D.T3.3.1 - Report 'TEGRAV analysis: an integrated model to compare risk management strategies'

GREEN
RISK
4 ALPS

WP 3

Responsibility for Deliverable

Francesca Poratelli (DISAFA)

Contributors

Cristian Accastello (DISAFA); Filippo Brun (DISAFA); Stefano Bruzzese (DISAFA); Simone Blanc (DISAFA)

Torino, June 2020

GreenRisk4ALPs Partnership

BFW - Austrian Research Centre for Forests (AT)
DISAFA - Department of Agricultural, Forest and Food Sciences, University of Turin (ITA)
EURAC - European Academy of Bozen-Bolzano – EURAC Research (ITA)
INRAE – French national research institute for agriculture, food and the environment, Grenoble regional centre (FRA)
LWF - Bavarian State Institute of Forestry (GER)
MFM - Forestry company Franz-Mayr-Melnhof-Saurau (AT)
SFM - Safe Mountain Foundation (ITA)
UL - University of Ljubljana, Biotechnical Faculty, Department of Forestry and Renewable Resources (SLO)
UGOE - University of Göttingen, Department of Forest and Nature Conservation Policy (GER)
WSL - Swiss Federal Institute for Forest, Snow and Landscape Research (CH)
WLV - Austrian Service for Torrent and Avalanche Control (AT)
SFS - Slovenia Forest Service (SLO)

Table of Contents

Table of Figures

Table of Tables

Table of Attachments

In the last decades natural hazards have gained higher attention due to the increasing losses and economic damages they have been causing. Researchers, practitioners and local administrations studied the best strategies to mitigate and prevent them, using both structural and non-structural defense techniques. In the last decade, the adoption of ecosystem-based solutions for Disaster Risk Reduction (Eco-DRR) has been particularly fostered by researchers (Accastello et al., 2019a, 2019b) and included in international development strategies (e.g. Sustainable Development Goals (Rosa, 2017); Sendai framework (UNISDR, 2015)).
Even though there are already several possible solutions to be used in risk management, such as the adoption of grey or green measures or the closure of entire areas to the public, decision makers are often challenged to choose the best option from both a technical and an economical point of view.

Our aim was therefore to build a model to help decision makers choose among different options by providing an overview of the direct and indirect costs, avoided damages and benefits of the different considered measures. The TEGRAV model (Technical, Green and Avoidance protection measures) can support the mainstreaming of Eco-DRR and raise the awareness of decision makers and stakeholders about the importance of protection forests in the Alps.
The main goal of the present report is to present the TEGRAV analysis methodology, its general principles, concepts, workflow and required data.

The present deliverable is the prosecution of the previous activities carried out within the GR4A project. Specifically, deliverable 3.1.1 “State-of-the-art of risk governance: approaches and tools to manage risk with special focus on forests” collected the state-of-the-art knowledge on the diffusion of Eco-DRR across the Alpine Space (AS), highlighting the limited relevance protection forests have had until now when dealing with protection of assets in mountain areas. Other relevant information regarding the development process of this model can be found in the deliverable 1.6.1 “Forest Assessment Tool - FAT”, where all the features of the online tool in which the TEGRAV is included are described; and in the deliverable 2.4.2 “Identification of potentially endangered assets and functional assessment of protection measures in PAR”, where the methodologies adopted for the assessment of the existing assets and protection measures in the project study areas were explained.

The TEGRAV model

The TEGRAV economic model (Technical, Green and Avoidance protection measures) was created on an empirical hazard model developed by the Austrian Research Centre for Forest (BFW) (see D. T1.2.5 and 1.3.3). Both the hazard and the economic model were developed in *Python* environment and coordinated on bitbucket, with the aim to create an online platform for the combined model, called Forest Assessment Tool (FAT).

The FAT is the final online product which integrates inputs from users, the hazard model and the TEGRAV economic model. The aim of the FAT is to allow online users to compare and valuate different protection measures and their combination. The workflow behind the TEGRAV analysis is presented below, with a focus on the external contributions that are required for the economic computation (Fig. 1).

