D.T2.4.2 Identification of potentially endangered assets and functional assessment of protection measures in the PARs

WP T2 ACTINA

Responsibility for Deliverable

Michaela Teich (BFW)

Contributors

DISAFA: Cristian Accastello, Francesca Poratelli
EURAC: Silvia Cocuccioni, Kathrin Renner, Monika Rabanser
UL: Petra Pečan, Milan Kobal

Innsbruck, March 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 Bozen-Bolzano – Eurac Research (ITA)
IRSTEA - National Research Institute of Science and Technology for the Environment and Agriculture, Grenoble regional centre, IRSTEA (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 (SI)
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 (SI)

Table of Contents

Table of Figures

Table of Tables

1 Introduction

The overall aim of GreenRisk4ALPs (GR4A) is to develop ecosystem-based approaches that support risk mitigation actions in connection with natural hazards and climate change. Understanding natural hazard processes and their potential consequences constitutes a prerequisite for the development and the implementation of ecosystem-based risk management strategies. Therefore, natural hazards, elements at risk and the possible effects of protection measures need to be studied encompassing a risk assessment process.

This report provides a summary of the main spatial and non-spatial data sets that constitute the elements at risk (potentially endangered assets) and protection measures that are located in each of the six GR4A Pilot Action Regions (PARs):

- PAR1: Val Ferret, Italy
- PAR2: Kranjska Gora, Slovenia
- PAR3: Oberammergau/Ettal, Germany
- PAR4: Parc des Baronnies, France
- PAR5: Southern Wipptal, Italy
- PAR6: Vals/Gries am Brenner, Austria

The collected data is the basis for four main activities that are part of the work packages (WPs) 1 to 3 within GR4A with the goal to develop approaches for evaluating and quantifying the risk from the three natural hazards, soil slope failures, rockfall and snow avalanches.

Risk is defined differently by different scientific communities. In the GR4A project, we follow the definition given by the IPCC (2014): "*The potential for consequences where something of value is at stake and where the outcome is uncertain (...)*". Risks therefore derive from the combination of natural hazards and the vulnerabilities of exposed elements (Cardona et al., 2012). The hazard itself does not constitute a risk if it occurs in an area where no assets or people are present; moreover, not all the elements exposed to the hazard are necessarily vulnerable. Therefore, risk *"results from the interaction of vulnerability, exposure, and hazard"* (IPCC, 2014; see Figure 1).

