D.T 3.5.1: Report on 'Results of the risk analysis and the strategy prioritization'

GREEN RISK 4 ALPS

WP 3

Responsibility for Deliverable

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1. Introduction

The project *GreenRisk4ALPs* aims to develop ecosystem-based approaches to support risk management of the Alpine region. In particular, the project intends to provide decision support tools for the development of ecosystem-based risk management strategies for mountain regions. In this context, this deliverable aims to provide an overview of the main outcomes developed within Work Package 3 (WP3). Firstly, an overview of the Rapid Risk Appraisal (RRA) results is presented in Chapter 2, comparing the different study areas where the participatory process took place. Secondly, Chapter 3 illustrates the exposure analysis results. Finally, Chapter 4 provides an overview on how the different WP3 approaches can be integrated to prioritise risk management strategies. This also includes the economic evaluation of protection measures (TEGRAV), integrated in the Forest Assessment Tool (FAT). The methodology behind the WP3 approaches was presented in previous deliverables (refer to DT 3.2.1. for the RRA and for the exposure analysis and to DT 3.3.1-3.3.2 for the TEGRAV analysis).

2. Rapid Risk Appraisal Results

As described in Deliverable D.T.3.2.1. the aim of the Rapid Risk Appraisal (RRA) is to (i) pinpoint the most relevant natural hazards in terms of risk in each PAR and to (ii) identify the strengths and the entry points of risk management in implementing future risk reduction measures.

The RRA makes use of local knowledge through the involvement of local experts in half-day workshops organised in the different *GreenRisk4Alps* Pilot Action Regions (PARs). Figure 1 depicts the location of the Pilot Action Areas of the project. Overall, RRA workshops were held in four different PARs.

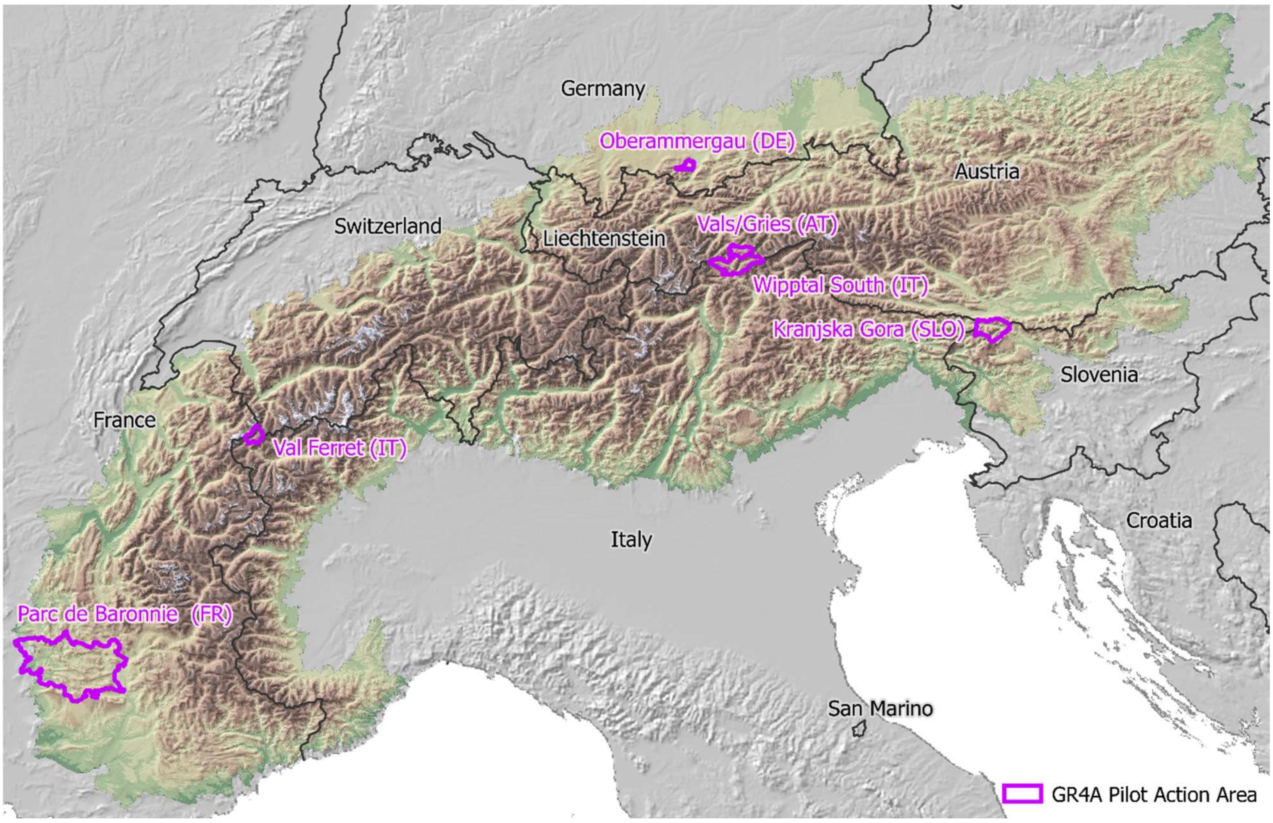

Figure 1: Location of GR4Alps Pilot Action Areas

Table 1 below provides an overview on the dates, format (online vs in person) and language in which the workshops took place as well as on the number of participants. The number of external participants, ranged from 6, who attended in person in Val Ferret, to 15, who joined online, in Oberammergau. The expertise of the participants in each of the PARs covered not only different natural hazards but also different phases of the risk management cycle, ranging from preparedness to response. The list of institutions which took part in the RRA workshops are listed in Annex 1. The methodology underlying the RRA workshops is presented in Deliverable D.T.3.2.1.

Table 1 Overview of RRA workshops held in four different PARs

PAR	*Date*	*Format*	*Language*	*Number of institutions/ departments*	*Natural hazards addressed*
Val Ferret (ITA)	19.11.2021	In person	Italian	4	Debris flows (DF) Avalanches (A)
Kransjka Gora (SLO)	17.09.2021	In person	Slovenian / English	5	Debris flows (DF) Rockfall (RF)
Oberammergau (DE)	26.11.2021	Online	German	8	Landslides (L) / Debris flows (DF) Rockfall (RF)
Southern Wipptal (ITA)	16.12.2021	Online	German	6	Debris flows (DF) Rockfall (RF)

In summary, the RRA comprises three main steps (Risk Identification, Risk Analysis and Risk Evaluation), whose results are presented in the following:

The **first step** consists of the **Risk Identification** which aims at identifying those two natural hazards which are considered the most relevant from a risk perspective among those addressed in the GreenRisk4Alps project, i.e. landslides, rockfalls, snow avalanches, and debris flows.

In the PAR of Val Ferret, debris flows and snow avalanches were selected by the experts during an initial discussion on past damage causing events. In other words, these processes were perceived as the two natural hazards leading to the most significant direct and indirect loss and damage in the past. In the area, these gravitational processes can occasionally reach roads, houses, or areas with numerous people. Past events have also led to business and road closures, also impacting the tourism sector and consequently the local economy. While avalanches characterise the winter season, debris flows are instead occurring rather in the non-winter period, leading to different risk management needs for the two seasons. Another relevant hazard considered to be under increasing media attention is ice avalanche related to two hanging glaciers that descend from the Mont Blanc massif: Whymper hanging glacier of Grandes Jorasses and Planpincieux glacier. Such hazards however were not selected for the RRA, as they were not subject of the project.

In the Slovenian PAR, water-related hazards, more specifically torrential flooding, were identified as the most threatening hazards for the municipality area of Kranjska Gora. Torrential flooding is directly related to channelized flow-type landslides, also known under the expression debris flows. After a discussion with the experts on the basis of existing maps, debris flows and rockfalls were selected as the most relevant hazards in the area. Rockfalls were reported to indeed occur more frequently than snow avalanches. Also, recent snow avalanches events did not lead to major consequences, being mainly small in size (20-50m^3). On the other hand, rocks falling in the torrential channels during heavy rain events constitute a threat also to settlements and infrastructure located lower in the valleys, in particular to the areas of Hladnik, Rateče, Vrata, Suhelj and Vršič.

In the PAR of Oberammergau, after an initial discussion on the basis of existing inventory data, the workshop participants selected rockfall, and decided to focus on landslides and debris flows as a combined hazard in the following steps of the RRA.

Finally, in Southern Wipptal, a similar focus was chosen, since also in this PAR the experts selected debris flow and rockfall as the hazards representing the greatest threat in the area. The Pfitsch Valley only has one access road which is susceptible to rockfall. Its closure caused by rockfall events can therefore cut off the entire valley. Moreover, between the municipalities of Sterzing/Vipiteno and Brenner/Brennero, the State road is also at risk from rockfall. Other identified hotspots were between Gossensass/Colle Isarco and Brenner where rockfall sometimes affects the railway. On the other hand, houses and tourist infrastructures are hardly affected by this natural hazard. Major debris flows events leading to losses and damage have also occurred recently, especially during the summer in Pfitsch/Val di Vizze and Pflersch/Fleres (fraction of Brenner) triggered by thunderstorms. Especially the valley bottoms, where streams have been narrowed or piped, face increasing problems connected to debris flows. In particular, in August 2012, the entire Pfitschtal/Val di Vizze valley was devastated by floods and debris flows.

