RECIPE

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

Multi-risk wildfire-avalanche assessment and planning in mountain areas

ENGLISH SUMMARY

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1 Introduction

This report is part of the deliverables of the RECIPE Project (Reinforcing Civil Protection capabilities into multi-hazard risk assessment under climate change) and corresponds to the Deliverable 4.2 of Task 4.3.

RECIPE is a two-year Prevention Project (January 2020 – November 2021) founded by the Civil Protection Mechanism of the European Commission (call identifier UCPM-2019-PP-AG), with the participation of 8 institutions from 5 EU countries:

- Forest Science and Technology Centre of Catalonia (CTFC), Spain (Project coordinator).
- Pau Costa Foundation (PCF), Spain.
- Civil Protection General Directorate of Catalonia (DGPC CAT), Spain.
- Forest Research Institute Baden-Württemberg (FVA), Germany.
- CIMA Research Foundation (CIMA), Italy.
- Austrian Research Centre for Forest Natural Hazards and Landscape (BFW), Austria.
- Institute of Cartography and Geology of Catalonia (ICGC), Spain.
- Higher Institute of Agronomy (ISA), Portugal.

The RECIPE Project seeks to develop operational recommendations and tools to reinforce Civil Protection capabilities into emergency management and risk planning of different natural hazards across Europe to address climate change impacts, by using an integrated risk management approach and the exchange of lessons learned and best practices.

By means of putting together multi-hazards' expertise from science and practice on wildfires, floods, storms, avalanches, rockfalls and landslides, main impacts of climate change in risk management will be identified. The potential scenarios of unprecedented multi-risk events will be considered. The interactions between prevention-preparedness-response-recovery actions in projected climate change scenarios will be analysed with an active participation of practitioners and other users. Accordingly, Civil Protection requirements to face new risk management challenges about climate change impacts will be identified.

Based on the above, transferable guidelines will be edited to incorporate the projected multi-risk impacts of climate change into operational decision support systems (DSS) that are used for risk management. Complementary, specific operational tools will be developed at pilot site level for each natural hazard to reinforce Civil Protection capabilities. Participation of public agencies will be promoted from the beginning to achieve an end-user oriented focus. Results will be actively disseminated into Civil Protection systems.

Furthermore, the project's workshops will promote the knowledge exchange in the existing networks to reinforce European landscapes' resilience to natural hazards.

The project is divided in 5 work packages (WP) as follows:

- WP1 Management and coordination of the action.
- WP2 Framing Civil Protection requirements for integrated multi-hazard risk management.
- WP3 Impacts of climate change projections on multi-hazard risk management.
- WP4 Guidelines and decision support tools to integrate climate scenarios into risk assessment and planning.
- WP5 Publicity and project outcomes transference.

Task 4.3 is part of the work package 4. This WP is composed by three tasks. On the one hand, in task 4.1 an analysis of existing decision support systems and the operability to include projected climate change impacts identified in previous WP3, is developed. In the second task (4.2), a description of the risk attributes and data requirements to be included into the DSS to address climate change impacts on multi-hazards risk management is done. Finally, the taks 4.3 includes a set of support tools for civil protection which will serve to address a specific need, taking into account all the work done in the previous WP.

As expected, each support tool will be edited in the local language of the territory of applicability (Italian, Catalan, German and Portuguese), and will be also a summary in english available, which is this document.

2 Multi-risk wildfire-avalanche assessment and planning in mountain areas

2.1 Objectives and scope

Climate change has a direct impact on natural hazards, modifying their intensity, frequency and distribution in most of the terrestrial regions (IPCC, 2021). This trend will affect mountain areas, posing new scenarios, as it could be the multi-hazard situations, where different hazards are interacting in a same territory, but not necessarily at the same time.

"Multi-hazard means (1) the selection of multiple major hazards that the country faces, and (2) the specific contexts where hazardous events may occur simultaneously, cascadingly or cumulatively over time, and taking into account the potential interrelated effects"[1].