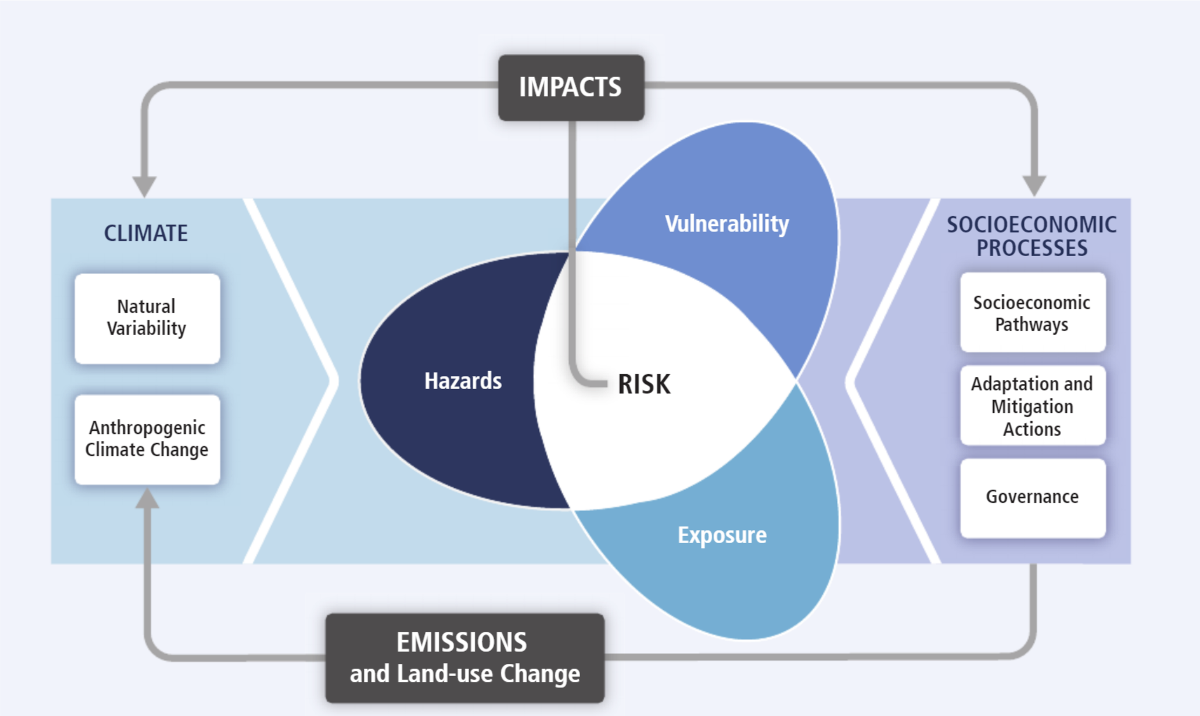


Figure 1. The IPCC AR5 conceptual framework. Source: IPCC (2014)

In this report, we focus on the identification of buildings and infrastructure potentially at risk as part of the exposure assessment, and on existing protection measures, which is required:

1) to define forests with a direct object protection function (part of WP1),
2) to identify areas, where forests as a protection measure could be especially suitable to reduce the risk for building, transportation and recreational infrastructure (parts of WPs2 and 3), and
3) to evaluate the effects of protection forests in more detail in comparison to other protection measures such as technical defense structures or risk avoidance strategies (part of WP3).

Thus, while WP1 focuses on the natural system, WPs2 and 3 follow a more interdisciplinary approach, focusing also on the social system; however, this report serves as a basis to gain information and data on the main assets and protection measures present in the six PARs.

In the following chapter, we will give short overviews of all four applied approaches, which work synergistically but on different levels of detail. In Chapter 3, we summarize the data that was provided for each PAR and also describe a method that can be used to collect data in the field, if no current data on protection measures is available. This method was developed to survey flood mitigation measures, but can also be applied to collect data on measures protecting against other natural hazards. We conclude with a short summary and an outlook of the next steps.

2 Overview of risk-based evaluation approaches

2.1 Identifying forests with protective functions

In GR4A, we focus on so-called object protection forest with a direct protective function based on the definitions of protection forest that were established within GR4A (see Figure 2; Kleemayr et al., 2019). Direct object protection forests protect objects in developed areas from gravitational natural hazards and can only be assigned by linking the precise locations of the hazard process with the assets potentially at risk.