The RRA second step, the **Risk Analysis**, builds on the previous discussion and represents the core of the RRA. The aim of this step is therefore to analyse existing risk management practices in the PAR, related to the two previously selected natural hazards. The experts provided a full answer to each question, explaining how each risk management related practice works in their PAR; moreover, they were invited to select a scenario which reflected how satisfied they felt about such measures. In particular, the different questions or indicators are grouped in eight categories, for which the respective PAR results are presented below.

The categories are (i) Hazard and Risk Assessment, (ii) Land Use Planning, (iii) Man-made measures, (iv) ECO-DRR (Protective forest), (v) Risk Communication, (vi) Early Warning, (vii) Response, (viii) Recovery and a final overarching category, Climate Change Adaptation.

Hazard and Risk Assessment

The indicators belonging to the Hazard and Risk assessment category address the quality, quantity and accessibility of data on past natural hazard events, the presence of official maps showing the likelihood of natural hazard occurrence (i.e. hazard or susceptibility maps) and finally the availability of (spatially explicit) information on assets potentially at risk (Table 2).

Table 2. Overview of the RRA scenarios assigned by the experts to all the indicators of the Hazard / Risk assessment category (green represents the Best practice scenario, yellow the Average scenario, and red the Points for improvement scenario).

Hazard / Risk assessment						
PARs/indicators	Database past events		Hazard maps		Exposure/ Risk maps	
Val Ferret (avalanche-AV/ debris-DF)	*AV*	*DF*	*AV*	*DF*	*AV*	*DF*
Kranjska Gora (rockfall-RF/ debris-DF)	*RF*	*DF*	*RF*	*DF*	*RF*	*DF*
Oberammergau (rockfall-RF/ landslide-LS + debris-DF)	*RF/ LS*	*DF*	*RF/ LS*	*DF*	*RF/ LS*	*DF*
Southern Wipptal (rockfall-RF/ debris-DF)	*RF*	*DF*	*RF*	*DF*	*RF*	*DF*

Overall, this RRA category was perceived as a strength by the experts of the Italian PARs of Southern Wipptal and Val Ferret, who assigned the Best Practice Scenario to all indicators belonging to this category.

Both PARs reported high satisfaction with the current practice of recording past events. In both study areas and for all selected natural hazards, data on past natural hazard events are indeed systematically collected both in terms of spatially explicit and descriptive information, moreover they are digitalised and available online. Furthermore, in both areas and for both hazards, spatially explicit information on the likelihood of occurrence of hazards and assets potentially at risk is available.

In Val Ferret, past snow avalanches are recorded systematically in the Snow Avalanches Cadastre of Aosta Valley Autonomous Region. The database is updated each year since the early seventies, and it became digitalised since the year 2005. Orthophoto documentation as well as descriptive information for many events (e.g. volume/size, triggering cause, date of occurrence) are recorded. Debris flows are instead recorded in the "*catasto dissesti regionale*" (regional hydrogeological cadastre), which was described by the experts as a very high-quality cadastre as well as the one for snow avalanches. Data on historical debris flows events started being collected in the 1990s from archives such as the one from CNR-IRPI of Turin, municipal and regional libraries and archives dating back to events from 1700s, first filling in appropriate paper forms then digitalized in 2000. Moreover, data regarding both natural hazards are accessible online[1]. Hazard maps at the municipality scale are also available for both hazards, however, debris flows susceptibility maps were estimated to carry a higher degree of uncertainty compared to the snow avalanche maps. Nevertheless, according to the participants, decreasing such uncertainty was not considered feasible; thus, no points for improvement were underlined. Finally, spatially explicit information on assets such as cadastre data is available, therefore the assets present in areas subject to natural hazards are known on a general level. However, a more detailed intersection could be possible since no official maps/GIS data is available[2]. Furthermore, no official list of assets exposed to natural hazards is present. In terms of risk, cartography data are limited as only critical infrastructure is mapped and updated. Vulnerability information of single structures is instead missing: acquiring such kind of data was stated to be challenging since this would also mean promptly recording all the changes to buildings (e.g. new windows, maintenance etc.).

In Southern Wipptal, the Provincial Geological Office systematically collects event data on mass movements that caused an intervention or damage and makes them available to the Provincial Agency for Civil Protection, the municipality affected and the deputy body for road management. A standardized and shared way to collect, report and also share data with the public and externals is in place since 2000. Users can freely download the data; however, detailed information associated with the data is only available on request (e.g. protocols for the events etc.) as they contain sensitive information (e.g. photos). They are mostly events involving urban areas or transport infrastructures but also include, as far as possible, some events which did not lead to damage. Events which occurred before 1998, were located and recorded using archival documents or newspaper articles as sources. Historical debris flow events go back to the Middle Ages. Over the years, the documentation has changed, with clear improvements in field surveys and information flow. The provincial database, managed and continuously updated by the Geology and Material Testing Office. Hydrogeological events data are

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[1] Avalanches: https://catastovalanghe.partout.it/ ;
Hydro-geological mass movements: https://catastodissesti.partout.it/

[2] After the workshop, in 2020, this portal was published where an overlay of hazards and assets for the general public is available

transmitted every six months to the national ISPRA database IFFI (Inventario dei Fenomeni Franosi in Italy), which provides an online and standardized database at national level since 2005. Hazard zone plans are available for almost all Municipalities of the Province of Bolzano: for the PAR areas, it has been already approved in Sterzing and is in the process of being approved in Pfitsch and Brenner. These maps are standardized for the entire province, allowing the comparison of hazard situations close to relevant infrastructure. More detailed information such as the number of inhabitants per address is available to the civil protection, however it is not included in such plans. The experts mentioned that overall, the South Tyrolean hazard zone planning scheme can currently be regarded as one of the most advanced hazard mapping schemes in the European Alps.

In the PARs of Kranjska Gora and Oberammergau on the other hand the different indicators received a lower score as the expert rounds found more points for improvement regarding this category.

In Kranjska Gora, the past event database mainly focuses on damage causing events: if a material damage or victims occur, the recording was judged of good quality. Moreover, these data are collected by several different offices and institutions. The aforementioned databases are not publicly accessible online, nor have historical past events been collected. Official maps showing the areas at risk are not present. Developing a map showing areas or assets potentially at risk was seen as a priority, also for restricting or prohibiting the construction of residential and infrastructure facilities in the area of the municipality of Kranjska Gora (see Land Use Planning category).

In the PAR of Oberammergau, the experts recognised a higher quality regarding the database of past events for landslides, compared to that for past rockfall events. All areas are subject to field surveys by local experts. Rockfalls are recorded but the experts reported that the recording process could be made more systematic. Susceptibility maps are available for landslides and rockfalls and developed through a systematic process; magnitude and frequency data however are not available, leaving some room for further improvement. The experts reported the greater challenges underlying the modelling of landslides compared to that of rockfalls; this constitutes a point for future improvement, although experts expressed their doubts on how this could be carried out in a feasible way. Moreover, the experts stated that the scale at which the maps are used impacts their explanatory power: the available maps are indeed perceived as not suitable for looking at small areas in details. Furthermore, potentially exposed assets are not officially pinpointed, as there is no official overlay of the susceptibility maps with an exposure layer.

Land Use Planning

The category Land Use Planning investigates the presence of land use planning tools which include legally binding natural hazard regulations. Some of the avoidance measures considered by the GreenRisk4lps project (e.g. potential building bans in risk prone areas) fall under this category. The situation and the subsequent expert satisfaction in this fields varies among the different PARs (Table 3).

Table 3. Overview of the RRA scenarios assigned by the experts to all the indicators of the Land Use Planning category (green represents the Best practice scenario, yellow the Average scenario, and red the Points for improvement scenario).

Land Use Planning		
PARs/ Indicators	Legally binding tools accounting for risk	
Val Ferret (avalanche-AV/debris-DF)	*AV*	*DF*
Kranjska Gora (rockfall-RF/ debris-DF)	*RF*	*DF*
Oberammergau (rockfall-RF/ landslide-LS + debris-DF)	*RF/ LS*	*DF*
Southern Wipptal (rockfall-RF/ debris-DF)	*RF*	*DF*

In Southern Wipptal, the Hazard Zone Plans are not only available but also legally binding, once approved. Through the approval of the provincial government, the hazard map receives a legal status superior to local land-use and development plans. The incorporation of such a tool in land use planning follows a systematic procedure. A hazard analysis should therefore be carried out for each new construction. As described in the previous sections, the experts showed a high degree of satisfaction with this available tool.

In Val Ferret, land use changes with respect to the hydrogeological risks are also regulated by law. This Regional Law classifies the regional territory into three different hazard classes (high, medium and low hazard) for each type of natural hazard (flooding, landslides, debris flows or avalanches) and for each hazard class identifies the eligible construction activities compatible with the hazard level of the area. The Regional Law No 11 of the 24th of June 2002 approved the procedures for relocating buildings located in areas with a high hydrogeological risk. [3], [4]

In the PAR of Oberammergau there is no clear process that municipalities must follow regarding gravitational hazard maps (while this is present for floods instead). The accuracy of the maps is not yet sufficient for detailed planning purposes. Therefore, land use planning takes into account hazard maps and provides recommendations are made; however, these are not legally binding.