In mountain areas, warmer environment could lead to favour the occurrence of wildfires (Resco de Dios et al., 2021, Müller et al., 2020), which could seriously threaten the forests protection role, for instance, from avalanche or rockfalls, and the cascade effect of wildfires affecting forest cover protection function.

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

This tool analyses this interaction between wildfires and avalanches in Catalonia based on 3 main approaches regarding multi-hazard management:

- At **regional level**, how should we act in case of wildfire-avalanche events interaction in a mountain area? The first part of the tool is based on a "Table-top" exercise[2], defining a concrete risk situation, and identifying the main steps to be carried out in case of a wildfire-avalanche emergency.
- At **massif level**, how may wildfires affect avalanche risk? A practical exercise analysing the risk drivers of avalanche and wildfire risk has been carried out in the valley of Núria (Catalan side of the Pyrenees) conducting the sequence among hazard, exposure and vulnerability (HEV) factors. Wildfire simulations have been developed in order to analyse the potential forest protection function affected, and the consequent impact on avalanche risk in a climate and land use change context.
- At **forest stand level**, is it possible to develop forest management to prevent both avalanche and wildfire risks? The third part of this tool approaches potential forest management guidelines addressed to decrease wildfire risk maintaining forest protection function in case of avalanche.

By this way, this tool is approaching the wildfire-avalanche multi-risk situation at different scales and from different perspectives: Risk assessment and mapping, technical measures and, emergency management and response capacity.

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

[2] Table-top exercises are based on a theorical emergency simulation, where the different participants discuss and define their roles and actions to develop.

2.2 Description of the tool

2.2.1 Protocol for a wildfire-avalanche risk management in mountain areas

The protocol identifies risk management main steps to develop in case of wildfire-avalanche risk interaction. For this, a specific situation was stated in order to better define each one of the actions and measures to apply.

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

The exercise is based on the risk factors (hazard, exposure and vulnerability) identification to develop mitigation measures in the whole Risk Management Cycle (Prevention, Preparedness, Response and Recovery) in order to enhance the population, infrastructures and environmental services protection.

The protocol content the following steps and measures, and the corresponding description:

STEP 1: Risk analysis. Expert Working Group

- Time triggering assessment after the wildfire to size possible response capacity in case of avalanche.
- Assessment of affected space (burned area) into the avalanche hazard map to analyse the effects on the forest protection function.
- Exposure and vulnerability assessment (from the cross-links between burnt area and potential avalanche areas) to prioritize areas/elements where to act.
- Proposed actions to reduce the risk on those areas prioritized.
- Assessment of simultaneity or very short-term triggering related to other risks (e.g., landslides or rockfalls).

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

- Measure 1.- Develop a protocol for action in the event of a large wildfire in avalanche paths.
- Measure 2.- Avalanche Terrain Assessment.
- Measure 3.- Assess the state (after the wildfire) of the vegetation and forest cover.
- Measure 4.- Burnt area forest cover restoration.
- Measure 5.- Check and restore avalanche protective structures.
- Measure 6.- Update the Intervention plans for avalanche triggering (PIDA) according to new multi-risk situation.

STEP 3: Emergency Planning

- Measure 7.- Close the access to potential avalanche zones where it has not been possible to restore forest protection function.
- Measure 8.- Extend the preventive triggering of avalanches in new risk areas.

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

- Measure 9.- Update the Civil Protection and Self-protection Municipality Plans according to the new multi-risk situation.
- Measure 10.- Update the ALLAUCAT plan (Civil Protection Emergency Plan for Avalanches in Catalonia) in the burnt area according to the new multi-risk situation.

STEP 5: Assessment of citizen collaboration and information measures

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

2.2.2 Susceptibility assessment of forest protection function loss in case of wildfire and its effect on avalanche risk

The presence of a wildfire in steep mountain areas can jeopardize the forest protection function, which is a fundamental nature-based solution to prevent, for instance, avalanches and rockfalls.

Theoretical exercise to assesses the potential interaction between wildfire and avalanche risks in mountain areas in a climate change context is carried out. Biophysical risk analysis according to fire-environs and land use scenarios is developed, in order to know the magnitude of forest protection function affected by wildfires and the consequent increase of avalanche risk in the area.