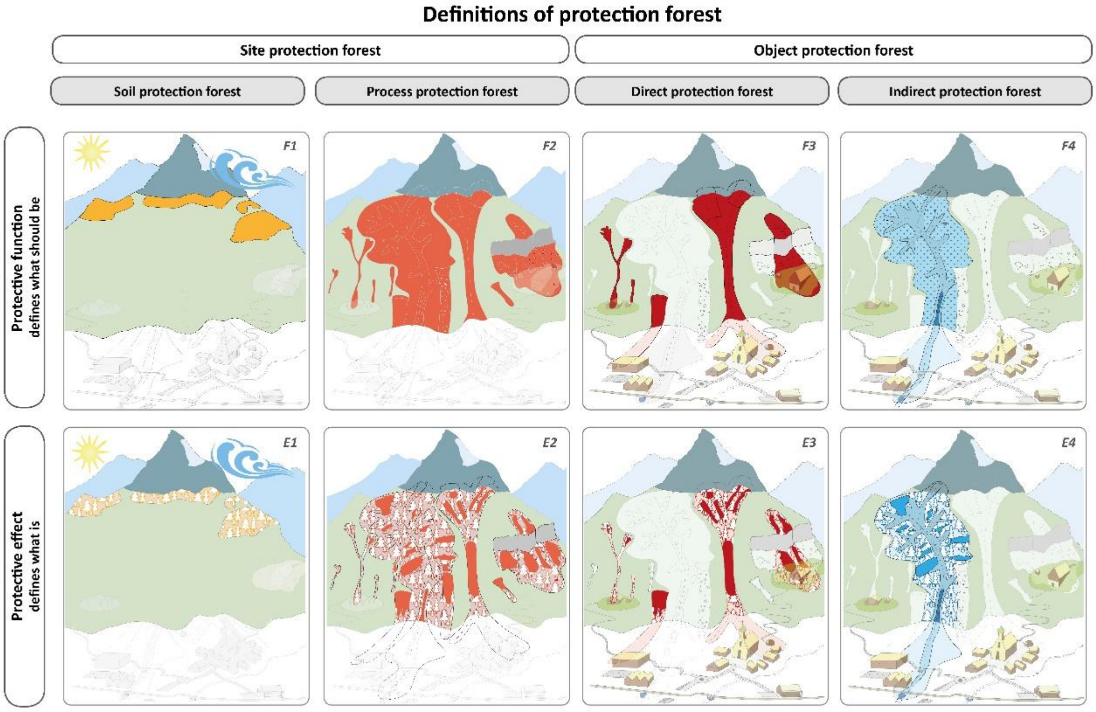


Figure 2. Protection Forest Definition Matrix. Column 1 (yellow): soil protection forest (function-F1, effect-E1); Column 2 (orange): protection forest on formation and process areas (F2, E2); Column 3 (red): forest that directly protects developed areas (settlements and infrastructure) from gravitational hazards (snow avalanches, rockfall, debris slides; F3, E3); Column 4 (blue): forest with indirect protection benefits on fluvial natural hazard processes (torrents, flooding) for developed areas (F4, E4). Potential forest area in green. Source: Kleemayr et al. (2019)

This link between assets and the natural hazard process is established in WP1 by applying natural hazard process models (see Activity A.T1.2 for details). Each hazard model consists of three parts: 1) Identification of the hazard starting zones, 2) calculation of hazard process paths, and 3) back-calculation of process paths to their starting point, if an object was located within these paths. The back-calculated process areas are intersected with areas that are defined as forest in land-use maps. The necessary input data are a digital elevation model (DEM), a forest cover map, and a map that includes assets potentially at risk such as buildings, transportation and recreational infrastructure. The resolution of all input raster data sets is 10 m; the outputs are 10-m resolution raster data sets showing the locations of forests with a protective function against soil slope failures, rockfall or snow avalanches.

The asset data that was available for each PAR, where key model inputs and thus the basis to create the 10-m raster data set of assets potentially at risk.

2.2 Spatially explicit risk assessment and Rapid Risk Appraisal

The methodological framework used for the risk assessment in the GR4A project follows a stepwise approach that allows for different depths of analysis. Two different approaches are integrated to assess the risk in the PARs:

- a **spatially explicit assessment** which uses the natural hazard and forest protective effects modelling results (see Activity A.T1.2). It consists of an exposure assessment and of a more detailed spatial analysis in selected hotspot areas (WP3),
- the "**Rapid Risk Appraisal**", a participatory tool, which provides an overview of the main perceived risks in each PAR and of their management practices (WPs2 and 3).