Finally, in Kranjska Gora, local authorities pose building bans and limitations due the exposure of infrastructure and residents through the municipal spatial management plan, but it is not linked to the database of past events, and therefore not updated. Since no official risk maps are available, land use planning restrictions and regulations are therefore based on expert knowledge and not on spatially explicit overlays of assets and natural hazard maps.

Man-made measures

[3] https://www.regione.vda.it/territorio/territorio/rischiidrogeologici/difendere_territorio_dai_rischi/regolamentazione_uso_territorio/default_i.aspx
[4] https://www.regione.vda.it/territorio/territorio/rischiidrogeologici/difendere_territorio_dai_rischi/previsione_prevenzione_rischi_i.aspx

This category looks into the availability of data and plans regarding man-made measures such as grey protection measures (i.e. avalanche nets) or prevention measures (i.e. avalanche blasting) (Table 4).

Table 4. Overview of the RRA scenarios assigned by the experts to all the indicators of the Man-made measures category (green represents the Best practice scenario, yellow the Average scenario, and red the Points for improvement scenario; white that the experts did not assign a scenario).

Man-made measures						
PARs/ Indicators	Inventory of technical measures		Maintenance		Prevention measures	
Val Ferret (avalanche-AV/debris-DF)	*AV*	*DF*	*AV*	*DF*	*AV*	*DF*
Kranjska Gora (rockfall-RF/ debris-DF)	*RF*	*DF*	*RF*	*DF*	*RF*	*DF*
Oberammergau (rockfall-RF/ landslide-LS + debris-DF)	*RF/ LS*	*DF*	*RF/ LS*	*DF*	*RF/ LS*	*DF*
Southern Wipptal (rockfall-RF/ debris-DF)	*RF*	*DF*	*RF*	*DF*	*RF*	*DF*

An inventory of existing technical measures is available in three PARs out of four, but only for measures addressing specific natural hazards. The inspection and maintenance responsibility of such measures lies with different authorities not only among the different PARs, but also in the same PAR, for different types of measures. Preventive measures (e.g. controlled explosions for avalanche control, evacuation of houses, closure of ski tracks/roads) are carried out when the necessity arises in all the PARs.

In Val Ferret, an inventory of technical measures is only available for snow avalanches, which is spatially explicit, digitalised and updated frequently. In this inventory the status of the measures is not explicitly expressed. On the other hand, a similar inventory is not available for debris flows measures, as no official spatially explicit information (i.e. a shapefile) exists. The experts saw this as a point for improvement, however, they reported a lack of resources to conduct such a task. Although measure monitoring and maintenance was reported to take place on regular basis: the experts are always promptly informed in case of damage to a measure or in the occurrence of a natural hazard. However, no official maintenance plan exists. As far as debris flow measures are concerned, the absence of a maintenance plan was reported to be connected to the non-existence of the inventory. Preventive measures against avalanches are carried out upon need; delays however occur due to bureaucracy behind blasting activities. The experts also underlined the challenge to take preventive measures in the context of debris considering them as too uncertain. Debris flows are not predictable at an appropriate level of detail at the current state of knowledge. The triggering and predisposing causes can be identified in high intensity summer precipitations. However, the high frequency of thunderstorms during the summer and their short duration as well as specific location makes a road closure plan complex. Avoidance strategies are in fact problematic as they can cause conflicts with commercial activities.

In Kranjska Gora an inventory of debris flow measures is also missing, as for that regarding rockfalls. The experts expressed the need to improve this point. Indeed, within the GreenRisk4Alps project an App has been already developed to record the location, size and status and constitute an inventory of debris flow measures. The majority of measures are maintained due to the fact that they are linked with infrastructure objects (regional, local and forest roads, cycling paths…); however, also in this PAR an official maintenance plan is not available. Some experts indeed considered maintenance as a potential point for improvement especially that addressing debris flow measures, as their status is sometimes poor leading to failure and malfunctioning.

In Southern Wipptal instead, an inventory for debris flow measures is already available. The available database contains all protective structures for rockfalls, including information on status, updated by the Road Authority. The maintenance obligation for rockfall measures lies with the competent authority which differs from measure to measure (i.e. road construction office; or if municipality is responsible, it depends on the municipality). Hydraulic works instead are the responsibility of the Autonomous Province of Bolzano. Due to this difference in ownership, data on the measures, including their status, are not known transversally among all the different actors. Preventive measures such as blasting are conducted not only for snow avalanches but also for rockfalls. However, a lack of technical means for blasting was reported, requiring longer time to bring material to the blasting site.

Finally, in the PAR of Oberammergau, the inventory exists for both hazards, but accessible only by specific entities, such as road construction offices. Inspection protocols are carried out once a year along roads, under a project initiated in 2016. Torrent structures are regularly monitored following a plan (1 to 10-year cycle). Some experts reported a need to optimise this process identifying this as a potential point to improve. Road maintenance crews drive the roads weekly to get an overview on the rockfall situation and map the areas; potentially threatening rocks are removed, or protective fences are built. Sometimes however, legal hurdles may interfere with the prompt treatment and intervention to prevent the potential hazard.

ECO-DRR (Protective forest)

While the previous category looked at technical measures, this category analyses green measures, in particular the protective forest, the focus of the project.

Table 5. Overview of the RRA scenarios assigned by the experts to all the indicators of the ECO-DRR category (green represents the Best practice scenario, yellow the Average scenario, and red the Points for improvement scenario; white that the experts did not assign a scenario).

Nature-based solutions						
PARs/ Indicators	Protective forest maps		Protective forest law		Integration in risk assessment	
Val Ferret (avalancheAV/debris-DF)	*AV*	*DF*	*AV*	*DF*	*AV*	*DF*
Kranskja Gora (rockfall-RF/ debris-DF)	*RF*	*DF*	*RF*	*DF*	*RF*	*DF*
Oberammergau (rockfall-RF/ landslide-LS + debris-DF)	*RF/ LS*	*DF*	*RF/ LS*	*DF*	*RF/ LS*	*DF*
Southern Wipptal (rockfall-RF/ debris-DF)	*RF*	*DF*	*RF*	*DF*	*RF*	*DF*

Protective forest maps are available in all the PARs analysed. However, in Val Ferret and in Kranjska Gora, the experts specified that these maps are not regularly updated, for example after storms and windthrows, due to a lack of resources. Also in Southern Wipptal, the map was lastly updated in 2013.

In all the PARs there is no differentiation of different natural hazards in the protective forest mapping. In Val Ferret, the answers referred mainly to snow avalanches as it was commented that forests have a limited effect on the mitigation of channelized debris flows. In this PAR, 50 percent of the existing forest is mapped as a protective forest, with no further prioritization or indication on where the forest plays the biggest role in protecting the assets. In Oberammergau the participants also underlined that the differentiation between object protection forest and site protection forest is not currently available. In all the PARs field surveys are conducted to realise the maps, which were perceived by the experts as "very precise in terms of coverage" in Oberammergau, while "not as detailed as in Austria" in terms of results in Southern Wipptal.

Protective forests are recognised and protected by law in all the considered PARs.

In Val Ferret, for instance, land use changes are possible but with limitations: these require an evaluation process limiting the number of trees which can be cut (e.g. if a ski track wants to expand). The cutting of trees requires a permission. Silvicultural actions on protective forests are not compulsory by law but manuals are available for protective forest management. In Oberammergau, silvicultural actions on the protective forest require permissions.

Forest is incorporated in hazard and risk assessments at different extents in the examined PARs.

In Kranjska Gora, forest is not accounted for in natural hazard and risk assessment as this is not systematically carried out.

In Val Ferret, although the experts showed a high degree of satisfaction with the available products and tools, forest is considered implicitly in risk assessment, through expert-based judgement. The knowledge is available but not included quantitatively and systematically in natural hazard modelling. A lack of resources to work on this topic was reported: for example, also when a forest is destroyed by a natural hazard, not only is the respective protective forest not mapped again post event but, as a consequence, re-assessment of risk is also rarely carried out.

In Southern Wipptal, forest is sufficiently considered within the hazard evaluation. The experts reported that after the occurrence of forest damage, modelling can be carried out again thanks to the available simulations.

In Oberammergau, both rockfall and landslide modelling takes into account the protective forest; however, according to some of the participants the results could be more detailed (for instance, including the conditions of the forest).

Risk communication

This category analyses how the public is informed on the potential risks in the different PARs, specifically looking at the quality and inclusiveness of risk communication activities. In general terms, many experts of the different study areas considered specific points of this category as potential points for improvement in the future (Table 6).

Table 6. Overview of the RRA scenarios assigned by the experts to all the indicators of the Risk Communication category (green represents the Best practice scenario, yellow the Average scenario, and red the Points for improvement scenario).