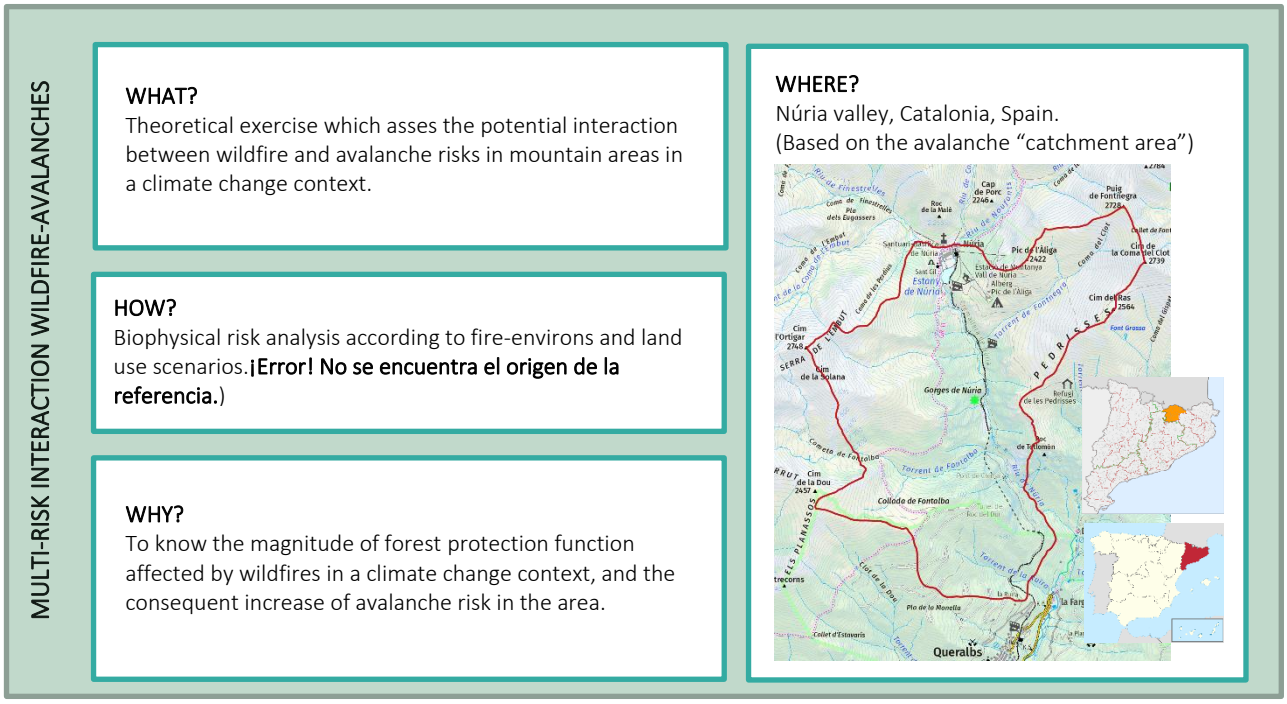


Figure 1. Wildfire and avalanche risk assessment in mountain areas: RECIPE case study procedure.

The definition of a case study area serves to focus the exercise on a concrete territory and evaluate the data and knowledge availability to carry out the proposed methodology. In this case, Núria valley was chosen due to different relevant attributes for testing the method:

- The area is within a Natural Park.
- An active touristic activity is promoted during winter.