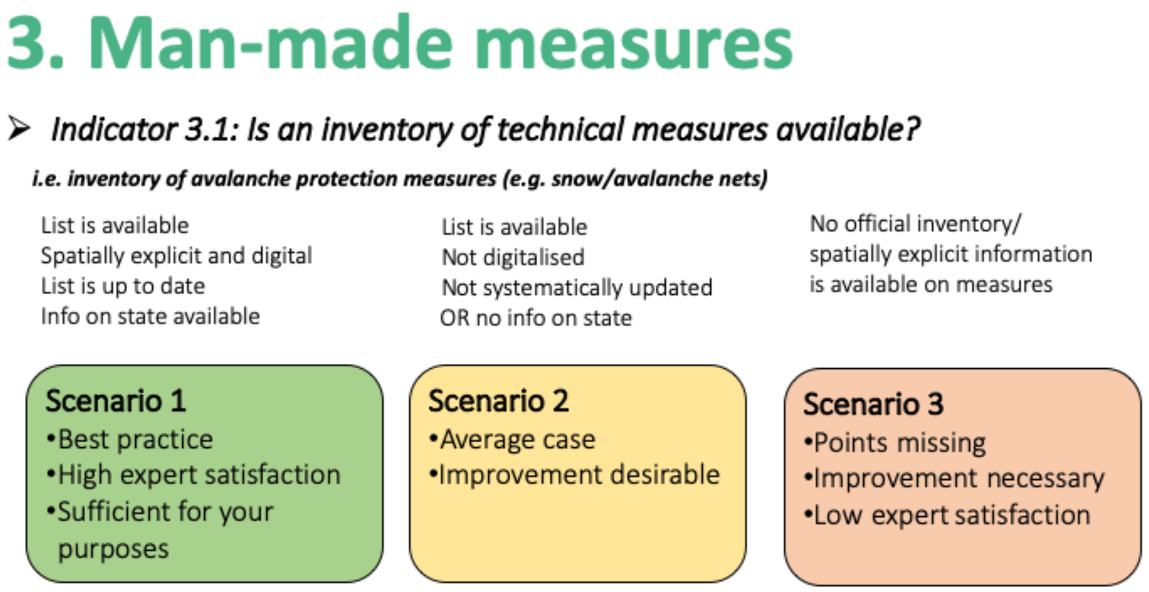
By integrating qualitative information collected from stakeholders (WP2) with data obtained from hazard modelling (WP1), the potentially exposed assets can be pinpointed and the efficiency of protection measures, in particular of protection forests, in reducing the risk can be estimated.

At a regional scale, quantitative hazard and risk assessments require an extensive range of data on both the natural hazard processes and on the characteristics of assets in order to acquire the full range of information needed to define the three components of risk (hazard, exposure, vulnerability). In a project such as GR4A with six study areas, conducting complete risk assessments would require a large data collection effort. Moreover, since the PARs are located in different countries, the quantity and quality of available data regarding assets differs from PAR to PAR. This makes the transfer of these risk assessment methods difficult (Promper and Glade, 2016). Therefore, the first step of the spatially explicit assessment methodology consists of an **exposure assessment**. Exposure assessments are considered an intermediate stage, linking the elements at risk with natural hazard susceptibility (Pellicani et al., 2012), enabling to highlight the potential hotspots for a subsequent more detailed risk analysis (Promper and Glade, 2016). In general terms the exposure of assets defines the location of elements at risk, which might experience damage in case of natural hazard occurrence (Pellicani et al., 2012).

The **exposure assessment methodology** developed for the GR4A project is built upon the "*multilayer-exposure*" approach by Promper (2014). It consists in the overlay of the susceptibility maps of the selected natural hazards (avalanches, rockfalls and soil slides), also considering the protective effects of forests, with asset layers (grouped in buildings, transportation and recreational infrastructure) at a regional scale. This approach allows flexibility depending on the data available. For example, in PARs where information on types of buildings are available, buildings can be categorized and grouped in more detailed classes (e.g. residential buildings, public buildings, commercial buildings, agricultural and other buildings); in PARs where this type of information is not available, a simple and more general "building" layer can be used. A similar approach can also be followed for roads (i.e., major roads of 1st order, minor roads of 2nd order). The exposure assessment allows to spatially identify those buildings and infrastructure that might be affected by a natural hazard and where the forest can provide a positive effect in protecting them.