Risk communication								
PARs/ Indicators	Variety of channels		School education		Variety of languages		Assessment of risk awareness	
Val Ferret (avalanche-AV/ debris-DF)	*AV*	*DF*	*AV*	*DF*	*AV*	*DF*	*AV*	*DF*
Kranjska Gora (rockfall-RF/ debris-DF)	*RF*	*DF*	*RF*	*DF*	*RF*	*DF*	*RF*	*DF*
Oberammergau (rockfall-RF/ landslide-LS + debris-DF)	*RF/ LS*	*DF*	*RF/ LS*	*DF*	*RF/ LS*	*DF*	*RF/ LS*	*DF*
Southern Wipptal (rockfall-RF/ debris-DF)	*RF*	*DF*	*RF*	*DF*	*RF*	*DF*	*RF*	*DF*

The public is generally informed through a diversity if channels both in peace time and during emergencies. Traditional and social media are often adopted as a means of communication as well as public meetings with active involvement of citizens.

In Val Ferret, an App is being implemented and a sms-alert system is available to inform citizens using the numbers obtained through the waste tax registration. This system however does not include all the people who are usually present in the valley as most of those are tourists in hotels or renting houses and therefore not registered in the waste management systems. The participants also underlined the need to further include the private sector to better collaborate in terms of risk communication to tourists, as also the Aosta Valley region is interested in the topic. Moreover, the expert reported as a best practice example the system in place on the other side of the Alps, in Chamonix (France) where a broader range of people is included: i.e. tourists have to leave their mobile number to the hotel for alerting purposes.

General considerations raised in more than one PAR regarded the difference in communication activities for the different natural hazards. Communication regarding debris flows seems weaker compared to that regarding other natural hazards in Val Ferret and Oberammergau due to the uncertainty underlining this natural hazard and to the lack of funding. Moreover, communication during emergency times was reported to work better compared to that of peace times.

Risk communication activities are conducted in different languages in the Southern Wipptal (e.g. the Euregio avalanche report is available in seven different languages) and in Val Ferret (most activities address French, Italian and English speakers). The PARs of Oberammergau and Kranjska Gora on the other hand acknowledged a lack of information in foreign languages, with a potential for improvement.

The experts of all the PARs underlined a lack of institutionalised, official education in the field of natural hazards and risks. Several punctual educational activities are ongoing in the different PARs: for instance, experts are sometimes invited to schools for seminars (Val Ferret, Oberammergau, Southern WIpptal), safety days are organised in schools by Civil Protection (Southern Wipptal); however, this does not occur in a systematic way and depends upon individual initiatives from single teachers or schools.

Overall, the results of the previously described risk communication activities are not systematically and officially assessed in any PAR. Some sporadic activities are conducted in some of the analysed PARs: for instance, in Southern Wipptal, the Interreg Alpine Space project RiKoSt conducted surveys to analyse risk perception and risk communication activities in several municipalities; moreover, a survey for ski tourers on risk awareness was also conducted in the same PAR. However, this type of activities is not conducted on a regular basis as they were funded and conducted within specific and time-limited projects. In Val Ferret, instead, experts reported to be aware of the efficiency of measures by observing tourist behaviours and transgressions to the rules. However, also this is not carried out systematically in space and time.

Early Warning

The following category addressed in the RRA is Early Warning, investigating the alert and automatic detection systems available in the study areas. Also for this category the experts perceive the local situations differently (Table 7).

Table 7. Overview of the RRA scenarios assigned by the experts to all the indicators of the Early Warning category (green represents the Best practice scenario, yellow the Average scenario, and red the Points for improvement scenario; white that the experts did not assign a scenario).

(Early)-Warning				
PARs/ Indicators	Alert systems		Automatic detection systems	
Val Ferret (avalanche-AV /debris-DF)	*AV*	*DF*	*AV*	*DF*
Kranjska Gora (rockfall-RF/ debris-DF)	*RF*	*DF*	*RF*	*DF*
Oberammergau (rockfall-RF/ landslide-LS + debris-DF)	*RF/ LS*	*DF*	*RF/ LS*	*DF*
Southern Wipptal (rockfall-RF/ debris-DF)	*RF*	*DF*	*RF*	*DF*

In Val Ferret, as described in the previous section, an SMS alert is available informing on both natural hazard forecasting and on behaviour (i.e. no parking, road closures, what to avoid…etc). The experts convened on the fact that the system can be improved to include also tourists in such alerts, who are at the moment excluded since their number is not available to the municipality of Courmayeur. Some detection systems for avalanches are present on specific slopes as well as an automatically activated traffic light. The use of automatic detection systems is limited to the presence of critical infrastructure as people are already subject to many restrictions throughout the year. Having also temporary bans due to automatic road closures (i.e. false alarms) would create further inconvenience; moreover they cannot be applied everywhere due to limits and costs, overall leading to scarce acceptance.

In Southern Wipptal, routines are in place, scenarios are discussed in the functional centre and instructions or recommendations are communicated to the citizens accordingly. All offices and authorities are involved before alerting the population; however, no automatised alert is in place and no specific measures are planned either as the initial situation was judged as not suitable for such option. The civil protection has been constantly in contact with companies offering monitoring technologies for avalanches; the reliability for debris flows is however not yet clear. In other localities on the Province of Bolzano, outside the PAR, many pilot projects have started but room for improvement is still present, according to the participants. Monitoring systems with geophones and pendulum systems are in place for debris flows (Antholz and Nalser Bach). Such systems work well, but are rarely used because the reaction time from movement detection is too short while the costs are high.

In the PAR of Oberammergau, a distinction between different natural hazards was made. Since rockfalls do not constitute a large-scale threat to the population but only happens in specific locations, warning was not considered feasible. A weather app is available (WetterWarnApp of the Deutscher Wetter Dienst-DWD) which provides indications on individual hazards, including rockfalls.

In Kranjska Gora there are practically no early warning systems, and none that would detect the danger automatically. There are some sensors in the biggest rockfall areas in Belca, but evacuation is carried out door to door by the firefighters.

Response

The next category addressed the response after an event has occurred. It firstly examines the assessment of loss and damage and then investigates the expert satisfaction with the existing emergency civil protection plan and with practical exercises carried out by different experts.

Table 8. Overview of the RRA scenarios assigned by the experts to all the indicators of the Response category (green represents the Best practice scenario, yellow the Average scenario, and red the Points for improvement scenario).

Response						
PARs/ Indicators	Damage assessment		Emergency/Civil Protection Plan		Practical exercises	
Val Ferret (avalanche-AV /debris-DF)	*AV*	*DF*	*AV*	*DF*	*AV*	*DF*
Kranjska Gora (rockfall-RF/ debris-DF)	*RF*	*DF*	*RF*	*DF*	*RF*	*DF*
Oberammergau (rockfall-RF/ landslide-LS + debris-DF)	*RF/ LS*	*DF*	*RF/ LS*	*DF*	*RF/ LS*	*DF*
Southern Wipptal (rockfall-RF/ debris-DF)	*RF*	*DF*	*RF*	*DF*	*RF*	*DF*

The experts of Val Ferret reported that assessment of loss and damage occurs promptly. Damage resulting from both avalanches and debris flows are recorded in the databases through a formal process, however no reference was made to how systematic the adopted approach is. The Courmayeur Municipality Civil Protection Plan, the official document that contains the operating procedures for dealing with a natural hazard event, is under revision but it was judged as complete according to some participants. Others reported that it is not sufficiently detailed from a technical point of view regarding the specific needs of a municipality like Courmayeur. Including concrete indications regarding risk areas and types of natural disasters would be a first step forward. Protection forest management could also be introduced in this plan. Moreover, practical simulations with a larger expert and community involvement (i.e. including population/volunteers) are planned but not yet carried out. Although experts regularly carry out simulations, these are not done in large groups and the collaboration between expert groups is not yet tested.

In the PAR of Kranjska Gora, damage estimates are carried out in the field, immediately after the threat stop, using a uniform system for the whole country. The emergency plans in case of events is elaborated and perceived as functional, with the full collaboration of different services and stakeholders (e.g. Municipality of Kranjska Gora, the local Utility Service, firefighting societies, construction and forestry services companies). The Utility Service has pre-prepared materials for quick action (sand, flooding bags, rocks, surfaces, morals). The municipality also holds regular meetings of the Utility Service and firefighting societies to be prepared for such events. According to the participants, the municipality is generally characterized by a very good response to natural disasters with its intervention system. They consequently identified this category as one of the strengths for this PAR. Nevertheless, no practical simulation or exercises are carried out for rockfall and debris flow events.

In the PAR of Southern Wipptal, damage is recorded, not only including that involving assets such as forest and access roads but also the one regarding forests, which is specifically surveyed and documented by foresters. The PAR municipalities have a Municipal Civil Protection plan providing different event scenarios. These however, according to the participants, are usually not practiced sufficiently by many actors. Practical exercises vary indeed from municipality to municipality. Moreover, a point for improvement which was reported is the lack of communication between the newly developed hazard zone plans and the older municipal civil protection plan.

Finally, in Oberammergau, as well as in the other PARs, damage is assessed and recorded systematically. During the discussion, diverging opinions regarding the civil protection plan were put forward: some experts underlined that the plan is not hazard-specific and there is room for improvement. For water related hazards, emergency drills take place regularly, also involving different experts, for instance firefighters.