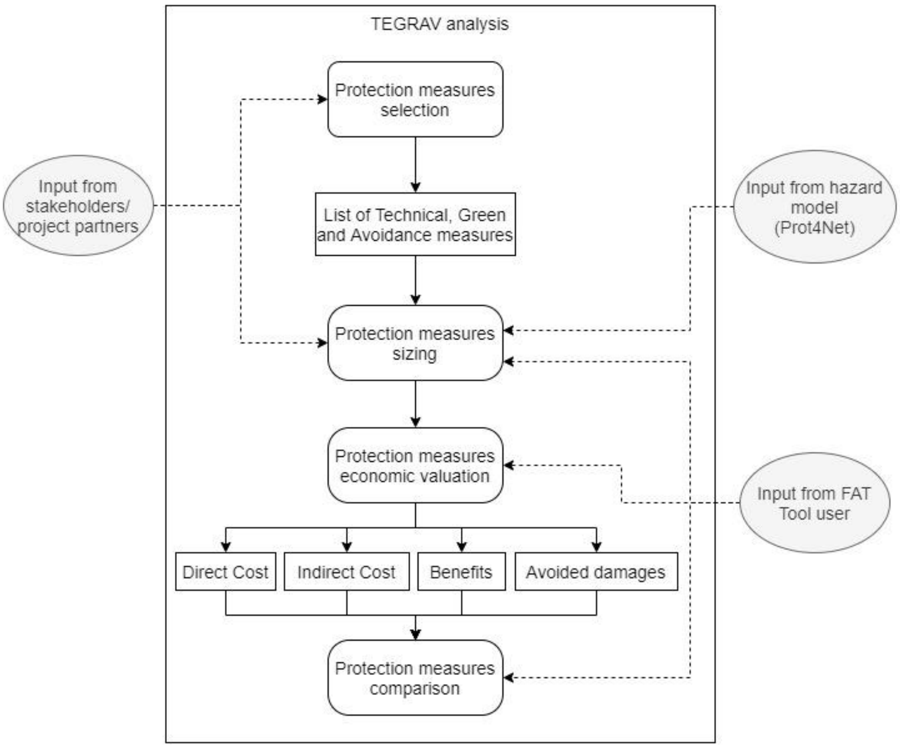

Figure 1- The TEGRAV analysis workflow. The stages of the model are in rounded rectangles, its products in rectangles, the external inputs are in the grey rounds.

As shown in Figure 1, the information needed in TEGRAV are mainly related to three fields:

i. the hazard data, derived from the Prot4Net tool;
ii. the information provided by the project partners, which served to create a database of standard economic values for each AS country (see D. T3.3.2 for more info), and
iii. the input from the users of the online tool concerning the profile of interest and its main forest, orographic and socioeconomic features.

Protection measures selection

The hazards considered in the model are avalanches, rockfall and soil slides, consistently with the general objectives of the project (D. T1.2.5 and 1.3.3). For each hazard, different protection measures have been selected, including technical, green and avoidance measures. The selection was carried out through the involvement of local risk managers and the other stakeholders involved in the project, in order to include in the model at list one example of each of the most common protection measures that are currently put in place in the Alps.

Among the technical, or grey, measures, snow fences and catching dams were considered for avalanches, while rockfall nets and catching dams for rockfall. These measures were chosen after an overview of the protection measures used in the different PARs: a list of the measures installed in the PAR areas was provided and the measures to be included in the model were chosen based on their frequency. No grey measure was considered applicable for preventing the soil slides. Among the green solutions, protection forests were considered as a suitable protection measure for all the hazards. Both the management of forests currently in place and afforestation of non-wooded areas placed along the hazard trajectory were included in the model. Lastly, the avoidance measures considered (common for all hazards) were road closure, building evacuation, building relocation and early warning systems.

The different measures were taken into consideration both singularly and in combination (e.g. considering both afforestation and catching dam). The complete list of measures included in the TEGRAV is presented in Figure 2: they cover all the hazards considered in the project and are placed both in the release area of the hazards and along its transit and runout area.