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

The methodology applied has followed a sequence of five methodological steps as follow:

1. **Definition of a case study area**, which should contain specific biophysical and socioeconomic characteristics according to avalanche and wildfire risk (e.g., between 1.600 and 2.800 m of altitude to cover potential wildfire and avalanche prone conditions, steep terrain focussing on slopes between 28-45º, exposed and vulnerable elements, etc.). as a high knowledge and data of avalanches, and a past wildfire events.
2. **Analysis of available data for the area defined**, as land use cover, meteorological data (nearby weather stations), recorded avalanche and wildfires events, forest fuels map, digital terrain model, avalanche hazard maps, etc.
3. **Definition of risk scenarios**, which will serve as a basis to simulate wildfire events, and thus, to analyse the impacts on forest protection function. A first scenario was based on the current climatic and land use conditions, and a second one simulates a climate change scenario (adding an increase of 2ºC temperatures and a decrease of humidity) and land use change scenario (natural reforestation due to a decrease of pastures and traditional grazing in the area).
4. **Wildfire simulation in the defined risk scenarios**, based on the local knowledge about wildfire patterns in the territory. In this case, wildfires are conducted by wind from the north and from the south. According to this synoptic conditions, different ignitions were located on the territory in order to simulate wildfire extension and fire intensity, identifying the crown fires (where the forest protection function will be jeopardized).
5. **Re-evaluation of avalanche risk**, analysing the areas affected by crown fires and their impact on potential avalanche hazard according to the terrain.

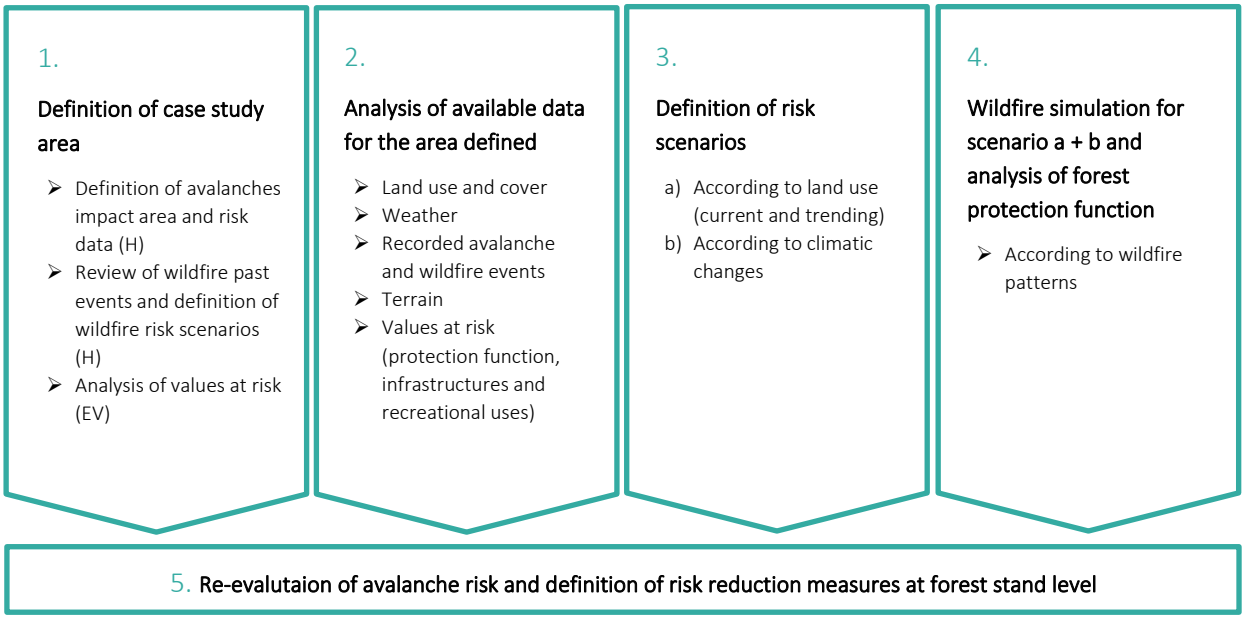


Figure 2. Multi-risk wildfire-avalanche exercise scheme.

According to the wildfire past event and known wildfire risk patterns in the study area, two different weather synoptic scenarios were stated: north wind-drive wildfire and topographic south wind-drive wildfire (wildfire event of Queralbs in 2007) (Figure 3). These two wildfire patterns were combined with two different land use scenarios (current situation, increase of forest cover up to the tree line, due to natural reforestation).

