case of a storm tend to fall easier. This poses an immediate risk for people in the forest, such as hikers and forest workers, as trees may fall unexpectedly at low wind speeds. A particular situation for risk interaction is the simultaneous appearance of two hazards. The interactions of risks combined with climate and land use changes, can generate new and unprecedented type of hazards.

An examples for a cascading risk interactions are avalanche events followed by a severe storm event. Vertical avalanche tracks create sharp edges in the affected forest stands downhill. These offer ideal structures for wind to enter a stand and ultimately increase the storm risk. Additionally, stems and roots of trees may be damaged, which makes them more susceptible to breakage and uprooting. Furthermore, accessibility of the terrain is limited by remaining avalanche debris. The consequence is a loss of the protective function of the forest, which ultimately increases the risk of new and more severe avalanches.

In economic terms, stands previously affected by fire show a reduced wind storm risk, as the value of wood has already drastically decreased with the preceding fire. The following storm event can increase the economic damage only by a small share. Moreover, firefighting may require to cut fuel breaks in forest stands, which, depending on their orientation to the main wind direction, creates sharp edges and funnel effects. In consequence, the remaining stands become more susceptible to storms.

In contrast, fire can also stimulate natural regeneration and increase nutrient availability, which leads to a more diversified stand structure and ultimately reduces storm risk.

Flooding prior to a storm results in wetting of the soil, which reduces the anchoring capacity of tree roots and overall stand stability. Depending on the duration of flooding, roots and entire trees may die off, which further reduces stand stability. Additionally, soaked roads and trails can reduce the accessibility of the terrain. In case of a storm event, this limits the ability to act during the response and recovery phase and increases damage.

In case of a storm event prior to another storm event, the risk is generally reduced, as susceptible trees already fell and the surviving trees are more tolerant to wind. In economic terms, most of the damage has occurred and the value of the remaining timber is significantly less than in an untouched stand. However, interaction of both storm events largely depends on the intensity and timing of both. A small and local storm event following a severe and large-scale storm event will have other implications than the other way round.

3.2 Risk management achievements and challenges

3.2.1 Risk and vulnerability assessment and mitigation

I) Achievements

Assessing risk and vulnerability provides necessary information to take active risk management decisions and identify successful mitigation measures. Within the project several tools and best practices have been identified and developed that help to directly or indirectly identify risk for a specific area.

An innovative risk assessment approach is the "Goal oriented risk management with the ICE (Influence-Change-Exposure) method"[5], which has been developed by the Forest Research Institute (FVA) in Germany. It is a criteria-based risk assessment, where the overall risk is formed by the three risk components: hazard, vulnerability, and exposure, as described in the IPCC SREX report. The method is centred around the idea that different management goals require different measures since the vulnerability and exposure of a forest enterprise is dependent on those goals. Applying this concept enables forest owners and enterprises to assess their individual risk factors, based on individual management goals and priorities. The ICE method also served as an underlying principle of the Risk Interaction Matrix, which has been developed within the NetRiskWork project.

The Risk Interaction Matrix aims at identifying existing and novel risk interactions. The applied harmonized risk assessment approach (i.e. goal oriented risk management method), allows to analyse and compare risks across different natural hazards (wildfire, storms, avalanches, and floods) independent of scale and location. In a first step, systematic single-risk assessments are conducted for each forest risk. In a second step, these are merged and new types of risk and interlinked relations of risk identified. In the course of the project, 23 single risk assessments and 26 risk interaction assessments were conducted and the method further refined. Assessment sheets and a self-explaining guideline can be downloaded from the NetRiskWork project website.

Tree species suitability maps are a decision support tool to help forest managers selecting tree species adapted to future climatic conditions. These maps have been developed for the German federal state of Baden-Württemberg and indicate the suitability of four tree species (i.e. Norway spruce, European beech, sessile oak, and silver fir) in a future climate scenario (IPCC scenario B2). Selecting site- and climate-adapted tree species helps to reduce the storm risk and is an effective mitigation strategy. A similar concept, is the German online portal "KlimafolgenOnline" (transl.: ClimateimpactOnline), which visualizes the changing climate conditions and their impact on land use sectors for different climate scenarios. Being able to identify changes in future growth conditions today, helps to prevent hazards and mitigate risk in the future.

Exchanging expertise and knowledge on risk assessment and mitigation measures related to storm risk has been a key activity within the project. Several Exchange of Experts (EoE) on risk management in general and storm risk specifically took place. Another successful case of cooperation connected to storm risk, has been the European Forest Risk Facility (FRISK) assistance following an ice sleet / snow break event in 2014 in Slovenia. German experts provided their experience in the management of crisis response, which they acquired during two major storm events and consulted their Slovenian colleagues.

[5] Method description available in Deliverable nº4 – Report on tools and best practices on risk planning and management for fire, storms, floods and avalanches

Generally, the analyses of past storm events offer valuable insights in the occurrence of storm damage. This has helped to improve risk management and to develop measures and methods that can help to mitigate future storm damage. Sharing and exchanging this knowledge is crucial. The recently established FRISK fulfils this task through its principles: connect-collect-exchange.

II) Challenges

Assessing the storm risk faces difficulties, as the hazard itself, in particular its return period, the potentially affected area and location, and its intensity, cannot be influenced and is highly variable. However, the risk components vulnerability and exposure can be influenced. Therefore, measures that aim at mitigating and preventing risk should focus on these two components.

Storm risk assessment and mapping are mostly based on the calculation of complex hazard indexes and require high levels of computation and accuracy of the risk modelling process. Typical outputs on maps, indicating colours according to the danger level have to be strongly rigorous, as information must be credible and trustworthy for building up confidence with the risk managers. However, despite all modelling efforts no comprehensive storm risk model exists. As most determining factor “tree height”, has been identified, which in combination with soil conditions can produce a satisfactory storm risk map.

3.2.2 Cost-effectiveness assessment

I) Achievements

Cost-effectiveness assessment evaluates measures according to their cost of implementation and effects of risk avoided. This enables forest managers, forest owners, as well as politicians to identify the most effective activities and to take deliberate decisions. The outcomes are measured by their qualitative effects and not in monetary terms. Experience shows that most resources are made available and spent directly after a catastrophic storm event. The general paradigm is to respond quickly, initiate the recovery and move back to a business as usual state. This approach follows a short-term logic and focusses on the response and recovery phase of the disaster risk management (DRM) cycle. In such a case, conducting a cost-effectiveness assessment can help to identify viable long-term alternatives, which initially might be more expensive, but will help to mitigate and avoid damage in the long run. These measures focus on activities in the prevention and preparedness phases of the DRM cycle.

The KoNeKKTiW project[6] (Competence network climate change, crisis management and transformation in forest ecosystems), funded by the German Forest Climate Fund, aims at sensitizing forest owners and managers to climate change related forest risks in German speaking countries. At the core is a Community of Practice of 17 partner organizations, with the common understanding that proper risk management above all needs risk aware actors. Providing target group oriented cost-free information activities and case specific consultation stimulates a structured risk assessment process. Conducting cost-effectiveness assessments is among these measures. Ultimately, it equips forest manager with directly applicable knowledge to take well-reflected decisions and coordinated actions to reduce storm risk.

The Storm Handbook offers a web based collection of best practices and guidelines for coping with storm damaged timber. While the content is not limited to a specific region, it is only in German language. The collection of instructions, checklists and leaflets encompasses the whole process of coping with storm

[6] Project description available in Deliverable nº4 – Report on tools and best practices on risk planning and management for fire, storms, floods and avalanches

damaged timber and provides basic information on how to handle the crisis in a well-equipped, calm and efficient manner. It also introduces the user to a prioritisation process of activities, which follows the logic of the cost-effectiveness assessment. Subsequently, the crisis manager can objectively decide, what tasks she should delegate or do by herself and for which activities she should consult or hire experts. This approach not only increases the efficiency of handling the crisis, but also reduces stress and prevents accidents.

II) Challenges

Cost-effectiveness assessments offer a powerful tool to evaluate the effectiveness of a broad variety of measures for risk reduction. However, while it is beneficial to not limit the analysis to monetary outcomes, it can still be challenging to compare the effects of different activities on the overall storm risk. These stretch across different implementation levels (forest, enterprise, policy), phases within the DRM cycle (response, recovery, prevention, preparedness) and time horizons (short-term, long-term), which still need to be considered.

The cost-effectiveness assessment approach offers a seemingly objective way to measure the effects of different activities. However, it would be wrong to simply choose and implement the activities that are identified best performing. Instead, it can provide useful insights on the effects of different measures and help the risk manager to arrange a case specific mixture of risk reducing activities.

At the enterprise level, sources of income should best have very diverse properties, in order to not depend too much on just one stream of income. Following this portfolio theory can help to spread the risk and is commonly applied in other sectors (e.g. finance, insurance, investment). Within the forestry sector, it is still quite new and not widely applied.

3.2.3 Risk planning, governance and policy framework

I) Achievements

Risk planning is closely linked to the set management objectives. The fundamental idea is that risk cannot be completely avoided. However, addressing risk proactively in planning and management can already help to mitigate potentially harmful consequences. For storm risk in forests, risk planning includes mostly measures from the prevention and preparedness phase of the DRM cycle, such as diversifying stand structures or developing a crisis management plan. Adapting management goals to the risk situation can also be a way of reducing risk. For instance: storm risk in forest stands (with objective wood production), is mostly influenced by the overall tree height. Lowering the maximum height of trees by reducing the length of the rotation period, while achieving similar target diameter, will imply a change in silvicultural treatment (i.e. more intense thinning) and ultimately reduce storm risk. To integrate risk planning in the regular management, it is important that forest managers have access about state of the art risk reduction strategies.

The KoNeKKTiW project (presented in detail in the previous section) aims at transferring existing knowledge into directly applicable knowledge, which practitioners often lack to find. The German speaking platform WALD-WIKI (Eng.: FOREST-WIKI; planned launch date in 2019) is a wiki for private forest associations and practitioners that enables them to generate and share expertise and empirical knowledge on climate change, crisis management, and transformation processes in forest ecosystems. Both projects are good examples that aim at sensitizing forest owners and managers to include aspects of risk management in their planning.

However, risk planning also needs to take place at a governance and policy level to set the necessary framework and provide security for the state of uncertainty. Following a major storm event, such measures can include direct subsidies or tax reductions for affected forest owners to cover short-term losses. In the long-term, this can be setting up funds and research projects that identify underlying drivers of risk and develop risk management strategies for the affected sector. Promoting the exchange of experts (EoE) at national and international scale is another method to benefit from the experience of others. The FRISK Assistance in Slovenia is a successful example for such a EoE. Government officials and members of the national forest administration could learn from the expertise of their German colleagues.

II) Challenges

Risk planning remains a complex issue and climate change adds even more uncertainty. To stay proactive and not become driven by responding to and recovery after storm events, it is important to address all phases of the DRM cycle. A particular emphasis should be on long-term prevention and preparedness activities. However, this may collide with the preference of politicians for short-term actions with visible results to increase their own popularity.

Natural hazards do not stop at a country's border. Therefore, cross border exchange and international collaboration on risk management need to be fostered. However, national legislations and different administrative responsibilities may hinder this development.