In order to select a limited number of hotspots both in terms of spatial areas and natural hazards, a participatory approach which uses local expert knowledge is applied: The **Rapid Risk Appraisal** (RRA). The RRA methodology focuses on acquiring information on both the natural and the social components which constitute different risks. The approach follows a series of steps based on the ISO standard 31000 and aims at developing an understanding of the risk by analyzing the causes or conditions which give rise to the risk situation. This way, the entry points for improved risk management measures can also be identified. While the exposure assessment focuses on the exposure component of risk, the RRA concentrates on the risk management capacities in place in the PAR to prevent, mitigate against, transfer, respond to and recover from an event, which is part of the vulnerability. The skills, capabilities, instruments and measures available (or the lack of them) are central to reducing disaster risk (UN, 2015). Therefore, assessing their presence (or their lack) contributes to the overall risk assessment process.

In particular, specific questions are directed to acquire information on the available man-made and green protection measures (see example, Figure 3).



3. Man-made measures

➢ *Indicator 3.1: Is an inventory of technical measures available?*

i.e. inventory of avalanche protection measures (e.g. snow/avalanche nets)

List is available Spatially explicit and digital List is up to date Info on state available	List is available Not digitalised Not systematically updated OR no info on state	No official inventory/ spatially explicit information is available on measures
Scenario 1 •Best practice •High expert satisfaction •Sufficient for your purposes	**Scenario 2** •Average case •Improvement desirable	**Scenario 3** •Points missing •Improvement necessary •Low expert satisfaction

Figure 3. Example of a question in the Rapid Risk Appraisal regarding protection measures.

Once hotspots are identified, a **more detailed spatial assessment** can be conducted. For this step, further information regarding the potentially exposed assets needs to be acquired (for example, construction type, frequency of use, economic value). The required information can either be collected from existing data sources or through observations in the field. Incorporating this kind of information allows to move towards a full risk assessment which considers all three components of risk.

Further background information, details and results from the Risk Assessment methodology will be provided in the reports D.T3.2.1 and D.T3.5.1.

2.3 Economic valuation of protection measures (TEGRAV)

An example of more detailed assessment is presented in this section of the report, which provides the information basis for the TEGRAV model, which is being developed within WP3. In order to create a common ground of measures and practices across the different countries of the alpine space (AS), the first step was to perform a screening of the most common protection measures that are present in the six PARs. Additionally, this data collection was coupled with a review of the scientific literature (see D.T3.1.1) and the formation of focus groups among project partners and observers, in order to gain a complete overview of the topic.

The aim of this data and information collection was two-fold. On one side, it was useful to have an overview of the current practices in risk mitigation which are already in place in the PARs, and consequently to identify weaknesses and strengths of each one of them. On the other side, the data collection and categorization serve as input for the TEGRAV model (see D.T3.3.1), enabling to select the most suitable protection measures to be included in a "short list", which will constitute the protection options available within the model. This process was supported by the combination of different data sources, which allowed selecting one or multiple "standard" protection measures for every process considered by TEGRAV: snow avalanches, rockfall and soil slope failures. The measures were also selected in relation to the effective zone/area, distinguishing between release area and transit/runout area as well as for their typology (technical, green or avoidance). This approach allowed to define a balanced group of measures able to cover every relevant protection strategy currently adopted in the PARs, and to meet the expectations of the final users of the TEGRAV model.

Consequently, the economic valuation presented in this report has been structured to serve the needs of the following developments of the TEGRAV model. For this reason, no monetary values are associated to the list of measures resulting from the data collection. This choice was made in consideration of both the difficulties in obtaining reliable values for all the different measures included in the list, but also due to the limited benefits from such monetary values, which do not serve as inputs for the TEGRAV model. For these reasons, the economic valuation presented in Section 3.3 focuses only on the “short list” of standard protection measures selected for the TEGRAV model. For each one of them, all the different costs contributing to their economic assessment are described. The outputs of this analysis will be the following:

- Direct costs: originating from the addition 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;
- 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;
- 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.

Based on this classification, Section 3.3 of the present report lists all the different information needed to compute the outputs for each protection measure considered in the TEGRAV model. To achieve such a goal, the economic data have to be coupled with technical and socio-economic information. This data collection phase will be carried out in parallel for the different AS countries in order to account for the differences in value that can originate in different countries and provide more reliable outputs to the final users of the model.

The results of this data collection phase, which is still ongoing, will be reported in D.T3.4.1, entirely focusing on the structure and functioning of the TEGRAV model.