Recovery

The last category of the RRA regards the recovery phase, after the emergency has passed. In particular, this includes the following topics: the availability of an insurance against the specific natural hazard, the prompt recovery and repair of the damages caused by the natural hazards and finally the analysis of the causes that led to the damage and loss to improve risk management practices in the future.

Table 9. Overview of the RRA scenarios assigned by the experts to all the indicators of the Recovery category (green represents the Best practice scenario, yellow the Average scenario, and red the Points for improvement scenario).

Recovery						
PARs/ Indicators	Insurance		Damage recovery		Assessment of what went wrong	
Val Ferret (avalanche-AV/ debris-DF)	*AV*	*DF*	*AV*	*DF*	*AV*	*DF*
Kranjska Gora (rockfall-RF/ debris-DF)	*RF*	*DF*	*RF*	*DF*	*RF*	*DF*
Oberammergau (rockfall-RF/ landslide-LS + debris-DF)	*RF/ LS*	*DF*	*RF/ LS*	*DF*	*RF/ LS*	*DF*
Southern Wipptal (rockfall-RF/ debris-DF)	*RF*	*DF*	*RF*	*DF*	*RF*	*DF*

Insurance against the selected natural hazard was reported as a potential point for improvement in all the PARs, because this is often not available or too expensive. However, the framework and implementation behind such measure should be developed at a higher level (i.e. national). For instance, in the past South Tyrol tried to introduce an insurance but this decision was subsequently vetoed by the State. In Val Ferret, for example, experts perceived that the people tend to transfer the entire responsibility towards the public authorities: "everything should be resolved by public entities". The State however only refunds material damages and not for example business closures.

Damage was said to be promptly addressed in all the PARs in case of public assets affected (i.e. critical infrastructure). In this case, an immediate response and recovery always occurs, also in case of minor damage; on the contrary, the repairing of damage to private properties depend on the situation (Val Ferret).

Past experiences are taken into account in different ways from the various PARs to improve risk management of the future. In Kranjska Gora, past experience are not systematically collected to improve future hazard management. In Val Ferret, a non-systematic assessment is carried out after an event occurs: often this leads to an identification of the points for improvement; these however are often challenging to be put in practice due to environmental and socio-economic factors. Considering the narrowness of the valley, the availability of space is limited. For example, although a law for relocation is available, it is applied in practice in very few cases both for political (votes/unpopular decision) and for practical reasons (moving does not necessarily solve the problem). Moreover, the high presence of second homes with no permanent residents makes the situation even more complicated. In Southern Wipptal, working groups meet regularly and discuss what has gone well and which points failed. In case of major incidents, major analyses are carried out. Lastly, in Oberammergau the experts highlighted that such process takes places systematically for flood events but could be improved for other natural hazards.

Climate Change Adaptation

This overarching category looks at the availability of local climate change adaptation strategies or plans and to the extent to which climate change is included in the modelling and planning related to the above-mentioned natural hazards.

A specific local adaptation strategy or plan is not available for any of the municipalities present in the PARs. However, climate change is a recurring topic in many projected carried out within the different study areas. For instance, the municipality of Courmayeur is involved in projects on climate change adaptation: Adapt Mont-Blanc (Adaptation of spatial planning to climate change in Mont-Blanc area) and the Carta di Budoia (action of Alpine municipalities in the field of local adaptation to climate change). Climate change scenarios are also being adapted to the Valle d'Aosta context. The goal is to develop a plan due next year (2020). In Kranjska Gora, protocols for climate change adaptation have been made, especially in the forestry sectors, but they have yet to be implemented into management plans.

After going over all the steps of the risk management cycle, the points given to each indicator were recorded, moving on to the last step of the RRA, the Risk Evaluation. In this step the RRA risk management profiles are created and discussed with the participants for each of the analysed PARs.

It should be noted once more that the RRA Profiles presented below provide an overview on the overall expert perception regarding risk management practices available in the different PARs (Figure 2). A higher or different score among different areas does not necessarily mean that the respective actions are carried out better or completely differently but only represents the satisfaction and the need for improvement pinpointed by the participants of the RRA workshops. For instance, in some cases points for improvement were found also for the measures or tools which were perceived as a best practice; in other cases, conversely, although some measures or tool were not fully available, experts were still satisfied with the status quo.

Figure 2- RRA Profile for the four different PARs.

3. Exposure Hotspot analysis Results

Background

This chapter contains the results of the spatially-explicit risk assessment and in particular the exposure analysis for five GR4Alps Pilot Action Regions (PARs). A definition of terminology and the risk concept applied as well as a description of objectives, how the exposure assessment fits in the overall risk analysis and the selection of asset types to be considered in each PAR is described in Deliverable 2.4.2 "Identification of potentially endangered assets and functional assessment of protection measures in the PARs". Deliverable 2.4.2 also contains a complete list of data sources used in the analysis of each PAR.

The spatially-explicit exposure assessment is complementary to the Rapid Risk Appraisal described in the previous chapter. It uses the results of the modelling of natural hazard and forest protective effects developed in WP1. Integrating the forest relevance exposure **hotspots**, or in other words **areas where forest is reducing the risk considerably**, with the knowledge gained in the expert-based Rapid Risk Appraisal workshops allows to identify potential focus areas for a subsequent more detailed risk analysis.

The aim: The overall objective of the exposure analysis was to identify hotspots at a regional scale where forest is most relevant to reduce the impact of mass movements on infrastructure.

Exposure in the risk framework

As described in report D.T3.2.1 and in Chapter 4.3 of Volume 1 of the GreenRisk4Alps Handbook: Alpine protective forests as Ecosystem-based solution for Disaster Risk Reduction (Eco-DRR) (Teich, et al., 2021), exposure is, besides hazard and vulnerability, one of the three components determining the risk. Exposure, as defined in the UNDRR (United Nations Disaster Risk Reduction) glossary, refers to *"… the situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas"* (OIEWG, 2016). Hazard is defined as "*a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation*" (OIEWG, 2016). Vulnerability was not considered in this analysis, even if it is possible to be exposed but not vulnerable. One could argue, though that modifying a building structure in such a way that it mitigates potential loss from rockfall, avalanche or landsliding, depending on the magnitude of a potential event, is hard to achieve at regional scale. Without exposure, though, there is no risk. Vulnerability was also excluded for simplicity reasons. The aim of this analysis was to develop a methodology that allows to identify and spatially map hotspots where forest plays a major role to protect static assets at regional scale. Those hotspots can subsequently be analysed in more detail by local experts considering the specific risk in that location and for locally relevant hazards and assets of value.

Data

Input data into the exposure hotspot analysis consisted of 1) hazard modelling outputs and 2) types of assets of value representing exposure. The analyses used the hazard model outputs of the three gravitational hazard types considered in GR4Alps, i.e. avalanche, rockfall and landslide (see Figure 3). Each model output has a 10 m resolution grid classified between 0 and 1, The closer the value to 1 the higher the relevance of the forest on reducing landslide impact on an area and the risk to infrastructure in the cases of rockfall and avalanches. See Deliverable D.T.2.4.2. for a description on the modelling of object protection forest with a direct protection function.

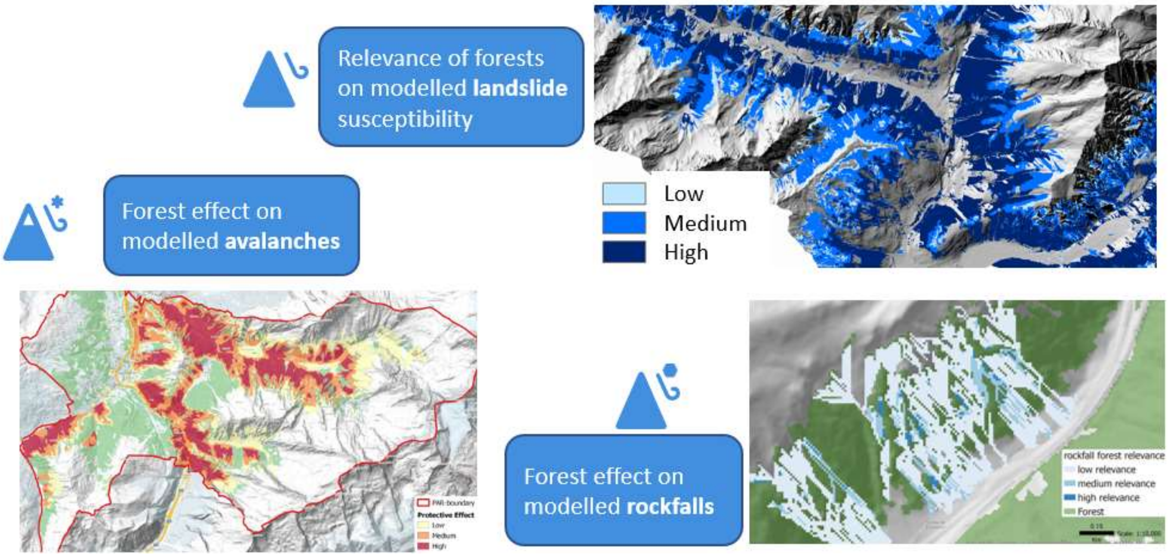

Figure 3: Hazard forest effect model outputs classified into low, medium, high

The second component of the analysis, the assets of value were sourced in their original format from each PAR (see Figure 1) The obtained building footprints, transport and recreational infrastructure data sets were pre-processed, rasterized and classified into two classes depending on type of asset (i.e. high value, low value). The resulting grids have a resolution of 10 m for each PAR. Asset types were classified in two classes in order to make a distinction of the importance of asset types. Class value 1 represents a lower asset value (e.g. tertiary road) and class value 2 a higher asset value (e.g. primary road). Figure 4 provides an overview of the different asset types considered in the analysis. The same 10 m asset grid was used in the avalanche and rockfall hazard modelling with the result that modelled outputs are present only in locations with forestand assets are present at the respective location or in reachable distance. More details on the forest effect hazard modelling are available in D.T.2.4.2. Figure 5 illustrates in a map of an alpine town the typical spatial distribution of buildings, different types of roads as well as recreational infrastructure.