3.2.4 Community involvement and risk communication

I) Achievements

Involving society in risk management planning and decision making is unavoidable and should be actively encouraged. The most affected stakeholder groups of forest related storm risk are private forest owners, forest managers, forest workers, and the saw mill industry. Engaging with these groups can help to change their risk perception and generate acceptance for the implementation of risk management activities.

The KoNeKKTiw network is an exemplary project, which aims to educate forest owners and forest managers about the complex issue of climate change and to offer directly applicable knowledge to implement risk management aspects into their daily routine. The key idea is that there is already a sufficient knowledge base on risks driven by climate change, but adaptation actions fall short of this knowledge. Stimulating exchange and discussions across stakeholder groups, as well as sharing practical insights with each other are at the core of the project. The partner organisations itself, officially form a community of practice (COP) and seek to constantly update one another on latest scientific findings and adapt their offers to what is needed and requested.

Another successful concept of risk communication, is the German online portal "KlimafolgenOnline". There, interested users have access to visualizations of the impact of different climate scenarios on land use sectors. Being able to identify changes in future growth conditions today, helps to prevent hazards and adapt to risk in the future. With this tool, land managers and forest owners are actively engaged and can educate themselves.

The devastating power of windstorms is made accessible to a broad audience in a forest educational trail in the Northern Black Forest region. The so-called "Lothar-Pfad" (Engl.: Lothar path) has been established

on the site of a vast wind throw area following the catastrophic winter storm Lothar in 1999. The self-guided trail informs visitors about this particular storm event, as well as general effects of storms on forests and generates awareness for storm risk. The area has been protected and left to natural succession.

II) Challenges

Due to the long return intervals of storms, it can be challenging to maintain a constant level of awareness for storm risk in society and even among forest owners and managers. Storm events are not considered as normal, but as one-in-a-lifetime catastrophic event. This mentality needs to be overcome in order to integrate storm risk into the general management and activate resources for long-term prevention and preparedness measures.

Among politicians, following a hazard event it is also popular to focus on short-term activities, as then the public attention for the topic is high. Long-term risk mitigation strategies are less attractive to be addressed and implemented.

3.2.5 Civil protection, emergency and post-disaster management

I) Achievements

Protecting human lives, infrastructure, and objects during and following a natural disaster event is one of the main goals of DRM. Characteristic for storm events is the relatively short time span during which the hazard takes place, with local differences in intensity and destructive potential. During the storm an immediate threat emanates from falling trees. Following the storm, the first priority is clearing critical infrastructure, which drastically reduces the danger level for the general public. Areas adjacent to or within forests, however, remain at a high level of danger. Therefore, the local authorities usually issue warnings and limit access to affected forest stands. The weeks after the storm, the danger of falling trees decreases gradually with progress of clearing most infrastructure. However, forest workers involved in the clean-up process are particularly at high risk and regularly suffer from accidents and even casualties. The emergency and response phase, require a well-structured coordination and crisis management, to limit and avoid secondary damages.

The European STODAFOR project[7] developed a technical guide with best practice for first measures after storm events. It specifically addresses the needs and questions of foresters and wood-industry managers facing storm-damaged forests. Key aspects are the description of safe harvesting systems and log storage and conservation methods to mitigate economic damages.

Similarly, the Storm Handbook offers a web based collection of best practices and guidelines for coping with storm damaged timber. In particular, it provides information on how to handle a crisis in a well-coordinated, calm, and efficient manner. It also introduces the user to a prioritisation process of activities and the identification of critical bottlenecks. Having this information at hand increases the efficiency of handling a crisis and reduces stress of the involved personnel and prevents accidents.

[7] Method description available in Deliverable nº4 – Report on tools and best practices on risk planning and management for fire, storms, floods and avalanches

II) Challenges

Within the DRM cycle the response and recovery phases often receive most public attention and resources. The hazard has happened, the devastation is visible and immediate action to respond and recover from such a shocking event is started. However, and in particular in case of storm damage, most of the damage occurred within forest stands, away from urban centres and therefore not visible and of interest for most of the public. The full extent of the damage usually only becomes tangible a few weeks after the event. This poses challenges of affected landowners to receive financial support. Additionally, there are long-term damages from losses in timber value, as well as clean-up and recovery costs.

In order to prevent damages, and better manage those that cannot be prevented, it is important to address storm hazard proactively and prior to the event. Therefore, efforts should be focussed on the preparedness and prevention phases within the risk management cycle to mitigate impacts and avoid damage.

3.3 Sendai and Disaster Risk Management Framework

SENDAI	**STORM**
Priorities	
#1 Understanding disaster risk	Raising awareness and create understanding for recent and future climate change related developments of storm risk among directly affected stakeholder groups (i.e. forest owners and forest managers) through trainings, presentations, booklets, online media, etc.
#2 Strengthening disaster risk governance to manage disaster risk	Learning from past experiences, failures and successes with storm risks. Share the insights and gained knowledge through networks of all levels (i.e. forest, enterprise, policy). Understand particularities of storm events: long return periods, high damage potential, large areas affected.
#3 Investing in disaster risk reduction for resilience	Long-term solutions are more effective than short-term fixes. Accept storm as the dominating natural disturbance regime in Central Europe. Identify what makes forest resilient and integrate it in management.
#4 Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction	"After the storm is before the storm"– preparation never stops. Develop crisis management plans that are regularly reviewed and adapted. See storm as a chance for change, to adapt species composition and diversify stand structure.
Targets	
Reduce global disaster mortality	Mortality related to storm risk in forest is comparably small. Particularly forest workers and private forest owners are exposed to high risk during the clearing phase, immediately after the event. Raising awareness, offering specific trainings and stricter work safety regulations helps to further reduce accidents and casualties.
Reduce the number of affected people	Only people directly affected that are in or adjacent to forest during the storm. Depends on risk communication and awareness in public. Local authorities can issue warnings to keep people out of the forest.
Reduce the direct disaster economic loss	Direct disaster economic losses of storm from devaluation of trees and premature felling are marginal. However, the indirect economic impacts originating from decrease of timber prices and an oversupply of wood are severe. Also enterprises not affected by the storm can be indirectly affected.
Reduce disaster damage to critical infrastructure	Critical infrastructure running through forests or adjacent areas is affected. Stricter minimum distance regulation for new constructions and existing infrastructure can lower risk.

Increase the number of national and local disaster risk reduction strategies	Beside storms, other and new types of hazards affect forests, particularly in a climate change context. Disaster risk reduction strategies for forests should therefore address all types of hazards.
Enhance international cooperation to developing countries	Extratropical winter storm events are particular for Central and Northern Europe. The benefits and possibilities of cooperation with developing countries are limited. However, within Europe, experience and knowledge is shared vividly.
Increase availability of and access to multi-hazard early warning systems and disaster risk information and assessment	Predictions of meteorological services of maximum wind speeds are quite precise and publicly accessible. Warning systems exist. However, there is no possibility for a direct influence on the storm event.
DRM	
Cycle phase	
Prevention	No possibility for direct influence on storm events. Measures in the prevention phase most effective for long-term damage mitigation. No short technical prevention possible or feasible, only long-term silvicultural measures are useful.
Preparedness	No possibility for direct influence on storm events. Actively address potential risk and develop crisis management plan before the hazard happens. Perform crisis management gap analysis and identify own strength and weaknesses. Be clear about internal expertise and capacities in case of a crisis and get to know external experts that can be contacted. Training of own forest workers and staff.
Response	Most dangerous phase. Accidents and casualties due to fast progress in salvage logging activities instead of proper planning and professional management. Consult external experts for guidance and increase of professionalism. Focus on the avoidance of secondary effects.
Recovery	Well-coordinated planning and strategic management needed not maximum velocity to go back to business as usual. Thorough analysis of what has happened and why stands fell. Consult latest scientific findings to identify suitable and climate change adapted tree species to create future resilient forests.
Domain	
Policy making	Activities in the policy making domain related to storm risk focus greatly on short-term measures of the response and recovery phase. Following a hazard event, the public attention is high and politicians want to show their support. Long-term risk mitigation strategies are less attractive to be addressed and implemented.
Early warning system	Meteorological forecasts for storms and maximum wind speeds are quite reliable and advanced in Europe. Early warnings are issued by local authorities and media to inform people not to expose themselves to falling trees.
Disaster response	Fast progress in salvage logging activities following a storm event regularly lead to accidents and casualties. These could be easily avoided by calm and strategically planned response activities.

4. Flood risk

4.1 General review and tendencies in the context of climate change

4.1.1 General review

Floods have become more severe during last decades. Generally extreme weather events are expected to increase in likelihood and intensity as a result of climate change, that contribute to an increase in likelihood and adverse impacts of flood events. Pluvial floods and flash floods, which are triggered by intense local precipitation events, are likely to become more frequent throughout Europe. However, quantitative projections of changes in flood frequency and magnitude remain highly uncertain.

Beyond present effects, most of the consequences of global change are at mid- to long-term time scales, and not all impacts of climate change, for instance, are already visible. The potential time lag of risk effects due to global change is not yet integrated into disaster risk reduction (DRR) strategies, as so far commonly the social focus is more on what is happening now.

In terms of social and economic impact, flood risk is probably the most important natural hazard at EU level, as the distribution of floods is normally situated in areas with more human activity (urbanisation, industry, agriculture or strategic infrastructures). Hydrogeological and hydraulic risk is as a consequence not only a natural one, but also a «human-induced risk» and social processes are consequently not negligible in risk hydrogeological assessment. Increase of exposure caused by urban sprawl and inappropriate territorial and urban managements are key causes of hydrogeological and hydraulic risks: urbanization takes to land use changes near rivers, and seems at least as important as climate change in terms of consequences on the modification of disturbance regimes and natural hazards impacts.

Managing flood risk implies the adoption of a combination of structural and non-structural measures. Forest plays a crucial role in the regulation and mitigation of flood risk in flood plains and upstream regions. In fact, among the major ecosystem types, forests have a large potential for water retention. Forests retain excess rainwater and help to moderate run-off patterns, preventing extreme run-offs. This in turn reduces damage from flooding and also helps to mitigate the effects of droughts.

In a changing risk context, however how detailed our management strategies may be, flood risks can never be reduced to zero: it will always be a risk of flood that can only be reduced to an acceptable level.

Finally, there is a lack of collaboration and a feeling of competition for resources between agencies and researchers: egos and hierarchy are constraint to network building.

4.1.2 How other natural hazards are affecting flood risk management

We know a lot about flood risk: many flood studies have been conducted in several European countries, and various methods to forecast and manage floods have been developed to reduce risk. However, there is still uncertainty about the many interacting factors that influence an event - water retention capacity, runoff reduction, magnitude of stream flows, that highly depend on pre-event groundwater levels, site conditions, and also, forest type - and how these factors are changing in time, and the consequences of a flood if it occurs. Extreme events increases, with a flood-drought cycle characterized by periods of severe drought followed by extensive flooding. In this sense, as climate change will have important

effects on the composition and development of forest communities, this will also change the water retention capacity of forests with all its consequences.

Many cases of cascading effects of risks, notably between forest fires and floods / flash floods are recorded in dry Mediterranean regions (for instance Spain, South east of France, Sardinia). The plant cover removal, caused by a wildfire, increase run off speed and erosion.