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

Current weather and land use scenario

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

Climate change weather and land use scenario

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

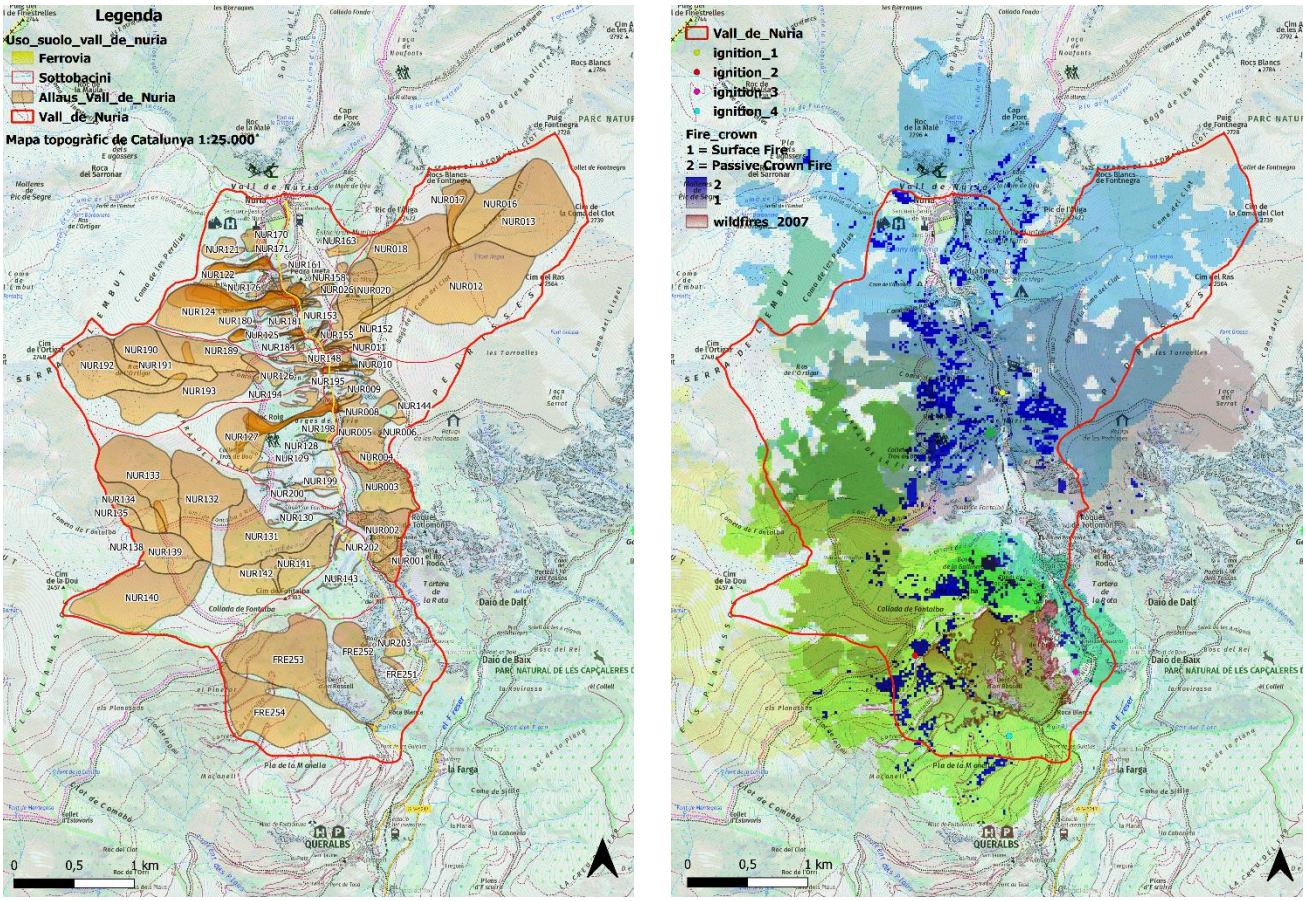


Figure 3. (Left) Avalanche cartography inside the study area. (Right) Wildfire simulations and high intensity fires identification (blue marks).