Figure 4: Types of assets constituting the exposure component of the analysis

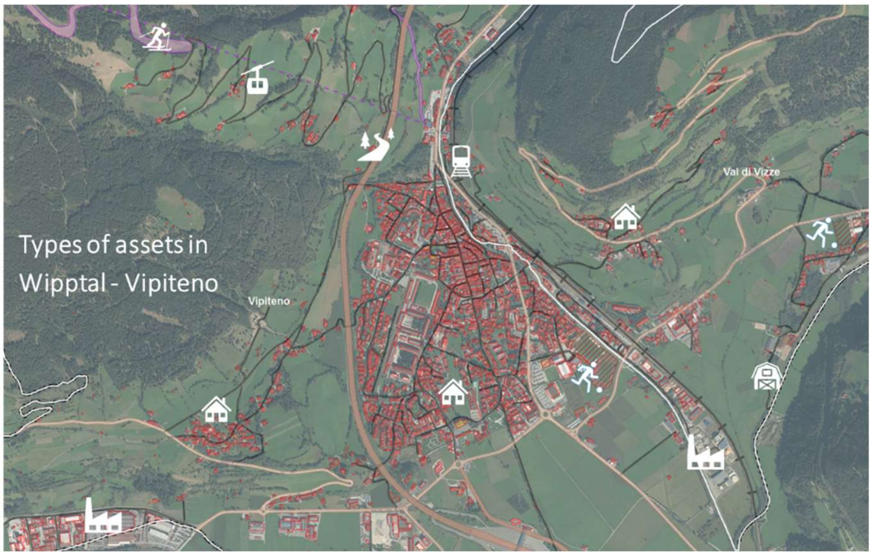

Figure 5: typical alpine town and locations of exposed elements

Methodology

The approach of identifying and mapping exposure hotspots developed in GR4Alps consists of a spatial overlay of the forest relevance of each modelled hazard with the assets of value, i.e. buildings, transportation and recreational infrastructure. The forest relevance model output was classified into three classes showing within each PAR of relatively low, medium and high forest relevance on the respective hazard. In simple terms, high forest relevance means that the hazard would be considerably higher without the presence of the current forest and low relevance indicates that the hazard situation is influenced only moderately by the current forest in place (or in reachable distance). Thus, if no forest is present the relevance of the forest is zero, however there might still be a hazard potential. Consequently, this analysis only considered hazards in their combination with the current forest.

Figure 6 shows an example of the landslide forest relevance model output classified into low, medium high and the asset class values higher and lower for the alpine town of Vipiteno, Sterzing in the PAR Wipptal South.

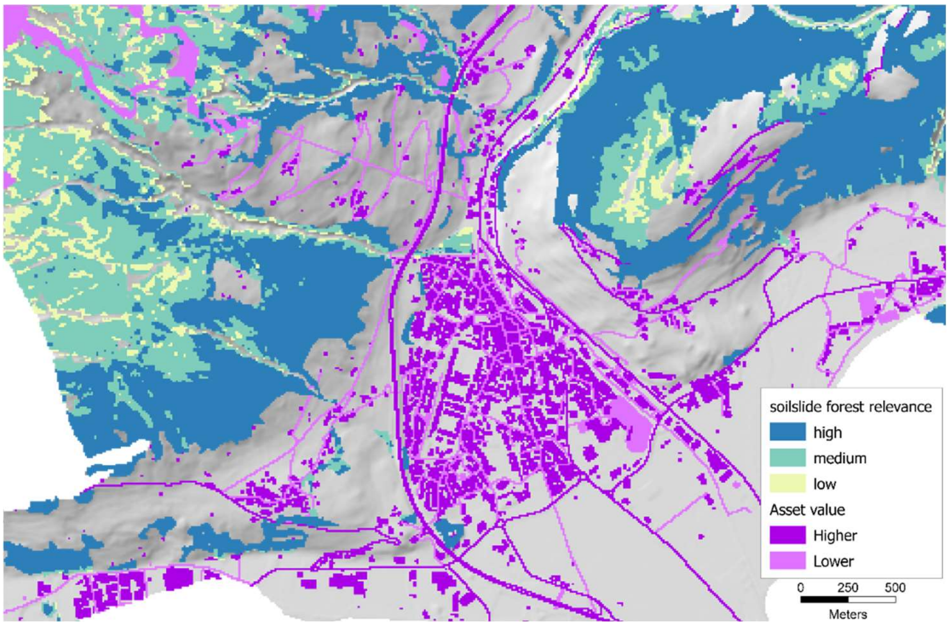

Figure 6: Map showing the landslide model output for the town of Vipiteno in the PAR Wipptal South showing forest relevance classified in low, medium and high. A spatial overlay of these layers resulted in a map showing all possible class combinations (see Figure 7, Figure 8).

Figure 7 shows the spatial combination of each forest relevance class with each asset type class. The purple areas depict asset locations where the forest was modelled to have no protecting function with regard to the respective hazard (i.e. in this case landslides). Instead, the areas with colours from red to green highlight locations where the current forest influences the hazard situation by a varying degree while assets of different value are present or in a distance reachable by the hazard of interest.

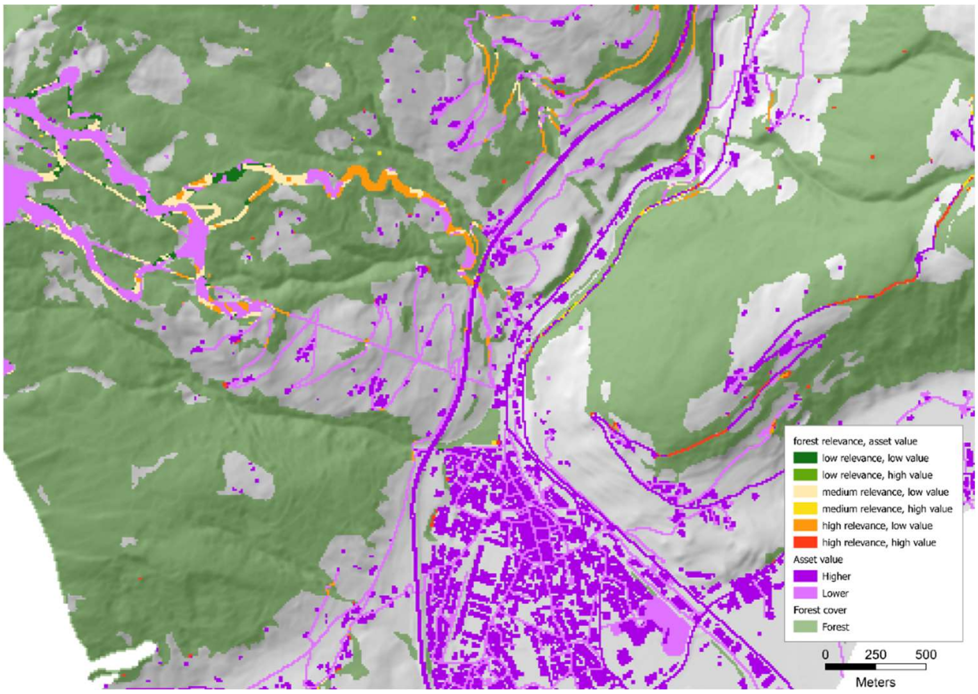

Figure 7: Map showing the possible combinations of forest relevance and asset value in a small area in WIpptal South

Figure 8 shows the steps of combining hazard model outputs and assets of value for the area of the Brenner pass, part of the European Transport Network and the most important alpine pass connecting northern and southern Europe with more than 2.5 million heavy good vehicles crossing in 2019 (European Commission, 2020). As this example demonstrates, the current forest has a substantial relevance on reducing the exposure of (high value) assets (e.g. highway) against avalanches.