In Atlantic and Northern regions, with peatland ecosystems, in case of a medium-intensity fires and smouldering fires followed, from weeks to years, by flood (short and mid-term rains) the risk increases. In fact, less capacity for water storage in short and mid-term increased likelihood of run-off and floods and ashes deposits (including minerals for plants) are leached with massive rains, leading to contamination of water in streams and rivers. On steep slopes management measures for reducing erosion and run off reduces the impacts of floods.

For mountain areas an examples for a cascading risk are avalanche events followed in short terms by flash flood. Avalanche damages the forest cover, and exposed the mineral soil to the flash floods. Forest located in north slopes are more vulnerable to dry / powder avalanches (the greatest destructive events). The consequence is the loss of the protective function of the forest, which increases the risk of more severe flash floods.

4.2 Risk management achievements and challenges

4.2.1 Risk and vulnerability assessment and mitigation

I) Achievements

Across Europe, for floods risk mapping, the common standards are based on experiences and data from past incidents, geography/morphology of the terrain, and the frequency of an event. One of these common standards is the definition of “flood return period”.

Knowing the stochastic occurrence, distribution, and intensity of floods offers significant advantages for risk mapping and allows to connect the benefits of prevention actions compared to avoided risk impacts. For this reason, vulnerability mapping and flood risk assessment is less contested compared to other risks and this can lead to a better acceptation to the mitigation measures proposed.

With reference to the flood mitigation, it can reasonably be said that this action cannot be absolute and must be ensured through the competition of structural measures, such as protective works (e.g. levees), and measures of a non-structural nature, among which the monitoring, forecasting and management of the emergency in a key role plays a key role full case.

The strategies of hydraulic defence are changing in favour of one more modern engineering approach to hydraulic risk and a more correct management of the systems fluvial: while in the past the soil defence policy was basically based on the works structural changes, the most recent trend is more oriented towards non-structural measures, attributable to knowledge and study actions, active maintenance of the territory, redevelopment, relocation, monitoring and prevention.

The Netherlands is well known for its long history and tradition of water management and flood defence, with strict safety standards, dedicated forms of governance, regular safety assessments and engineering. After the 1995 flood was adopted the National “Room for the River” flood policy Programme, to give

back more space to the rivers in order to reduce the risk of flooding. The goal of the government programme (34 projects, 2,2 billion euro, realised 2008-2017) was to create more room for the rivers to address flood protection, master landscaping and be able to safely process higher water levels. At more than 30 locations, measures have been taken to give the river space to reduce flood risks (new high water gullies, river city-parks, dike relocation, floodplain with agricultural use, removing obstacles, new bridges that replaces dikes, etc.).

II) Challenges

Effects of flooding in plains can be modified, if prevention measures are developed (flood-pools) along the river course at long distance before the impact area.

Once the hazard has hit, prevention and preparedness actions are crucial for limiting the impacts and reducing the risk. In such an interconnected system, in case more efforts are done during the prevention stage, less efforts are necessary during the response phase, and if needed can be complemented by an intermediate preparedness stage. Therefore, risk mitigation measures must be based on a good understanding of the functioning of hydrogeological risks, putting more attention to the underlying factors of the "hazard build-up process".

A paradigm shift is necessary, setting priorities according to social values and implying socialization of risks (from "protecting everything" towards "protect the crucial"). Meanwhile the guiding question could be "what value does society place on this landscape, what have to be preserved and why"? More and more, civil protection issues seem to be a strong criterion for risk planning at spatial/urban level. For this reason, plan for mitigating flood risk should prevail over the plans and sectoral programs at municipal, provincial and regional level as it is aimed at the safeguarding people, assets and activities from hazards and hydrogeological risks.

High rates of uncertainty and complexity posed by climate change combined with land uses changes is a main concern for efficient risk planning and forest management, and complicate the implementation of proactive prevention measures. In principle, there is more capacity on reducing unknown effects of land use change, than improving ecosystem resilience towards climate change consequences. Including these high rates of complexity and uncertainty into decision support tools through different scenarios and establishing a dialog between risk managers and society can help to increase the robustness of decision making processes.

The three risk components (hazard, vulnerability, exposure) should be always taken into account in risk assessment and mapping and form an integrative approach. Although it could be a long and expensive process that is not easily updatable, the visualisation of trade-offs between prevention-preparedness-response and recovery efforts improves technical and social acceptability in decision making processes, while offering better cost-efficient solutions.

One successful methodology to increase and to improve the response to new risks should be the organization of expert exchanges, training events, workshops, and delivered mutual support, across Europe and in the world. New risks in non-traditional areas (e.g. wildfire in Northern Europe) can be faced through the exchange of experts and professionals from the South of Europe that are used to work on the emerging risk come back with a lot of confidence.

Independently of the event's magnitude, analysis and reflection afterwards can offer useful information for improving risk management. Collecting data and lessons learned of low impact hazard experiences,

could help to ensure a better analysis of high magnitude and impact events, as in such situations there is normally no capacity to collect and analyse the experience.

To manage the residual risk appropriately, and also to deal with the uncertainty associated with changes in climate, flood risk awareness measures are needed to substantially limit exposure of life and property to flooding over time.

In general, also in the field of flood risk and emergency management, most of the potential risk interactions under global change scenarios are not fully considered within the national/regionals risk plans. A holistic, integrative and multidisciplinary approach within the public bodies (commonly segmented on different administrative competences), complemented with participatory approaches, should help to deal with increasing risk complexity and uncertainties.

4.2.2 Cost-effectiveness assessment

I) Achievements

The European Flood Directive 2007/60/CE has stated that the flood-risk evaluation should include a cost-benefit analysis and an integrated decision-making process to help Authorities to optimize in planning new flood control works and in defining operating rules for risk management.

An applying example for cost-effectiveness assessment of flood impact has been conducted by the University of Cagliari to determine a water depth damage curves using the database of claimed refunds after floods registered in Sardinia in October 2008 and November 2013. The study, an example of application in the Mediterranean that could be useful for comparing with other EU contexts, is focused on the evaluation of the direct component of the tangible flood damage by applying the water-depth damage functions.

The IDEA project[8] propose valid tools to the public administration to carry out a more cost-benefit risk management: first, selecting and meeting relevant stakeholders responsible for damage data collection and management; analysing the already available data and completed as much as possible; selecting specific and relevant case studies; identifying what were the main drivers of the disaster according to forensic analysis. Finally, providing the logic architecture of an information system enabling stakeholders to carry out the activities of forensic investigation, compensation to victims and reconstruction, and pre-event modelling using improved damage data.

II) Challenges

Cost-benefit assessments can be valid tools to show there is the need of planning and raising awareness and preparedness. Cost-benefit analysis is in fact a good way of convincing people, since the risk culture is more developed when property comes into play. In general, risk assessments are often done by insurances companies, just focusing and covering the physical, but not the social damages caused by disturbances. All in all, there is still work to do in integrating vulnerability assessments into insurance accountability as a means of motivating social awareness and own responsibility in managing risk.

[8] Project description available in Deliverable nº4 – Report on tools and best practices on risk planning and management for fire, storms, floods and avalanches

4.2.3 Risk planning, governance and policy framework

I) Achievements

Tragic flood events occurred in the past forced the necessary change at the urban planning and water management. According to the European Directive 2007/60/EC of evaluation and management of flood risk[9], Sardinia Region (Italy) has a special management Plan for mitigating flood risk in the region. The aim of the Regional Plan is to increase the safety of the people at risk, stabilize the cost of damage in short term (and reduce it in medium term), and increase resilience of the vulnerable affected territories of the Region. Therefore, this plan includes all aspects related to flood management, especially prevention measures, and prevention and protection in relation to flood events; all the measures are tailored on each hydrological zone of Sardinia. The plan contains all knowledge and information about flood risk in Sardinia, and is also useful for urban planning.

Water management is governed under each one hydrographical basin; watersheds are often under the management of different local and political authorities. As far as natural hazards dynamics follow physical boundaries, administrative boundaries should not be constraint to risk planning and management. When facing natural hazards in a globalized and interconnected Europe, the risk planning and governance cannot have a country's borders. In that sense, a valid example is the flood management in the Upper Rhine Region: Rhine control/situation centre near Khel (D) and Strasbourg (FR) is in charge of flood forecasting and control along the Upper Rhine to prevent flood damages downstream by restoring the retention capacity of the area alongside with increasing ecosystem adaption to flooding stress in the affected polder areas.

In Catalonia, the urban normative involves hydrological administration, municipalities, flood experts and flood risk officers, urban planners. The Water Agency, inside the Department of Territory and Sustainability, undertakes flood risk zoning and vulnerability cartography, framework for establishing the urban regulations. An official reference cartography is created and regulated into the urban regional law. The land is classified according to the flood risk: zoning is divided at different risk levels according to the "return period" (10, 50, 100 and 500 years).

II) Challenges

Successful emergency collaboration protocols at local-regional-national and cross-border levels should be extended to the risk analysis and planning phases, especially looking at the root causes of the risk up to the prevention stage. Natural hazards development, done following according physical criteria needs more cooperation at all administrative levels, nationally and internationally, for data sharing and homogeneous risk assessment, as well as mapping procedures based on geographic limits instead of administrative boundaries.

The focus tends to be on getting new plans and funding, but rarely on developing more integrative processes. This can be related to the "political cycle", which explains a preference of politicians for short-term actions with visible results, as well as structural measures being favoured instead of non-structural measures. Funding need also to be allocated to "invisible measures".

The inertia of the legislative process can be a constraint to develop risk management, as by the time the law or regulation comes into force and is being implemented, new solutions can arise and the addressed change might already be outdated. The rhythm of risk appearance and development is different than the

[9] https://www.regione.sardegna.it/pianogestionerischioalluvioni/piano/

political/legislative rhythm: a response and emergency new challenge in case of new risks or risk interactions is to change the legislation according new scenarios. This legislative changes are necessary to adapt the response and emergency capacity to real situation/scenarios.

4.2.4 Community involvement and risk communication

I) Achievements

The standardization of the alert messages for flood risk has brought the whole civil protection system to communicate better to the citizens. With the same language, in terms of colours, symbols, visual codes, all linked to an expected behaviour, people develop a memory of the messages after repeating events, and also across risks.

A valid example of risk communication is the Multiplatform alert system of Sardinia Region that deliver bulletins of meteorological and hydro-hydrogeological risk. The multiplatform facilitate the spread of alert messages, so Mayors can alert citizens quickly about potential risks and alert civil protection apparatus.

Best practice of community involvement is, in England, the action of Flood Actions Groups - National Flood Forum UK that help communities to prepare for floods risk, representing people at risk so that decision making accounts of local knowledge, common concerns and grassroots expertise were represented, and working to put flooding issues at the centre of policy making arena. Actors involved are citizens, local authorities, land planners, environmental departments of regional administration.

The project PRoNTI[10] ("Ready" - acronym for "Protection in your Island"), promoted by the Civil Protection of Sardinia Region in line with the Italian Civil Protection National Department communication policy, is aimed at the promotion of a multi-risk culture of prevention, training a more conscious citizenship and initiating a process that will bring in particular youth citizens to take an active role in knowing their environment and reducing the risks.