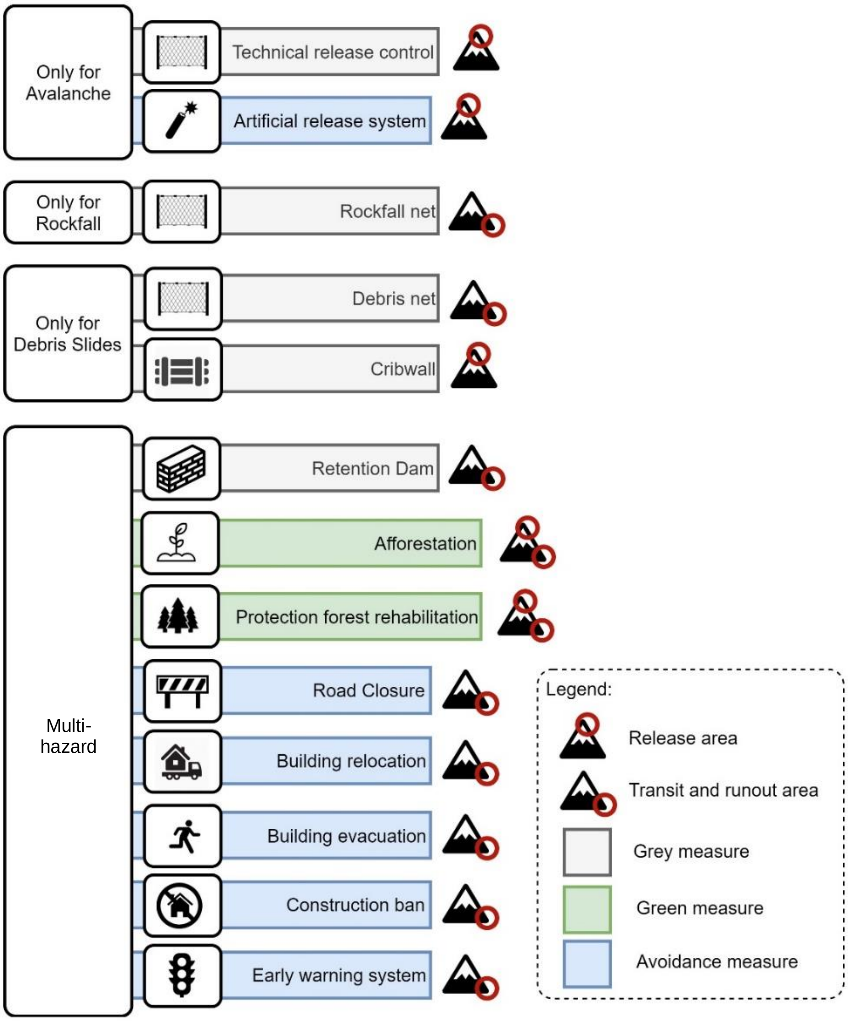

Figure 2 - The complete list of protection measures included in the TEGRAV, distinguished by hazard, area of implementation and typology.

Protection measures economic valuation

The TEGRAV economic model was built on the empirical hazard model called Prot4Net (see deliverables T1.2.5 and 1.3.3 for more info). The aim of this economic module was to perform a full socio-economic assessment of the direct and indirect costs and benefits deriving from the adoption of one or more risk mitigation measures on the selected slopes. In order to accomplish this task, a simplified structure dimensioning of the different protection measures had to be carried out. To do so, some input data were needed from different sources:

- input data such as the profile width or the maximum snow height in the studied area, are meant to be provided by the users while using the FAT to model his own study area features;

- other information is provided by the hazard model, which computes the Energy Line Height (ELH) of the profile in order to dimension the catching dam. The ELH parameter consists of the distance between the ground and the line connecting the top of the hazard path (release area) to the furthest run-out point of the path (Heim, 1932). The alpha angle of the line has to be calibrated using recorded and mapped past events. Alpha angle is usually calibrated on the national/regional scale and based on the type of mass movement process. For example, in Prot4Net $\alpha\_base=25°$ was applied for avalanches based on Austria inventories that describe avalanche events with a 100 year or greater return period (A. Huber et al., 2017).
- finally, some parameters, such as afforestation cost or road repairing cost, were set through a bibliographic research coupled with a consultation of selected risk managers across the Alps. Therefore, depending on the location of the studied profile across the Alps, the user can select the most appropriate value for his own country (mean values are adopted if data are missing). The complete database of the different data for each protection measure is presented in D.T3.3.2.

Once the measures were sized, an economic evaluation of the different available options was possible, providing a comparison of four output parameters:

- direct costs, originated from the sum of construction/implementation cost of a measure; its maintenance costs, which runs along the whole lifetime of the measure; and the dismantling cost, which can occur at the end of its lifetime;
- indirect costs, those originated by the construction/implementation of the measure, which presumably modify an existing situation causing some costs or expenses in the surrounding environment;
- benefits: the sums which, in opposition to indirect costs, are saved or earned due to the construction/implementation of the measure, which modifies an existing situation causing positive economic consequences in the surrounding environment;
- avoided damages: the monetary sum equal to all the different detriments to infrastructures, people and assets that could happen, if the protection measure considered would not have been present or effective.