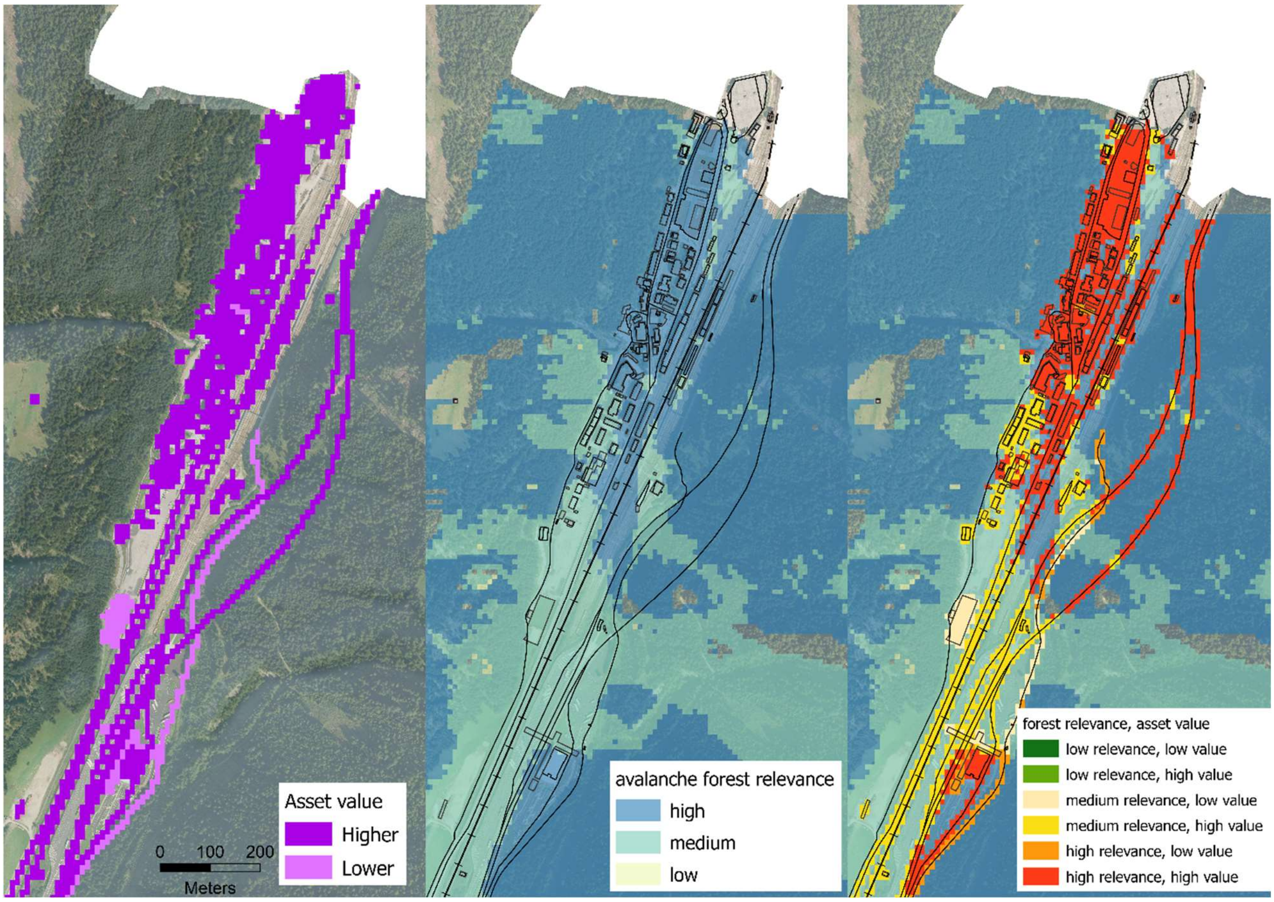

Figure 8: Map showing the two asset value classes (left panel), the three levels of forest relevance (center panel) and the combination of the two (right panel). The area show in at the Brenner pass in the north of the Wipptal South Pilot Action Area.

The area covered by each of the combined forest relevance/asset type classes for a PAR provides insights into the magnitude of protection provided to infrastructure by the current forest against the respective hazard. See Figure 9 for the example of avalanche forest relevance in the PAR Wipptal South.

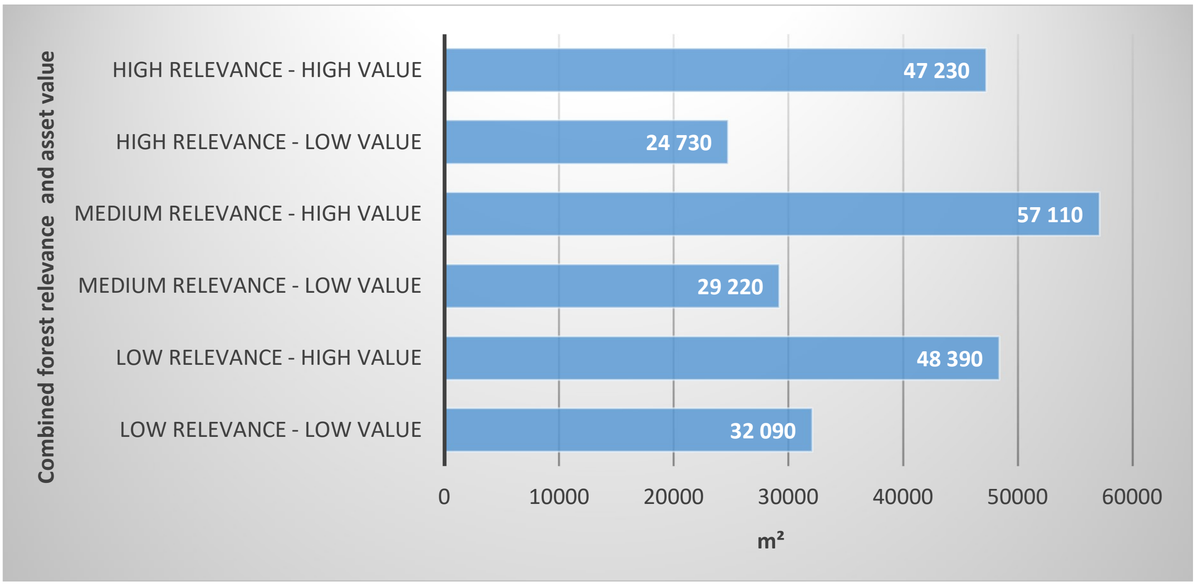

Figure 9: This chart shows the area in m² of assets of value where the forest is of relevance on the modelled hazard ((results for avalanches in the PAR Wipptal South)

Results

As a key output of the analysis exposure hotspots were visualised in maps for each PAR by showing those areas enlarged in red where both, the forest relevance on the modelled hazard and the asset value is high. See Figure 10 for an example of the PAR Wipptal South and the exposure hotspots for avalanche forest relevance.

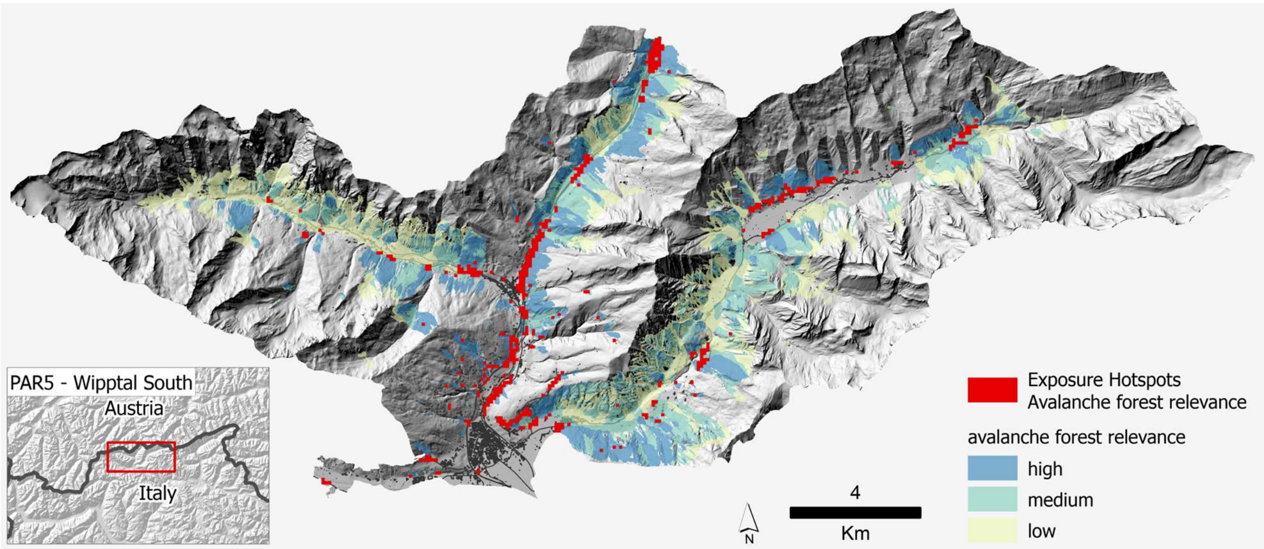

Figure 10: This map shows exposure hotspots of forest relevance on the avalanches modelled in the PAR Wipptal South. In simple terms, the red areas show where forest provide a considerable protection to static assets with a high value (e.g. buildings, higher ranked streets)

Finally multi-hazard exposure relevance exposure hotspot maps were created by combining the hotspots of the three hazard types considered. See Figure 11 for the multi-hazard forest relevance exposure hotspot map for the PAR Vals/Gries

Exposure hotspot maps were produced for all GreenRisk4Alps Pilot Action Region and are available for download on the project communication portal.