2.4 Data and workflow between approaches

The four approaches described above that are developed and applied within GR4A to support ecosystem-based risk management strategies, require information of different levels of detail by referring to the same type of input data. In order to be as consistent as possible, we follow a workflow that ensures consistency and the use of the same data sources (Figure 4). For example, the 10-m raster data sets of assets potentially at risk that is required to identify forests with a direct object protective function (see Section 2.1) are based on 1-m resolution raster data sets produced for the spatially explicit exposure assessment (see Section 2.2). The information on existing protection measures gathered during the Rapid Risk Appraisal (see Section 2.2) is used to define a catalogue of protection measures for the TEGRAV tool (see Section 2.3).

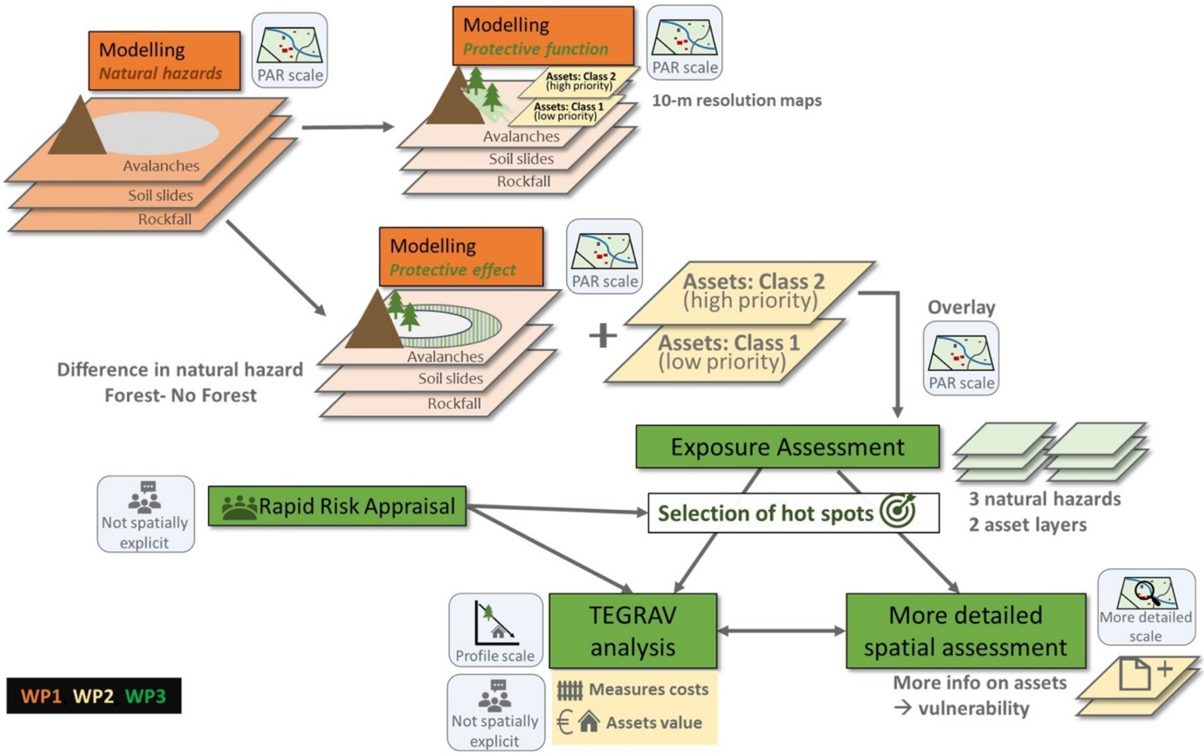


Figure 4. Data flow, workflow and links between the four risk-based evaluation approaches: Modelling forest protective function, spatially explicit risk assessment, Rapid Risk Appraisal, and TEGRAV analysis.