The list adopted to compute these values is presented in table 1 for each available measure.

Table 1: methodology to compute the economic values related to the adoption of the different protection measures

N.	Measure	Direct cost			Indirect cost	Avoided damages	Benefits
		Construction/ implementation	Maintenance	Dismantling			
1	Technical release control	€/m, with height classes	% of construction cost	% of construction cost	-	Road, people and/or building value	Avoided damages
2	Artificial release system	€	% of implementation cost	% of implementation cost	-	Road, people and/or building value	Avoided damages
3	Rockfall net	€/m, with energy classes	% of construction cost	% of construction cost	-	Road, people and/or building value	Avoided damages
4	Debris net	€/m, with energy classes	% of construction cost	% of construction cost	-	Road, people and/or building value	Avoided damages
5	Crib wall	€/m2	% of construction cost	-	-	Road, people and/or building value	Avoided damages
6	Retention dam	€/m3, with height classes	% of construction cost	-	-	Road, people and/or building value	Avoided damages
7	Afforestation	€/ha	% of implementation cost	-	-	Road, people, building and/or plantation value	Avoided damages
8	Protection forest rehabilitation	€/ha/year	-	-	-	Road, people, building and/or forest value	Timber revenues, Avoided damages
9	Road closure	-	-	-	Reroute; road damages	People and/or building value	Avoided damages - indirect cost
10	Building relocation	€/m2	-	-	Compensation	People and building value	Avoided damages - indirect cost
11	Building evacuation	-	-	-	Compensation, accommodation	People value	Avoided damages - indirect cost
12	Construction ban	-	-	-	Property depreciation	People and building value	Avoided damages - indirect cost
13	Early warning system	€	% of construction cost	% of construction cost	Reroute; road damages	People value	Avoided damages - indirect cost

As for the dimensioning, the computation of some of the economic functions need inputs parameters by the users as well. Particularly, choices needed to be made by the users in relation to the type of road or the type of building at risk, selecting from the different options available. Similarly, also the traffic level of the road needs to be indicated by the users (D. T3.3.2.).

Protection measures comparison

The main output of the TEGRAV analysis is therefore represented by the four economic variables: direct costs, indirect costs, avoided damages and benefits.. Their importance within the project is relevant, constituting the main output of the FAT online tool. Particularly, the framework of the tool will allow the user to easily modify the typology, size, and location of alternative protection measures, in order to identify the most cost-effective and satisfactory mix to be applied along the user profile. Additionally, being the lifetime of each measure one of the parameters included in the analysis, also their effectiveness over time can be valued.

Conclusions

The implementation of the TEGRAV analysis and its integration within the FAT represents the steppingstone for the last stage of the stakeholders engagement planned within the project. Notwithstanding the potential of the tool, its aim is not to be used for designing real-life protection measures on exposed assets and neither to achieve cost-benefit analysis of projected interventions. This analysis, and the tool in which it is embedded, is meant as a general assessment to illustrate how Eco-DRR measures could represent an affordable and effective solution among the wide range of options already available for decision makers.

References

A. Huber, Fischer, J.T., Kleemayr, K., 2017. DAKUMO. Tecnical report from Federal Research and Training Centre for Forests, Natural Hazards and Landscape, Innsbruck, Austria.
Accastello, C., Bianchi, E., Blanc, S., Brun, F., 2019a. ASFORESEE: A Harmonized Model for Economic Evaluation of Forest Protection against Rockfall. Forests 10, 578. https://doi.org/10.3390/f10070578
Accastello, C., Blanc, S., Brun, F., 2019b. A Framework for the Integration of Nature-Based Solutions into Environmental Risk Management Strategies. Sustainability 11, 489. https://doi.org/10.3390/su11020489
Heim, D.A., 1932. Bergsturz und Mellitser eieben. 220.
Rosa, W. (Ed.), 2017. Transforming Our World: The 2030 Agenda for Sustainable Development, in: A New Era in Global Health. Springer Publishing Company, New York, NY. https://doi.org/10.1891/9780826190123.ap02
UNISDR, 2015. Sendai Framework for Disaster Risk Reduction 2015-2030. United Nations, Geneva, Switzerland.