In The Netherlands, the already mentioned "Room for the river" Programme is a good example of measures designed with population, local actors and experts, that participate to the improving of the quality of their surroundings identifying problems, opportunities, possible solutions and policies, effects and means for realization and do it together.

II) Challenges

Due to social changes, people are less connected to the land and its dynamics, among which are also natural hazards, than they used to be. A deep social process is necessary to reconnect population to their natural environment and therefore develop consciousness, knowledge and concern, and finally encourage accountability and responsibility. Social sciences are central in that aspect.

There is a big gap in the communication between the emergency services and the citizens. Often risk for flood is not well communicated to the potential affected society, and neither one person has participated on a flood emergency drill. Not all the municipalities have already adopted flood plans, or have plans that are regularly updated: often local authorities make plans as requested by the law, but they don't really

[10] Project description available in Deliverable nº4 – Report on tools and best practices on risk planning and management for fire, storms, floods and avalanches

own the procedures that they have to apply in case an event occur. They are not well trained on the practical application of the plan. Population should be more involved directly to train how to react in case of flood and be ready and prepared to be put on flood risk. Intermediary (territorial) level can probably deliver a more effective communication, helping to fill the gap.

Participatory processes should be integrated into civil protection plan for floods as a core element for promoting the corresponding awareness and initiative based on the own risk mitigation responsibility.

Uncertainties posed by a climate change context can also be tackled through participatory approaches along the flood risk planning process. Societal participation offers also an opportunity to make the benefits of mitigation strategies in front of avoided costs of potential damages visible.

It is important to be open about the consequences of uncertainty for risk planning, communicating to the people that risk occurrence estimation is based on probability, and therefore is not possible to eliminate uncertainty. Forecasts are one thing; the operational aspects of the plan are another thing. If there is an alert and nothing happens, decision makers can be the object of many protests. This requires effective and honest communication between decision makers and the general public where the nature of the decisions and the strengths (and weaknesses) of the risk information are transparent and understood by all. It is necessary to act on the three levels of awareness to create such momentum: cognition, affect, and behaviour. As risk will never disappear completely, the introduction of the “acceptable risk” concept, which indicates the risk that people collectively and individually are willing to accept, is needed. There is no single simple recipe for communication and a collaboration and alliance with the media has to be found (journalists should be trained about the communication of risk, e.g. through workshops).

It is important to not over inform people: risk communication has to be clear, precise and understandable. Different narratives and frames are needed according to the target audience. Information need to fit people’s priorities. Being credible, inspired and confident are core elements of risk communication and awareness. Once again, close institutions or local actors can help in making the message more effective in changing attitudes.

Finally, in order to reduce the risk of floods to communities, economies and environments, it is important learn and not forget lessons from past floods. In that sense, it is important the reactivation of memory and the transfer of hazard memory from generation to generation, commemorating anniversaries (with activities at school, municipal civil protection simulation exercises, picture books, etc.), studying the names of geographical localities and cultivating memories to manage risks.

4.2.5 Civil protection, emergency and post-disaster management

I) Achievements

In the framework of the project PROTERINA 2, supported by the Interreg Italy-France Maritime European initiative, an experimental participatory approach for the update of the Municipal civil protection plan has been tested. The action was implemented in Quiliano, a municipality in the province of Savona. Outcomes of the process include, among the others: strengthened awareness raising procedures; efficient dissemination of information on existing risks through institutional and trustworthy channels; diffusion of adequate behaviour and self-protective skills among the population. The involvement of institutions, scientific institutions and citizens has granted a collaborative synergy of all involved stakeholders greatly increased community resilience.

Given the positive results of such procedures, which have been officially introduced in the current reorganization of the national Civil Protection system with the Legislative Degree n. 1 of 2018, the experiment of Quiliano can be seen as a good practice and an exportable model of emergency planning.

II) Challenges

Providing adequate information to citizens in relation to the different levels of risk of the territory, in such a way they will be aware and informed, is a fundamental issue. In fact, people don't know enough about risks and need to be trained regarding self-protection measures and self -protection assistance. Prevention actions and communication about risks are not deemed sufficient, and it's difficult to manage a crisis situation if citizens don't know what to do. The objective is not to convince: the priority should rather be on education and collective learning instead of an only-one-direction communication. It is necessary to work on awareness, avoiding top-down processes, with a paradigm shift from a top-down to a bottom-up approach and from authority to responsibility. People have to be part of the process to feel acknowledged; they have to trust in the action they can do by themselves. The results of the process were improved operational capacities, increased community awareness, collaborative synergy of all involved stakeholders, effective dissemination of Civil Protection culture, diffusion of adequate behaviour and self-protective skills among the population, strengthened awareness raising procedures. A new approach, more based on real skills and resources of the territory, together with an increased awareness of the community, will produce as a result self-protection and resilience.

The use of innovative technologies as improved the definition of multi-disciplinary scenarios and response plans, providing integrated assets to support emergency management, such as monitoring, modelling, situation and risk assessment, decision support and communication tools. Advances in technology (such as drones) and social media can lead to a more effective disaster risk information and assessment and an increased public awareness. However, technology can make things worse on the long run, because they can decouple people from reality. In the medium and long-term, social processes aimed to reconnect population to the natural environment and develop consciousness, knowledge and concern need to be encouraged and promoted.

Finally, also for the flood risk, windows of opportunity appear most of the time after a catastrophe ("the big one"). To make the most of this momentum, proposals and advice need to come quickly after the event, and therefore, should be prepared before. In case of events with smaller magnitude and higher recurrence, it might get difficult to open a real window of opportunity, though the cumulated damage over time may be higher.

4.1 Sendai and Disaster Risk Management Framework

SENDAI	**FLOOD**
Priorities	
#1 Understanding disaster risk	Is crucial to move from risk information to risk knowledge, building awareness of flood risk at all levels, with the participation of civil society, scientific community and private sector through sharing experiences, lessons learned, good practices and training.

#2 Strengthening disaster risk governance to manage disaster risk	The focus should be on developing more integrative processes rather than getting new plans and funding, promoting technical cooperation, development of methodologies and standards for flood hazard and flood vulnerability monitoring and assessment. It is also important to develop common procedures for reviewing progress including systems for cost benefit analysis and ongoing monitoring of risk, including also the integration of tourism dynamics in flood risk management.
#3 Investing in disaster risk reduction for resilience	Structural and non-structural measures are essential to build a culture of safety and resilience at all levels. Review and periodically update flood plans and programmes considering climate change scenarios and their impact, with the involvement of relevant institutions and stakeholders. Investing in the mainstreaming of flood risk assessments into urban planning.
#4 Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction	The recovery, rehabilitation and reconstruction phases after a flood need to be used to increase the resilience of communities through integrating flood risk reduction measures into the restoration of physical infrastructure, and into the revitalization of assets and the environment.
Targets	
Reduce global disaster mortality	To more effectively protect persons and communities and strengthen their resilience it is necessary to raising awareness, anticipate, plan for and reduce flood risk.
Reduce the number of affected people	Join efforts to raise awareness and preparing against local flood hazards have to be promoted, in particular among young generation, equipping people with knowledge and skills that may potentially save their lives as well as avoiding emergency situation.
Reduce the direct disaster economic loss	For limiting the impacts and reducing the risk, flood mitigation measures, in particular socio-economic measures, need to be integrated into the local emergency plans. Mechanisms for prediction and early warning of disasters can be improved; maintenance should be the routine practice.
Reduce disaster damage to critical infrastructure	Given the EU and global interconnectedness, it as to be warranted an approach that enhance cooperation on the development of common standards and exchanging best-practices on protection measures involving all relevant EU partners and organizations. The balance of public interests in reliability of services (against the reduction of prices) must be managed.
Increase the number of national and local disaster risk reduction strategies	A strong commitment of political leadership and involvement of all stakeholders at all levels is required. The focus will be on governance, including integration of flood risk reduction and climate change adaptation into planning, addressing elements of capacity building and financial resources.
Enhance international cooperation to developing countries	Training and mobilising networks of experts, disseminating lessons learned and good practices, regular exchanges with, in particular, disaster-prone developing countries should be encouraged and strengthened.
Increase availability of and access to multi-hazard early warning systems and disaster risk information and assessment	In the short run, advances in technology (such as drones) and social media can lead to a more effective disaster risk information and assessment and an increased public awareness. In the medium and long-term, social processes aimed to reconnect population to the natural environment and develop consciousness, knowledge and concern need to be encouraged and promoted.
DRM	
Cycle phase	
Prevention	As more countries start feeling the effects of the climate change, prevention measures and flood control systems need to be developed, not only to prevent floods but also to combat droughts. In that sense,

	systematic data collection is crucial to address some of the challenges required.
Preparedness	Disaster preparedness plans need to be put in place at all administrative levels, holding regular training to test them. An increasing attention in the costs and benefits of funding preparedness and early action should be developed.
Response	The response phase can be better supported by governing institutions and agencies through greater sensitivity to on-going community-led responses, with attentiveness to the importance of community cohesion, for example, in evacuation protocols.
Recovery	The recovery, rehabilitation and reconstruction phase is a critical opportunity to operate back better, including through integrating flood risk reduction into development measures.
Domain	
Policy making	Making the flood risk reduction "everyone's business" through a more informed decision-making, gathering and involving a widening range of stakeholders and building an inclusive cross-sectoral approach at all level.
Early warning system	Forecast for floods are quite widespread and advanced in Europe. A challenge is to create a more comprehensive strategy and standard agreed upon by all relevant stakeholders to ensure effective governance, useful for the efficient delivery of early warnings
Disaster response	Common challenge refers to a better coordination between stakeholders and to the dissemination of relevant information in a hazard situation to all actors. Lessons from post disaster reviews should be reflected in policy.

5. Avalanche risk

5.1 General review and tendencies in the context of climate change

5.1.1 General review

The winter of 1950/51 is generally regarded as the starting point of modern avalanche risk management[11].

This risk management had a focus on technical protection through building of protective infrastructure in the avalanche release areas. A detailed analysis of the situation also led to the continuous collection of meteorological data and information on snow cover properties and traits. These are the basic ingredients of today's avalanche prediction.

Parallel to this, it was realized that sufficient avalanche protection can not only be delivered by technical, biological (protection forests, afforestation) and organizational measures, but that an additional instrument of spatial planning was required.

This led on the one hand to the development of the first avalanche risk maps in the Alpine countries and on the other hand it led to a legal framework that is describing the responsibility for "avalanche risk zoning" to keep endangered areas free of infrastructure.

Another milestone in avalanche risk management was the winter of 1999. Large parts of the Alps received more than 5m snow in a time frame of only five weeks. Switzerland alone recorded 1200 damage-causing avalanches, 17 casualties and a damage of 600 million Swiss Francs. An in-depth analysis of the situation led to the following developments in Switzerland (as well as other alpine countries).