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

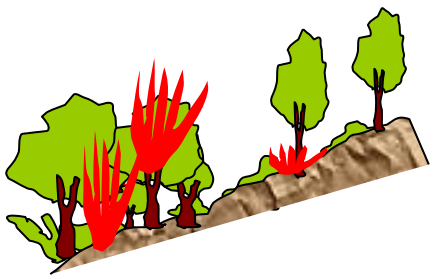
Consequently, from avalanche risk management point of view, to identify "Susceptible avalanche starting zones due to wildfire" on those areas with values at risk become a priority. In those areas, forest management practices should be oriented to achieve forest stands resistant to crown-fire impact (see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

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

2.2.3 Forest management guidelines towards common wildfire-avalanche risk mitigation approach at forest stand level

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

The proposed forest management guidelines for multi-risk avalanche and wildfire reduction are based in approaching different fuel treatments (and the consequent forest structure) according to the physical situation of the forest cover along the slope and avalanche zones (Figure 4 and 5). The main objective is to reduce crown fires risk to the forest situated in the avalanche starting point. For this reason, an open forest stands should be provided with some distance to down fire from canopies to the surface, in the case a wildfire is spreading form the bottom. In the middle slope, dense forest structures should be ensured to reduce rockfalls risk and, consequently, crown fires are possible. Moreover, in the bottom part, open forest stands should be provided to help first attack fire control but also reduce the biomass in the run-out avalanche zone.



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

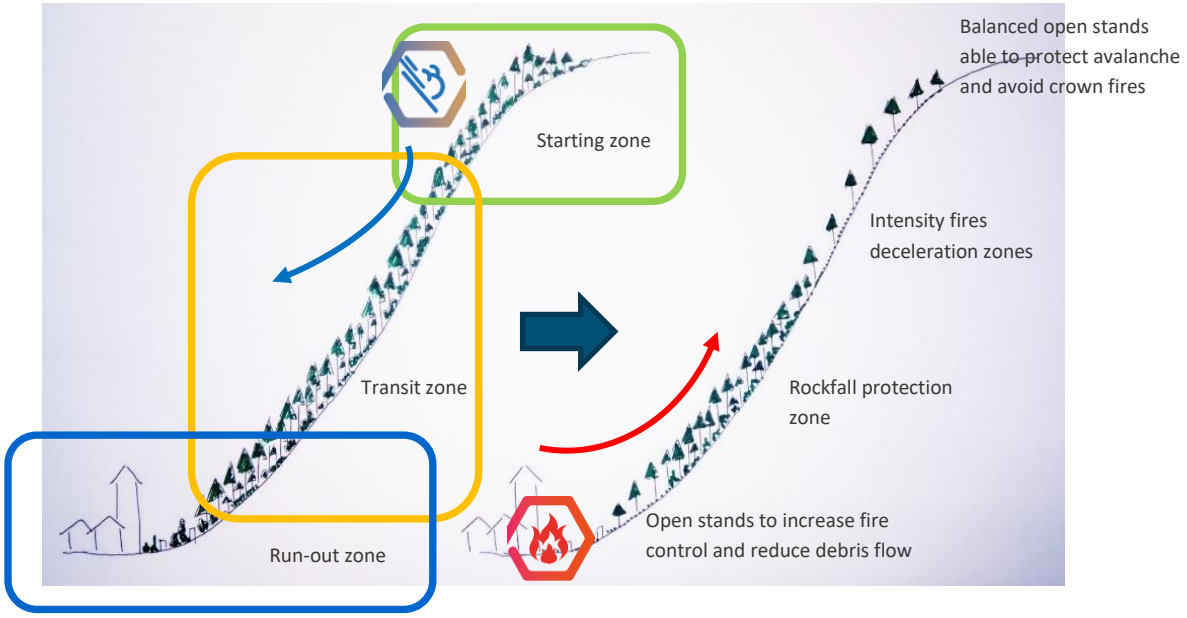


Figure 4. Scheme of forest management prescriptions towards common wildfire-avalanche risk mitigation approach at forest stand level.