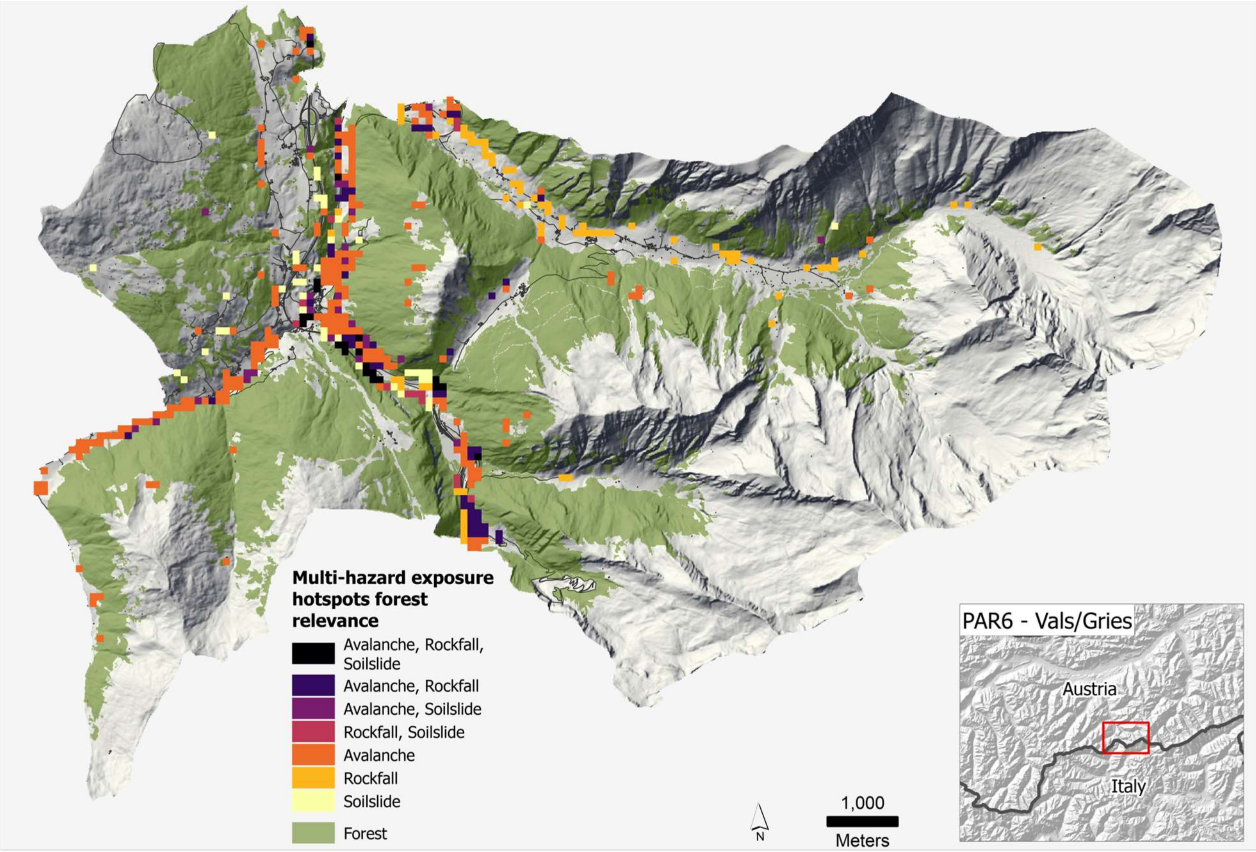

Figure 11: This map shows forest relevance exposure hotspots combining the three hazard types under consideration. Here the example of the GR4Alps Pilot Action Area Vals/Gries.

Conclusion

Aim of this analysis was to provide decision makers of alpine regions with maps of information where forest has the biggest relevance on risk reduction in their region. This maps were produced using model outputs from GreenRisk4Alps on forest relevance for avalanche, rockfall and landslide processes and local spatial information on assets of value. Regional and local decision makers and stakeholders can consult the exposure-hotspot per hazard type as well as multi-hazard exposure hazard forest relevance maps in order to discuss with each other incorporating local knowledge and other existing information, plans and maps how to develop those areas in the future.

4. WP3 Workflow for risk management strategy prioritization

The decision support tools presented in this deliverable as well as the Forest Assessment Tool (FAT) available online under https://gr4a.geocodis.com/ and the underling TEGRAV analysis, presented in Deliverables DT 3.3.1, DT3.3.2 can be integrated and used jointly to prioritise risk management measures. Figure 12 provides an overview on the workflow and combination of the different approaches.

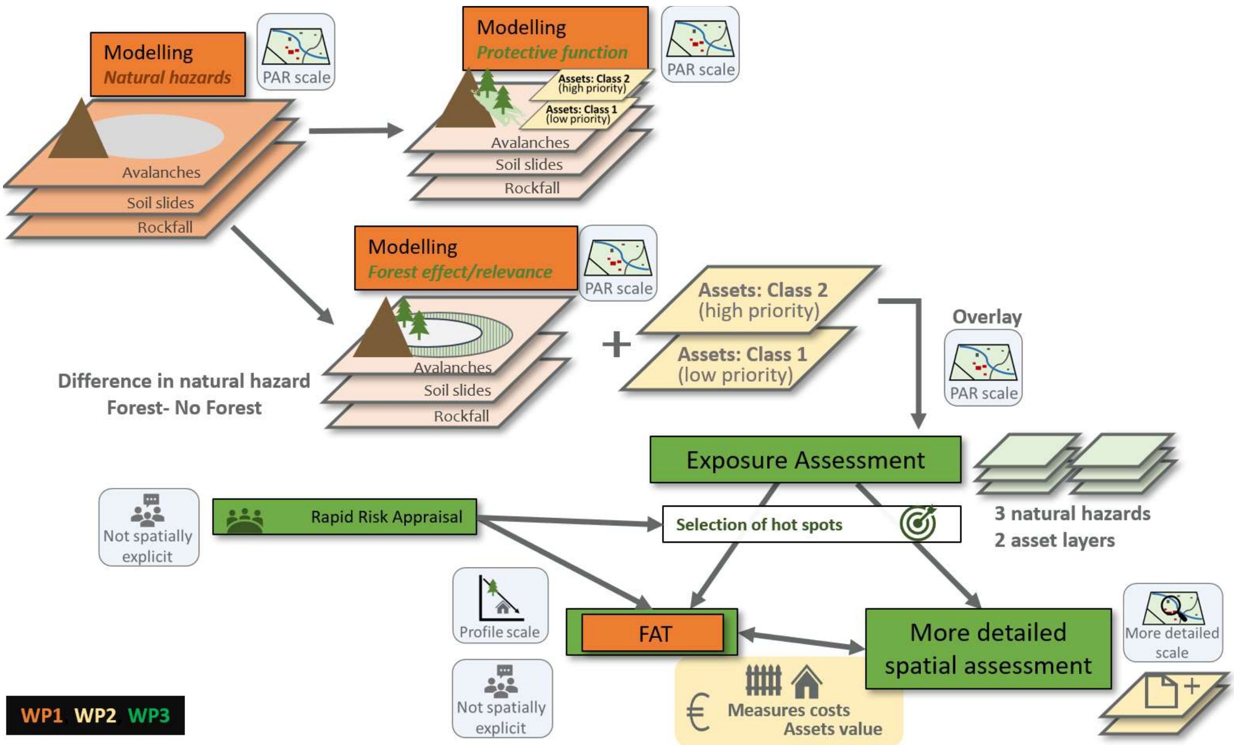

Figure 12. Workflow and links between the different GreenRisk4Alps risk-based decision support tools (Rapid Risk Appraisal, Exposure hotspot analysis and FAT)

As described in Chapter 2, the RRA provides an overview on the perceived strengths and weaknesses of existing risk management practices, leading to a joint identification of potential improvements. Understanding the current situation and the resultant expert satisfaction can serve as a basis to define an improved risk management strategy, including ECO-DRR measures, such as protective forests. Recognising the strengths and weaknesses of the different measures and tools available can also help to show which GreenRisk4Alps products are of most interest for each study area. Moreover, thanks to the identification step, the RRA approach can serve as a starting point to get to know a specific area under consideration and thus allowing a better interpretation of the spatially explicit assessment, generated within the GreenRisk4Alps project.

The Exposure Hotspot Analysis (Chapter 3) provides a spatial overview and proxy of the relevance of forests for risk reduction at regional scale. This can help to define areas where specific measures on the protective forest are relevant and should be studied in greater detail. Being aware of expert satisfaction regarding the current protective forests instruments helps to better define future measures in this field. Moreover, the exposure analysis can serve to select hotspots and specific profiles where to run the Forest Assessment Tool (FAT). Thanks to the FAT, an economic evaluation of the different measures can be carried out at profile scale, providing an overview on the costs and benefits of different green measures, technical measures as well as avoidance measures. As for the protective forests, the RRA provides insights into other existing measures allowing local stakeholders to make more informed decisions.

All the above-mentioned tools provide a systematic, flexible, and easily reproducible approach which can be applied in other areas or repeated regularly in the same area when improved knowledge, data sets or models are available.

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