> It was a three-month period during the winter of **1950–1951** when an unprecedented number of avalanches took place in the Alps. The series of 649 avalanches killed over 256 people and caused large amounts of damage to residential and other human-made structures. Austria suffered most damage and loss of human life with 135 killed and many villages destroyed. Thousands of hectares of economically valuable forest in both Austria and Switzerland, were also damaged during the period.
> The Valais canton of Switzerland suffered 92 human deaths, approximately 500 cattle deaths, and destruction of 900 human-made structures. As in Austria, economically important forests were also damaged during the period.
> The Swiss town of Andermatt in the Adula Alps was hit by six avalanches within a 60-minute period, resulting in 13 human deaths.
> This period is thought to be a result of atypical weather conditions in the Alps: high precipitation due to the meeting of an Atlantic warm front with a polar cold front resulted in 3–4.5 metres of snow being deposited in a two- to three-day period. More than 600 buildings were destroyed and over 40,000 people were buried under snow. (Wikipedia)

Technical and Structural Avalanche Protection

The extensive investments in the structural avalanche protection, which have been carried out since the avalanche winter of 1950/51, had proven in 1999 for the most part. The death toll was much lower in 1999 (17 deaths) compared to 1950/51 (98 deaths), despite the very high number of tourists in the avalanche situation. However, many avalanche barriers encountered their load limit. When reviewing the relevant guidelines for avalanche control, the extreme snow depths of winter 1999 were taken into account. The financially costly maintenance of existing structures is a major challenge.

[11] http://www.szf-jfs.org/doi/pdf/10.3188/szf.2001.0025?code=swis-site

Improved Early Warning and Crisis Information System

An intervention can only be initiated in good time if the observations on the ground are reliable and if appropriate warnings reach the responsible crisis units and avalanche services early enough. Here the event analysis of 1999 showed optimization potential. Therefore, the Early Warning and Crisis Information Systems were developed and further updated.

A central part of IFKIS (the Swiss Early Warning System) for instance was the daily feedback from the field observers on the current weather and avalanche situation.

A second important component of the Early Warning is a "Joint Information Platform" GIN. Security officers use this online platform to query early warnings, avalanche bulletins, and snowpack and weather data. GIN includes measurement and observation data, forecasts, warnings, models and bulletins. This gives security officers quick and clear information about important information.

In addition to the communication with the security officers, the communication of the security officers with each other is of central importance. Information on measures (road closures, evacuations) or events (avalanches) can be entered on this platform. This data then makes IFKIS immediately accessible to all participants.

Thanks to IFKIS and its successor systems, better integration of all involved stakeholders means that intervention measures can be initiated earlier and implemented more efficiently.

Progress in the training and organization of avalanche services

The uneven level in the organization and training of avalanche services proved as a weak point in crisis management in the avalanche winter 1999. As part of the IFKIS project, a training concept was developed by the SLF in cooperation with the FOEN and the mountain cantons. A checklist, for example, mentions all the points that must be set when organizing an avalanche service. The course program has meanwhile led to a significant advance in the level of avalanche training in Switzerland.

Development and implementation a risk concept

The avalanche winter of 1999 has once again shown that natural hazards cannot be completely avoided in alpine habitats. Despite significant investments in avalanche barriers or turf barriers, they continue to endanger people or destroy buildings and traffic routes. Safety experts have therefore started to rethink: Instead of preventing natural hazards by any means, today they try to reduce their risks. The National Platform for Natural Hazards PLANAT held in 2004 in its strategy that this concept of risk minimization should be the core element in dealing with natural hazards.

Better avalanche understanding thanks to research

An important contribution to the prevention of danger is provided by a hazard-conscious spatial planning, which respects the natural hazards and creates space for extraordinary events. Danger zone plans play an important basis. Information about the flow behavior of avalanches is required for hazard mapping and dimensioning of protective structures.

The better we understand the formation and flow processes of avalanches, the more accurate computer simulations can provide information about potential areas of rupture and danger zones as well as the necessary protective measures. The structure and spatial distribution of the snowpack have an effect on

the avalanche danger. We are investigating these conditions with a large number of new measuring systems and on different experimental surfaces. The results flow u.a. in the further development of the snow cover model Alpine-3D, which calculates from weather data how the snowpack in a region will be designed. The aim is to be able to use the model also for operational avalanche forecasting.

Protective Forests

In addition to the above mentioned tools and processes, the most important component of risk minimization is protection forest. They cover the majority of area, are natural, could be cost-free and also provide additional ecosystem services.

Around half of the alpine forest area has a protective effect in case of natural hazards. The protective forests prevent the avalanches from breaking through, stabilize slopes, stop rockfall and reduce the entry of wood and debris into channels. This is a prerequisite to enable people to live, work and move in the alpine landscape.

As the protection forest grows naturally, it is considered to be the least expensive and ecologically most valuable protection against natural hazards.

Protective forests are subject to a variety of abiotic and biotic effects. They are exposed to constant environmental changes. Man-made climate change is helping to improve the protection afforded to previously cold-constrained sites as the forest spreads and becomes denser.

In drought-limited protected forests, however, especially in the second half of the 21st century, the mortality of trees will increase. Greater losses with respect to the protective effect will also occur in connection with large-scale disturbances in the forest caused by fire, wind throws or bark beetle calamities.

Depending on the natural hazard process, the effects of climate change are different. Major avalanche protection functions are increasingly restricted to smaller areas and rarer events at lower altitudes, but remain significant until the end of the 21st century, at least in the subalpine stage.

Protection against rock fall, shallow landslides, and floods will become more important over the longer term relative to avalanche protection. The flood protection could be slightly improved by a climate-induced spread of the beech in today's coniferous forests.

By promoting pre-rejuvenation (natural tree regeneration) and a broad tree species spectrum adapted to the site conditions, the negative consequences of climate change for natural hazard protection can be counteracted. It is important that both forest and wildlife management as well as natural disturbances are used to adapt tree species composition to climate change and protection against the relevant natural hazards.

The avalanche protection effect of the forest is primarily to prevent the formation of avalanches. In addition, trees and other forest structures extract mass from an avalanche that has already been torn, thus reducing the range of small to medium-sized avalanches. Unfavorable for avalanche protection are, in particular, larger gaps and a low interception of the canopy, but also a low roughness. Such conditions prevail especially in higher-lying, snow-rich forests with larger forest gaps or dissolved degree of closure, possibly reinforced by the presence of larch (*Larix decidua*), as well as in deciduous and mixed forests, where a moistened snow cover with low surface roughness can directly "flow" on the ground.

On the one hand, climate change has a direct impact on the snow situation: the duration of critical snowpack should be shorter and the proportion of wet snow situations higher. On the other hand, climate-related changes in forest structure and species composition affect the protective effect of the forest. In the future, less powerful snow-packs can be expected at all altitudes. Forest avalanches (so-called forest avalanches) that occur in the forest occur, above all, at snow depths of at least 50 cm (measured in the open field

The number of days with such "critical" snowfalls is likely to be halved at altitudes of 1400 to 1700 m by the middle of the 21st century (compared to the reference period from 1983 to 2010), and down to probably only a few days at the end of the 21st century. In lower elevations below about 1400 m above sea level, as early as the middle of the 21st century, it is hardly to be expected any more critical snow packs in the forest. The higher temperatures will not be compensated by an increase in winter precipitation. Therefore, we assume that avalanche protection will remain important in subalpine forests beyond the next turn of the century, but at lower altitudes it will become less important than other forest functions.

Forest avalanches occur mainly during two typical snow and weather situations: Either after recent snowfalls in cold and often stormy weather conditions without stabilization of the forest snowpack by solar radiation (fresh snow avalanches) or after strong warming and sun radiation in wet snow cover (gliding and wet snow avalanches. While fresh snow forest avalanches are particularly characteristic of open and disintegrated mountain conifer forests of the subalpine stage, gliding and wet snow forest avalanches occur especially in deeper deciduous and mixed forests. Between 1970 and 2011, the number of potential forest avalanche days, that is, combinations of favorable snow and weather conditions, decreased for both types of avalanche and all considered altitudes.

In the case of fresh snow avalanches, a future further decline in the frequency of critical situations is plausible. At higher temperatures, the typical conditions for such avalanches with much cold, low-cohesion fresh snow are less likely to occur. In addition, vulnerable sub-alpine forests are often becoming denser due to their increased vigor. Nevertheless, we still have to expect such avalanches, at least in the subalpine stage. The proportion of wet snow and especially sliding snow avalanches is likely to increase compared to other avalanche types.

While wet snow avalanches occur at various elevations and exposures, gliding avalanches are most common in southwest to southeast exposed deciduous and mixed forests of the montane stage, where the snow may slip off when the snow cover is soaked and the surface warm and smooth. When it gets warmer, such conditions are increasingly to be expected even at higher altitudes, which is important silvicultural, as sliding snow avalanches slide in relatively narrow gaps directly on the forest floor with wet snow cover and low surface roughness and already a slightly increased roughness makes a major contribution to prevent it.

Therefore, the promotion of beech (*Fagus sylvatica*) and other winter-bald trees in typical gliding-snow avalanche release areas in higher locations is also problematic in the future. Probably the greatest uncertainties regarding the future avalanche deforestation forest are the effects of residual debris and deadwood after natural disturbances.

Our knowledge is to a large extent limited to observations and experiments in Vivian storm areas: Criss-crossing stems initially provided good avalanche protection. However, their resistance and effective heights had already been reduced to 40% of the original effect 20 years after the storm. With snow-packs with widths from about 1.8 m, such trunks can no longer withstand the occurring forces in every case.

That even in the first 25 years after Vivian, even in snowy winters, hardly any avalanches were released in the storm affected areas, suggests that the increased surface roughness is more important than previously thought.

Remaining trees, stumps and horizontal strains are particularly effective against sliding snow avalanches. For snow boards and loose snow avalanches in extreme snowfall and in addition with large amounts of fresh snowfall at higher altitudes, reminiscent trees and structures have to be seen more critical. Because of the limited data base, general statements about the avalanche protection effect on other disturbed areas are associated with great uncertainties.

It can be assumed that forest stands after smaller snow breakage and beetle damage act rather reliable against avalanches due to the longer-lasting protective effect of initially still standing trees compared to un-cleared storm felled areas. But, for example, large forest fires in which the so called advanced-regeneration and soil are destroyed, are dramatically reducing the protective effect of forests.

This is leading to the most crucial and critical topic when discussing protective forests: The natural regeneration and the continuous provision of so called advanced-regeneration. A forest is in a continuous state of renewing itself. In a balanced equilibrium of environmental factors these processes are cost-free and therefore a protection forest can be seen as the most cost effective measure for protection. However, across the forest landscape of the alpine region, we are facing high ungulate population densities, namely roe and red deer as well as chamois. They all use young seedlings as forage and their selective browsing is limiting the species composition of the natural regeneration. I a majority of the forest natural regeneration or artificial regeneration by planting is only successful with protection like fences against deer impact. This is especially true for the most recommended tree species, i.e. Silver Fir, Sycamore maple, Oak spec, or Larch. However, in mountainous terrain, fences are seldom effective over the required time period.

So, an integrated forest and deer management with a shared and commonly agreed objective is the key to successful management of mountain protection forest. This is putting hunting and the hunting policies in the focus now also of Civil Protection.

5.1.2 How other natural hazards are affecting avalanche risk management

In general, natural hazards are not affecting the protection function of structural and technical avalanche protection. The majority of area in the alpine countries however is protected by forests; we therefore focus here on the influences and inter-actions between natural hazards and the effect on avalanche protection forest.