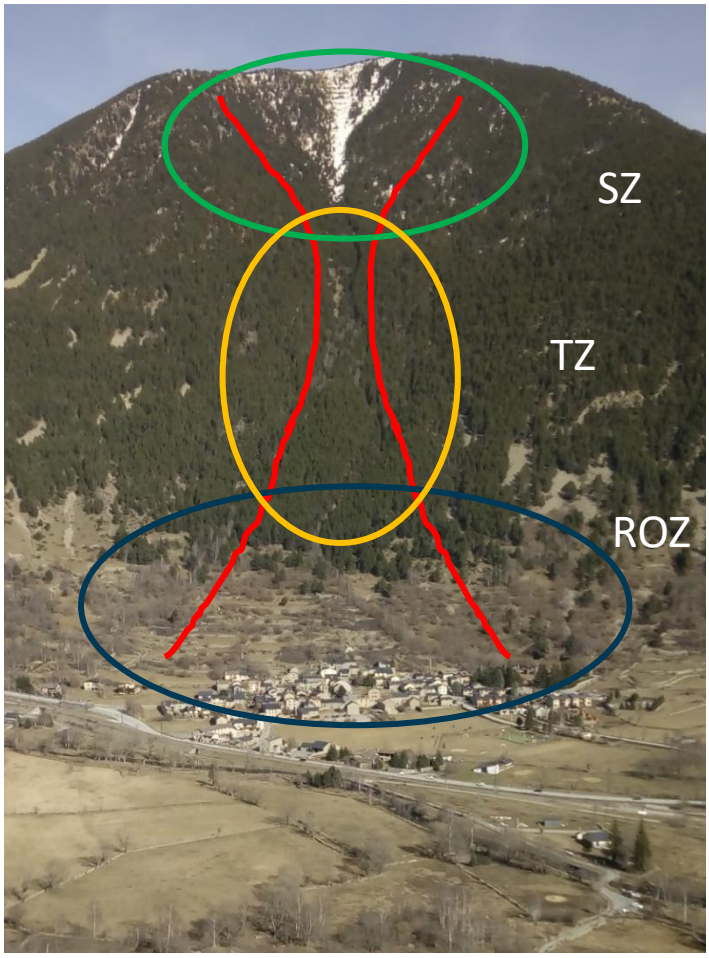


Figure 5. Classification of avalanche zones.

Figure 6. Núria valley. Avalanche transit area affecting the train railway which is protected with defensive infrastructures and a protocol of controlled avalanche trigger (left). Area affected by 2007 wildfire of Queralbs (right).

3 Recommendations for the EU scalability of the support tool

These preliminary guidelines can be further developed and adapted to prepare similar wildfire-avalanche multi-risk scenarios across EU mountain landscapes.

Nevertheless, the proper knowledge of wildfire patterns in the territory may help to base decision making in robust pre-defined risk scenarios. Some important gaps on that sense can be expected in those areas where the fire phenomena are not usual.

Moreover, fire ecology of predominant forest species is fundamental. The proposed guidelines are adapted to tree species naturally adapted and resistant to low intensity fires (thanks to bark protection such as Pinus nigra or Pinus sylvestris). In the case of thin bark species sensitive to fire heat, the same multi-risk strategy at forest stand level should not be adopted.

This multi-risk situation shows the contribution of forest protection function as a nature-based solution, ensuring soil, avalanche and rockfall protection to citizens, infrastructure and economic activities on the land. Although in many mountain areas the combination of both risks is still rare, climate change may make them more often. In any case, those actions to adapt ecosystems and forest practices to this combined risk approach takes time and may imply cultural changes about traditional forestry activities (even, proposing the change of species as adaptation strategy, moving towards low intensity fires resistant ones).

In the meanwhile, risk mapping of the most wildfire hazardous areas, together with commonly existing avalanche maps in mountain areas and the values at risk, can guide the risk reduction actions.

This case study also shows how an in depth understanding of both natural risks merging both expertise, together with combination of research and operational bodies, are fundamental to carry out similar multi-hazard risk management approach.

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