Forest disturbances are among the most important processes that shape forest dynamics and landscapes. It is of Paramount importance to understand the dynamics of disturbance and their inter-connectivity.

Forest disturbances are amplified and accelerated by a changing climate in addition. The understanding of disturbance dynamics in response to climatic changes remains incomplete, particularly regarding large-scale patterns, interaction effects and dampening feedbacks. Climate change effects on important abiotic (fire, drought, wind, snow and ice) and biotic (ungulates, insects and pathogens) disturbance agents are of particular concern in mountain protection forests.

Warmer and drier conditions particularly facilitate fire, drought and insect disturbances, while warmer and wetter conditions increase disturbances from wind and pathogens. Widespread interactions between agents are likely to amplify disturbances, while indirect climate effects such as vegetation changes can dampen long-term disturbance sensitivities to climate. Future changes in disturbance are likely to be most pronounced in coniferous forests, the boreal biome and, again, in mountain protection forest[12].

Disturbances disrupt the structure, composition and function of an ecosystem, community or population, and change resource availability or the physical environment. Disturbance change is expected to be among the most profound impacts that climate change will have on forest ecosystems in the coming decades. Less synthetic knowledge is available on interactions among disturbance agents; and with this project we tried to address these knowledge gaps. Interaction effects are defined as inter acting and interdependent relationships between disturbance agents, such as an increased risk of bark beetle outbreaks resulting from wind disturbance (creating large amounts of effectively defenceless breeding material supporting the build-up of beetle populations) or drought (weakening tree defences against beetles).

With respect to avalanche protection, generally any disturbance by like fire, storm or bark beetle is seen as reducing the protection effect. This project researched the effects of different disturbances on the protection function and tried to describe if and how the effects are amplifying or dampening the avalanche protection function. Where in the beginning of the project we followed the general opinion that a damaged forest is consequently losing or at least reducing its avalanche protection effect, we found that the conclusion is by far not so easy and relations between disturbances are not linear and not always in the same direction.

If a disturbance by fire for instance has a positive or negative effect on the forest and its protective function has a number of variables to be considered. To describe and quantify if a disturbance has a positive or negative effect depends on time in the year, weather conditions, size and scale, on forest type, on previous forest management practices and to a great extent on post-fire or post-bark beetle or post-storm management. A further fact to be considered is for instance fire severity and to what extend mature trees, advance regeneration and soil functions are affected.

Small scale disturbance can also have a positive effect in promoting forest regeneration, better structure and age distribution, species composition. Again, one has to differentiate and analyse the dependencies of time and scale. If a small gap in the forest cover in the short term has positive effects on the forest, it might have secondary damages by bark beetle that reach a scale that have a negative effect on the forest. And if high deer densities have successfully removed all advance regeneration the negative effect can last decades before new forest cover can be established.

Remaining trees, stumps and horizontal strains are particularly effective against sliding snow avalanches. For snow boards and loose snow avalanches in extreme snowfall and in addition with large amounts of fresh snowfall at higher altitudes, reminiscent trees and structures have to be seen more critical. Because of the limited data base, general statements about the avalanche protection effect on other disturbed areas are associated with great uncertainties.

[12] Seidl, R., Thom, D., Kautz, M., Martin-Benito, D., Peltoniemi, M., Vacchiano, G., Wild, J., Ascoli, D., Petr, M., Honkaniemi, J., Lexer, M.J., Trotsiuk, V., Mairota, P., Svoboda, M., Fabrika, M., Nagel, T.A., Reyer, C.P.O. (2017) Forest disturbances under climate change. Nat Clim Change 7(6):395–402

It can be assumed that forest stands after smaller snow breakage and beetle damage act rather reliable against avalanches due to the longer-lasting protective effect of initially still standing trees compared to un-cleared storm felled areas. But, for example, large forest fires in which the so called advanced-regeneration and soil are destroyed, are dramatically reducing the protective effect of forests.

In this project we can conclude that there is no clear evidence in what direction the interacting disturbances are having an effect. As often in forestry, general rules have to be validated and tested against the local conditions to decide on the positive or negative effect, to decide if a disturbances are having good or bad consequences and how that assumption is changing over time.

We can also conclude that it is of paramount importance (not only for avalanche protection purposes) to have mixed-species, un-even aged forest stands that can regenerate naturally on a continuous basis. Having continuous regeneration and enough advance regeneration potential in a forest, the consequences of any disturbances are mitigated. This requires only two, but conditional, management objectives: silvicultural treatments must allow for enough light and structure to promote natural regeneration and deer densities have to be on a level that allow this regeneration to survive and to establish.

With regard to the vast extend and extreme protective value of mountain protection forest, these two management objectives should also be strongly supported and promoted by the Civil Protection Sector.

5.2 Risk management achievements and challenges

5.2.1 Risk and vulnerability assessment and mitigation

I) Achievements

Avalanches are one of the most significant natural hazards in the mountains. In countries like Switzerland, Austria, Germany and others, avalanche early warning was developed as early as 1945 and the public is informed about the current snow and avalanche situation.

One of the most important products for instance is the so called “avalanche bulletin”. It is an important planning and decision-making basis for local avalanche and security services, for winter sports enthusiasts and other people who are outside the secure areas in the winter mountains. A number of other products such as snow maps or weekly reports supplement or deepen the information on the snow and avalanche situation.

The avalanche bulletin has the character of a warning. It appears twice a day in winter and contains as the most important information a forecast of avalanche danger for the Swiss Alps, Liechtenstein and, if there is enough snow, also for the Jura Mountains. The avalanche bulletin can be requested via the internet as well as the mobile app "White Risk". In the summer avalanche bulletins are given out on a need basis.

Measurements, observations, assessments of avalanche danger on-site and modelling results - the avalanche warning service provides a wide range of data. Only the situation-based combination and evaluating of the individual values is enabling creating a reliable avalanche bulletin in all the different situations. Current information from the area are essential for this. For this purpose, the Switzerland for instance, maintains its own network of observers. The official observers are trained by the avalanche

warning service, report regularly and are compensated for their reports. Additional information comes from local security services, rescue organizations, police and, last but not least, winter sports enthusiasts.

II) Challenges

Forests as biological entities are constantly changing. Their properties are not constant over time, at least over a small area. Therefore, the long-term safeguarding of natural hazards through the forest is a significant challenge. This was already well known to the inhabitants of the Alpine valleys, as some forests were already protected in the Middle Ages; nevertheless, centuries of overuse led to widespread concern about the protective effect of the forest.

Since the end of the 19th century, the forest legislation (at least in Austria and Switzerland), the abandonment of agricultural management and intensive forest grazing and afforestation have led to the forest in the Alpine region having expanded considerably (+31% in the Alps between 1880 and 2004/06;) and overall, the protective effect of the forest has greatly improved. Protection forest management has contributed considerably to this.

A consequence of the history of use is also the large proportion of the same age (even aged) protection forests with an increasing stock of living and dead wood:
50% of the forests in the Alpine foothills and 43% of the forests in the Alps are between 80 and 180 years old. Stocks of live trees have again increased by more than 10% in the areas not affected by storm "Lothar" (1999). The amount of deadwood has increased by as much as 80% during the same period, partly because of the storm Lothar, but also because of active deadwood management and low timber prices. Only because of these basic conditions can a further increase in mortality be expected in the case of forest regeneration that is not guaranteed everywhere, which makes protection forest management a demanding task.

How strongly climate change has already influenced this development is difficult to assess. However, it is important that these framework conditions, which are predetermined by the use and disturbance history of the alpine forest, are taken into account when assessing the protection benefits under the influence of climate change. Climate change will greatly change the impact of the protection forest on the various natural hazards processes as well as the interactions between the protection forest and the natural hazard processes. Depending on the location and natural hazards involved, the expected changes are different.

5.2.2 Cost-effectiveness assessment

I) Achievements

In a similar way than flood risk, in avalanche risk assessment can be implemented a cost benefit analysis, mainly because the potential affected area can be limited in advance, as well as pre design the mitigation and defence structures such us deflector dams, release prevention nets, etc., according to the potential avalanche calculated and the values at risk. Consequently, the costs and benefits of avalanche defence structures will be increasingly determined to allow for a comparison of the cost-effectiveness of different measures and an evaluation of the economic efficiency of avalanche mitigation strategies.

Nowadays, the various levels of government are no longer fund avalanche defence structures in fixed proportions and without consideration of their economic efficiency and only mitigation measures with net economic benefits are implemented by public funds. This tendency is spreading across many European Alpine regions, where avalanche risk is a major concern and affects critic infrastructures, as it is the case of Switzerland and Austria.

In the present, firsts efforts are being concentrate in determining the cost-efficiency rate of the avalanche protection forest, in order to being able to associate a specific value to the protection function benefits, and justify a minimum of budget to maintain and improve the forest.

II) Challenges

The main challenges that face cost-efficiency and even and cost-benefit analysis in avalanche risk, is related to the uncertainty of climate change effect on the evolution of avalanche hazard, in the sense that a significant decrease of accumulate snowpack could unbalance the expected results of the initial analysis. In a similar manner, climate change will most probably affect forest composition and structure until the point of experiencing a complete substitution of the present specie, with special attention the loss of evergreen tree for broadleaf species. In addition, new forest threats such as forest fires, windstorms, pest and disease, seeds depredation or a combination of its, can alter the ongoing and future functionality of the forest and event suppose the loss of it. All these considerations could lead to recalculate all cost-efficiency analysis in the case of protection forest, if they are not taking into account at the present when conducting the analysis.

5.2.3 Risk planning, governance and policy framework

I) Achievements

Forest Laws form the legal basis for protection against natural hazards such as avalanches, landslides, erosion and rock fall, in most avalanche affected countries. Also based on legal regulations, those responsible for civil protection are called upon to protect human lives, property and infrastructure:
Create a risk register and hazard maps (planning measures), set up and operate measuring points and early warning services (organizational measures), create and maintain protective structures and facilities (technical measures), and create and maintain protection forests (biological measures).

In doing so, the principles of integral risk management (see below SENDAI Framework) must be taken into account, i.e. the measures must be planned and implemented holistically and taking into account sustainability and proportionality as well as prevention, preparedness, response and recovery with the overall objective to mitigate the risk and the negative impacts.

In the field of planning measures, the areas endangered by natural hazards must first be identified. Spatial planning in these areas must be adapted to the dangers, risk and hazards. In hazard assessment, the spheres of action, intensities and occurrence probabilities of dangerous natural processes are determined. Also considered is the effect of existing protective measures (technical and biological). The cornerstone of every assessment is a good incident documentation.

This contains information on incident events, their causes and their damage. The central event registry “StorMe” in Switzerland for instance today contains 35,547 entries, with 23 districts using the central database. A result of the hazard assessment is the hazard map; further results would be intensity maps,

risk maps or intervention maps. The districts are obliged to create hazard maps for endangered areas. The central government supports the drafting of hazard maps for avalanches and other mass movements (landslides, debris flows, rock falls, etc.) as part of the program "Protective structures and hazard basics". The risk assessment (Switzerland as example) is now 96% complete. Because the human land use and also the danger can change, periodical revisions are necessary.

Regarding the organizational measures, not all natural hazards can be avoided. During periods of high risk, the affected areas must be avoided. Warning organizations then block endangered streets and evacuate houses. A reliable alarm system can be lifesaving. The cornerstone of such an alarm system are corresponding measuring and early warning devices and systems as described above. An example of this is the avalanche warning “IMIS”. As an early-warning and crisis information system, the common GIN information platform serves all natural hazards.

When talking about technical measures, in permanently inhabited settlements and important objects, technical protective structures are used in addition to the protection forest. Protective structures can prevent natural events in the area of origin, slow down, distract or capture them in the transit and deposit areas. If the results of the risk assessment are compared with the selected protection goals, an overview of the protection deficits is obtained. In order to eliminate such deficits, often protective structures are created. Their planning is based on an analysis of risk and proportionality.

Instead, when the focus is fore biological measures (protective forest), it can be affirmed that many forests provide effective protection against natural hazards such as avalanches, rock falls, landslides, debris flows and floods. In doing so, the forest protects people and material assets by preventing the danger processes (e.g., avalanches), reducing their impact (e.g. damping the occurring energies in case of a rock fall) or completely stopping them.

Together with the planning, the organizational and the technical measures, the protection forest forms the framework of integral risk management for natural hazard defense. The protection forest as a biological system occupies a special position because it acts on a large scale and at the same time can offer protection against various natural hazards. On the other hand, due to the slow growth of the trees, its protective effect can only be influenced in the medium to long term. In Switzerland, again for exemplary reasons, the protection area is 585.791 ha, corresponding to the 44% of the national forested surface.

II) Challenges

Climate change has different effects on the protective effect depending on the natural hazard and the time horizon considered. Adaptation strategies of protection forest management must be considered differently depending on the location:

On already drought-limited sites, (relatively strong) silvicultural interventions, combined with forest fire prevention, include the promotion of drought-adapted tree species, such as the rowan (*Sorbus aria*), and possibly a reduction in competition from the shrub and herb layers (grazing, cut) on the main control instruments for the preservation of protective effects.

Where indigenous tree species are no longer viable as a result of increased and prolonged drought and greater susceptibility to insect and other disturbances, would be in the long term also supplementary plantations of other tree species, such as oak, maple and pine species from Central and Southern Europe

and Douglas fir (*Pseudotsuga menziesii*) as well as, in extreme cases, technical structures to support natural hazard protection (especially against rock fall and erosion).
At cold-limited locations we expect further forest expansion and increase of volume. This is especially welcome where additional natural hazard protection is needed. On the other hand, the progressive development of previously open mountain forests into dense stands with low resilience should be counteracted.

This can be done by timely silvicultural interventions and possibly by maintaining extensive and adapted to the site grazing.

In the subalpine stage, the avalanche protection function, which is still relevant there, and temporarily even increasing hazards due to wet snow limit the scope for rapid climate adaptation in the tree species spectrum. Wherever there are new opportunities to increase the variety of tree species - especially fir (*Abies alba*) in spruce-dominated forests - this should be exploited.

Where currently neither cold nor drought is the main limitation over large areas and various small sites, a disturbance management is important, which promotes resilience, without allowing decisive losses in natural hazards protection.

5.2.4 Community involvement and risk communication

I) Achievements

More precise models, the better networking of all involved and the new technical guidelines help to predict, avert, or manage extreme avalanche events even better in the future. Politicians, authorities and researchers alike are called upon to constantly improve risk management. After all, it is the avalanche services that are responsible for the safety of the local population and must make the right decisions quickly in crisis situations. The measures taken in the past decades should support them in this work.

As described earlier, the communication on avalanche risk has improved due to good governance, good leadership, an enabling environment and financial support for the mandated agencies.

The engagement of and the outreach to the general public has been greatly improved by using all modern communication tools. In Austria and Switzerland, avalanche warnings are available on the web, via SMS, email, mobile apps, and on TV. Also the active engagement of “field observers” to report on local and actual snow cover conditions seems to be a motivating tool that is creating a strong sense of “ownership” in the avalanche early warning.

II) Challenges

If all the systems are well developed, risk maps and hazard registers available and reflected in spatial planning, an effective Early Warning System is established and widely and actively communicated, do avalanches still cause damage and claim human lives? Yes.

Why is it tragic but regular recurring news that every winter people are ignoring the Avalanche Warning, expose themselves, accept their vulnerability and enter the high risk areas? The information available is obviously not converted to behaviour change by all the information recipients. In the modern IT communication world, we never had so much information available than today. It remains a challenge to

create information that is willingly received, accepted and converted to cognisance, leading to behaviour change. Most of the available information seems to be treated as “noise” and is not received and accepted. So the challenge after the technical development of avalanche risk management still remains: create communication that makes information become recognised, leading to behavioural change.

5.2.5 Civil protection, emergency and post-disaster management

I) Achievements

Civil Protection, in the avalanche context namely the Fire and Rescue Services and the Mountain Rescue Service and Mountain Rescue Associations, have collected a wealth of expertise and technology since 1945.

Regarding the pre-Incident stage, based on the risk assessment and the Early Warning in the actual snow situation, the Civil Protection can act pre-emptive. The standard measures are blocking of public roads, evacuations of endangered infrastructure and settlements. The controlled release of avalanches, especially around winter sport areas with a high amount of tourists, is an interesting concept and widely applied in the alpine countries. The concept is comparable to the use of controlled burning or prescribed burning. In situations where it is only a question of “when” a fire will occur or “when” an avalanche will be released and not “if”, it is advisable and preventive to influence the “when” and choose preferable conditions to avoid negative consequences. Choosing the time and weather conditions under which a controlled fire can safely remove fine fuel from a fire prone areas and burning controlled with low intensity fire is clearly to be preferred over uncontrolled high intensity wildfires. The same way of thinking is applied when artificially releasing avalanches. Time and conditions can be determined. The release is often done using explosives or artillery fire. The explosive devices can be detonated above or on the snow surface, they can be delivered on foot or from helicopter and release smaller avalanches in a controlled way.

In the case of the post-incident stage, if avalanches happen in terrain with no human use, normally post-incident management is not required. Should forests have been damaged, then of course the standard silvicultural measures will be applied to ensure forest functionality as soon as possible. The silvicultural measures and the related challenges are described in detail across this chapter 5. In case of damage causing avalanches, the post-incident management will provide opening of blocked roads and railways, restore critical infrastructure and conduct Search and Rescue SAR missions should people be missing. Finally, an important task is also to record all the incidents to feed the data into the risk register and database.

II) Challenges

All the above chapters described the state of the art avalanche risk management, the interaction with other disturbances like fire or storm or bark beetle, the early warning systems and how the information is communicated.

With regards the avalanche protection forest, the main challenge in terms of mitigating the negative consequences of avalanches is the maintenance of a well-functioning continuous forest ecosystem. It was elaborated that forest cover by far the most area in the alpine counties and provide additional ecosystem services; is managed well, forest provide protection on a continuous basis, whereas structural protection has a life-span and needs to be replaced. We also elaborated on some of the challenges for

protection forest management, namely the role of natural regeneration and the negative impact of high ungulate populations.

Particularly important are the following three components:

1) Promotion of advanced regeneration: Gap felling's to stimulate regeneration are the most important control instrument for increasing natural regeneration and thus resilience in protective forest stands. In the interests of climate adaptation, regeneration felling's should be increasingly used to adapt the tree species composition to the requirements of the future climate. Especially in spruce forests of the montane stage, which would have a higher fir and hardwood content due to the site conditions, the fir and deciduous trees, in terms of climate adaptation, should be given top priority. However, in areas with high ungulate browsing pressure, this is only realistic with recusing ungulate densities.

2) Treatment of disturbance areas: In addition to regeneration fellings, natural disturbances offer the opportunity to adapt to climate change, whereby the pioneer vegetation can be specifically supplemented with additional (climate-adapted) plantings. In addition, after natural disturbances, it is of great importance to exploit the positive effect of deadwood for protection against avalanches and rock fall and to increase resilience, provided that this does not involve disproportionate risks resulting from consequential damage.

3) Forest fire prevention: Measures to reduce the risk of forest fire and improve forest firefighting are of increasing importance in the area of fire prone protective forests

In the last 150 years, the protection forest management has successfully developed from the fastest possible reforestation in the direction of improving the regeneration capacity of the forest through existing gaps. Climate change will lead to priority shifts within protection forest management, and avalanche protection will become less important than protection against other natural hazards in the longer term. However, current trends and scenarios support an intensified continuation of the current developments in the direction of resilience enhancement by situationally adapted gaps in the forest cover.
This should facilitate climate adjustments without jeopardizing the future protective effect against natural hazards.

5.3 Sendai and Disaster Risk Management Framework

SENDAI **Priorities**	**AVALANCHE**
#1 Understanding disaster risk	The understanding of why, how and what causes avalanches is well developed in countries like Switzerland and Austria. This expertise and knowledge is shared and well communicated.
#2 Strengthening disaster risk governance to manage disaster risk	Legal frameworks and regulations are in place and provide framework for risk management on all levels; in Switzerland especially well developed.
#3 Investing in disaster risk reduction for resilience	The most effective, wide-spread and eco-friendly measure for risk reduction is a well-structured, uneven-aged, mixed species continuous forest cover. However, forest history, climate change and high ungulate densities pose significant challenges to forest regeneration.
#4 Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction	Early Warning reflects in the preparedness levels avalanche service and mountain rescue services. The build-Back-Better concept is reflected in the fact that all incidents are fed into a database that feeds into risk analysis and mapping

Targets	
Reduce global disaster mortality	Countries like Switzerland and Austria are sharing their avalanche knowledge and skills as well as research openly with other countries.
Reduce the number of affected people	Early Warning, diverting traffic, closure of risk areas and evacuations are reducing the number of affected people. However, the level of ignorance towards EW is also a fact
Reduce the direct disaster economic loss	see above
Reduce disaster damage to critical infrastructure	Critical infrastructure can be protected by additional structural protection. Spatial planning is the most effective tool to define safer locations for critical infrastructure
Increase the number of national and local disaster risk reduction strategies	
Enhance international cooperation to developing countries	Switzerland and Austria have well established knowledge sharing tools and cooperate on avalanche risk globally
Increase availability of and access to multi-hazard early warning systems and disaster risk information and assessment	Switzerland again as best practice example is making all natural hazard information available on one platform http://www.natural-hazards.ch/home/current-natural-hazards.html as well as mobile apps, sms and email distribution.
DRM	
Cycle phase	
Prevention	Structural protection, controlled release and protective forests
Preparedness	Monitoring of actual risk, road closure, evacuation, etc.
Response	Mountain Rescue service established
Recovery	Recovery of infrastructure as after any other incident. recovery of protection forest a challenge due to climate change, forest history and disturbance management and high ungulate densities
Domain	
Policy making	Swiss and Austrian laws and regulations can serve as role models
Early warning system	Well established, role model available
Disaster response	

6. Final remarks and conclusions

European forests are a relevant protecting infrastructure against natural hazards, and play an important role in risks prevention and mitigation of exposed populations, goods and services. In such, forests protection functions seek to limit the level of risk and to ensure socio-economics activities. For instance, this is the case for protection forests in mountain areas preventing avalanches, rock fall and landslides. This protection function has been promoted actively by active forest management, or it has been indirectly provided through traditional land use; e.g. wood and fire wood mobilisation or understory grazing result in open canopy forests that prevent wildfires.

However, wooded lands are facing several socio-economic and environmental changes that are compromising this protective function. For instance, the accumulation of biomass fuel loads after land abandonment increases wildfire risk. On the other hand, severe environmental conditions, such as heavy droughts and heat waves, changes in snow or rain fall patterns or intense wind storms increase in a climate change context. Consequently, forests are increasingly threatened by natural hazards in such human-natural influenced processes. Ultimately, the likeliness of forest risks to impact populations increases, generating significant levels of social, economic and environmental damages.

Therefore, in a climate and land use change context, natural hazards could worsen and pose a major concern for ensuring and promoting the maintenance of forests' protection function, together with all other forests functions (e.g. biodiversity conservation, provision of wood and non-wood products, water and air regulations, scenic beauty and recreation, etc.). Overall, climate change scenarios show a significant increase on intensity and frequency of the occurrence of severe environmental conditions related to wildfires, storms, floods and avalanche risk. In this context of changing risk, natural hazards are becoming more severe (e.g. unprecedented severe mega-fires hitting along Mediterranean region during summer 2017 and 2018) or are appearing in usually not exposed areas (e.g. large forest fires in Alpine and Scandinavian regions).

Furthermore, potential multi-hazards interactions could generate new risk situations and emergency dimensions at multiple levels due to cascade effects. For instance, protection function of forests against avalanches can be compromised by the increase of wildfire risk in Alpine areas. This situation could imply an important loss of the protective forest cover and, as a consequence, require redesigning avalanche risk planning.

To successfully adapt forests to this new hazard context, efforts should be focused mainly in reducing their vulnerability. Normally, long term management actions will be necessary as changes in forests' resilience to natural hazards take time. Uncertainties posed by different climate change scenarios add additional difficulties to the implementation of tested and reliable solutions and actions. In this sense, aiming at minimizing uncertainties, experts' knowledge and experience sharing networks and initiatives are being proposed as an efficient way to improve the know-how of the upcoming forest's risks assessment and management across Europe.

The amelioration and adaptation of forests to potential hazards, together with a robust and extended risk culture among all implied stakeholders and communities, could allow minimizing the impacts of forest risks.

Particular remarks by risk management cross-sectoral components – achievements and challenges

Risk and vulnerability assessment and mitigation

- Proper risk assessment is crucial for developing efficient prevention and mitigation strategies that in some cases are crucial to ensure the viability of socioeconomic activities in an environment affected by natural hazards, e.g. urban development in valleys of mountain areas with high avalanche risk. In this sense, risk assessment protocols should integrate different scenarios and reflect potential time lag of the appearance of risk effects due to global change, beyond what is happening today.

- For natural hazards whose spatial and temporal distribution can be defined, the benefits of prevention actions compared to avoided risk impacts can be estimated more easily. This is the case for flood and avalanche risk, normally established with return periods and a spatial occurrence, where uncertainties posed by climate change can be integrated on many severity scenarios. The random distribution of storm or wildfire events adds difficulties on managing the related risks and promoting cost-efficient mitigation measures within the region. Nevertheless, in case of wildfire risk, the level of exposition and vulnerability of goods and services can be easily estimated knowing the main fire behavior patterns within a region. The structure and composition of forests have high influence on its vulnerability towards storms risk.

- In all cases, risk management must be based on a good understanding of the functioning of natural hazard dynamics, putting attention to the physical and social factors of the "risk build-up and mitigation process".

Cost-effectiveness risk management assessment

- Normally forests are the main cost-effectiveness infrastructures for risk reduction compared to civil engineering works and measures. This is especially relevant in the case of forests with protection function. Additionally, to the risk reduction role of forests, they provide multiple valuable environmental services and goods and mitigate climate change effects.

- As long as the severity of natural hazards increases, the influence during the response phase for risk mitigation is limited. This is facilitating the recognition of the interconnections between prevention-preparedness and response capacities. It also shows how investing more in the prevention and preparedness phases, requires less efforts for the response phase and optimizes cost-efficient risk management alternatives. Therefore, cash-flow between phases of the risk cycle should be properly defined and organized in DRR strategies, which also consider all direct and indirect benefits of prevention measures and the conservation of healthy forest cover.

- More efforts are required in integrating community disaster risk reduction involvement into insurance accountability, as a means of motivating and promoting social awareness and shared responsibility in managing hazard prevention and risk mitigation measures.

Risk planning, governance and policy framework

- Risk planning is closely linked to set management objectives, for instance, protecting forest from wildfires or infrastructures from avalanches or floods, under defined thresholds, normally assuming that risk cannot be completely avoided. In the context of global change, since the likeliness of hazards to impact urban areas increases, addressing risk proactively in urban and spatial planning will mitigate potentially harmful consequences of risk exposed populations. In this sense, beyond sectoral policies, transverse approaches dealing with social and physical vulnerability from a multidisciplinary perspective, should be promoted.

- Legal recognition of the protection function of forests could help to promote their maintenance and effective integration into hazard prevention and emergency plans as a defensive infrastructure.

- The necessity for cross-sectoral coordination of managing risk is even more necessary when dealing with interactions of several forest risks. Meeting experts on different natural hazards and phases of the risk management cycle should help to identify main drivers and more effective mitigation measures of short, medium, and long term effects of different management options and to achieve an integrated multi-risk planning.

- Risk planning is normally based on administrative levels for operational reasons. In this sense, necessary collaboration protocols at local/regional/national or international levels should be defined being able to integrate mitigation measures according to physical boundaries that normally define natural hazards.

- For an effective integration of forest risks into spatial/urban planning, it is necessary to adapt the risk assessment information to the requirements of land planners, which are not necessarily the same as for answering a forest or risk manager's objectives. The more the impacts affectation is related to risk mitigation measures on public/private rights and duties, the more robust, in legal and technical terms, the risk information has to be.

- Within the context of changing risk, adaptation of regulations based on potential risk scenarios is required. Promoting science, connecting risk managers and policy making, as well as exchange and networking and awareness raising at a societal level should accelerate the mainstreaming of innovations and lessons learned into legislations/policies.

- Integration of participatory approaches along the risk planning process allows promoting social awareness and enhancing the commitment of exposed populations for planed risk mitigation actions. Illustrating risks management alternatives through different scenarios, as well as establishing a dialog between risk managers and society can help to increase the robustness of decision making processes.

Community involvement and risk communication

- Active involvement of communities exposed to risks should be promoted, getting them concerned and aware about their exposure and vulnerability to forest risks and building up a robust culture of risk. This should facilitate the implementation of mitigation measures through understanding of

their own responsibility in managing risks, including the collaboration of individuals during crisis and emergency management.

- In this sense, risk communication becomes a more and more crucial component of DRR strategies, keeping populations updated and ready to act for the current and coming risk situation, as well as educating and transferring best practices and knowledge to face potential future events by means of renewing and refreshing lessons learned in the past. This keeps social risk perception alive and reliable to potential new events, while facilitating the introduction of new challenges to be faced. However, also non-permanent population groups have to be considered; e.g. visitors or tourists, which may be similarly exposed and even more vulnerable than native communities due to language and cultural barriers.

- Establishing consistent collaborations and alliances with media and environmental groups can improve risk communication. Advances in technology and social media can lead to more effective disaster risk information, and an increased public awareness and involvement. However, important attention has to be put in technological advances in the long run, because people can decouple from reality, for instance due to excessive and non-contrasted information; i.e. the so-called fake news. An effective and active involvement of citizenship requires confident, credible, robust, and recognized communications and communicators from the risk management authorities, but also needs to facilitate bi-directional communication.

Civil protection, emergency and post-disaster management:

- The use of innovative technologies has improved the definition of multi-disciplinary scenarios and response plans, providing integrated assets to support emergency management, such as monitoring, modelling, situations and risk assessment, decision support and communication tools. This will need to be accompanied with specific training and courses for risk managers and emergency staff, responsible to ensure the well understanding and practical implementation of the civil protection plans.

- Civil protection servants and related practitioners will have to deal with new risk scenarios and unprecedented hazard events. Promoting the exchange of experts at national and international level is an efficient method to benefit from the lessons learned and experiences of others regions that were dealing with these types of risk for a long time. Strengthen relations between different European civil protection organizations and levels, will enhance a common sense of responsibility and duty prior to the upcoming challenges of global change.

- Recovery and post-disaster phases offer a chance in improving risk management. On one side, restoring landscapes in a more resilient manner and, on the other, updating DRR strategies taking advantage of the political commitment linked to the social concern following a disaster.

7. Annexes

7.1 Single risk and risks interaction matrix

Risk Interaction Assessment

General Information

Author	*(Name and institution)*
Management Objective	Category of management objective: Please choose
	Please specify: *(e.g. expected outcome / yield, desired state / function of forest)*
Hazard type	Hazard analyzed: Please choose Previous hazard: Please choose
	Please specify: *(e.g. intensity of impact, areal extent, duration of impact, probability of occurrence, predictability of the event)*
Area of applicability	Please describe regional limitations etc. *(e.g. geographic region, climate zone, socio-cultural context)*

Please copy and paste the analysis from the→ single risk assessment

Impact on Vulnerability

Natural Influence	Description	Effect on vulnerability
Please name	Please describe	choose...
		choose...
		choose...
		choose...

Human Influence	Description	Effect on vulnerability	13
Please name	Please describe	choose...	☐
		choose...	☐
		choose...	☐
		choose...	☐

[13] Best practice or tool in risk management

Impact on Exposure

Natural Influence	Description	Effect on Exposure
Please name	Please describe	choose...
		choose...
		choose...
		choose...

Human Influence	Description	Effect on Exposure	14
Please name	Please describe	choose...	☐
		choose...	☐
		choose...	☐
		choose...	☐

[14] Best practice or tool in risk management

Single Risk Assessment

General Information

Author	*(Name and institution)*
Management Objective	Category of management objective: Please choose
	Please specify: *(e.g. expected outcome / yield, desired state / function of forest)*
Hazard type	Hazard analyzed: Please choose
	Please specify: *(e.g. intensity of impact, areal extent, duration of impact, probability of occurrence, predictability of the event)*
Area of applicability	Please describe regional limitations etc. *(e.g. geographic region, climate zone, socio-cultural context)*

Impact on Vulnerability

Natural Influence	Description	Effect on vulnerability
Please name	Please describe	choose...
		choose...
		choose...
		choose...

Human Influence	Description	Effect on vulnerability	15
Please name	Please describe	choose...	☐
		choose...	☐
		choose...	☐
		choose...	☐

Impact on Exposure

Natural Influence	Description	Effect on Exposure
Please name	Please describe	choose...
		choose...
		choose...
		choose...

[15] Best practice or tool in risk management

Human Influence	Description	Effect on Exposure	16
Please name	Please describe	choose...	☐
		choose...	☐
		choose...	☐
		choose...	☐

[16] Best practice or tool in risk management