3 Assets potentially at risk and existing protection measures

3.1 Assets potentially at risk

To prepare the input data needed for modeling forest protective functions and the spatially explicit risk assessment, the institutions responsible for the PARs were asked to provide the most current spatial information on:

- PAR border
- Transportation infrastructure (roads, railways)
- Buildings (including building type, e.g., residential buildings, public buildings, commercial buildings)
- Recreational infrastructure (e.g., ski areas, cable cars, golf courses, football fields etc.)
- Land use

Table 1 provides an overview of the data sets that were provided and used to build a common asset data set as a 1-m resolution raster for each PAR. A short description of how each data set for each PAR was assembled and classified can be found in Appendix A (a more detailed description will be provided in D.T3.2.1 and/or D.T3.5.1.).

The areas to be protected by a forest against natural hazards (the objects) can be defined and categorized in object classes as, for example, in the Austrian Forest Development Plan (Waldentwicklungsplan; WEP-R, 2012) where they are classified in three classes based on an assigned object category. An object class is a result of the definition and evaluation of protection goals and translates the public interest in the preservation and use of the that object. However, the definition of these classes can have a significant impact on the modeling of the object protection forest function as well as the exposure assessment within the spatially explicit risk assessment. For example, if a forest road is classified as an object of high priority to be protected, the entire forest above such a road, even if the road is seldom used, will be identified as object protection forest. This makes it difficult to prioritize forest management measures between such a forest and a forest that protects a settlement against natural hazards (Perzl et al., 2014).

To acknowledge these commonly existing public interests in the protection of objects that are used frequently, we therefore applied whenever possible (provided the input data was available) a simplified classification scheme (Table 2). Our scheme follows the recommendations by Perzl et al. (2014) who applied a much more detailed classification of objects potentially at risk to model object protection forests in Austria. Perzl et al. (2014) also thoroughly discuss the challenge of finding a common classification scheme based on existing laws and regulations, especially if one aims to compare model outcomes between different regions, or as in our case between countries. However, the chosen scheme fits our purpose and goal to get a first overview of objects potentially at risk at a regional scale that can be followed by a more detailed risk assessment.

Table 1. Overview of the asset data sets that were submitted and used to build a common asset data set for each PAR.

Data set name	Data description	Data time (year)	Data source	Notes
PAR1 Val Ferret, Italy				
Fabbricati.shp	Building footprints	2005	Aosta Valley Autonomous Region (http://geoportale.regione.vda.it/download/)	No information on building types
grandi_impianti.shp	Roads	2005	Aosta Valley Autonomous Region	No railways within PAR
		2019	Aosta Valley Autonomous Region	No ski areas or cable cars within PAR boundaries
Golf_course.shp	Recreational infrastructure: golf course	2019	FMS	
PAR2 Kranjska Gora, Slovenia				
buildings_2.shp	Building footprints	2018	The surveying and mapping authority of The Republic of Slovenia http://www.e-prostor.gov.si/brezplacni-podatki/	
roads_2.shp	Roads	2018		No railway within PAR
ski_trails2.asc	Recreational infrastructure: ski runs	2018	PISO portal for Kranjska Gora https://www.kranjska-gora.si/sl/info/zemljevidi	No other recreational infrastructure available
PAR3 Oberammergau/Ettal, Germany				
7_landuse_map.shp	Polygons with assigned land-use classes	2008-2017	LBM-DE (BKG)	Polygons with building infrastructure were selected (see Appendix A)
6_Bahn.shp	Railways, cable cars/ski lifts	2013-2016	Basis-DLM-DTK25	
6_Strasse.shp	Roads	2013-2016	Basis-DLM-DTK25	
PAR4 Parc des Baronnies, France				
Not asset data set created at the time of report submission				
PAR5 Southern Wipptal, Italy				
Technische Vektorgrundkarte (VGK)	Building foot prints	2007	Autonomous Province of Bolzano	Assets data was selected and combined from both data sets (Technische Vektorgrundkarte (VGK) and Gebäudekataster
Gebäudekataster	Building foot prints and types	17 July 2019	Autonomous Province of Bolzano	
Wege.shp	Roads, railways,	2010	Autonomous Province of Bolzano	
Recreational infra	Ski lifts, ski runs	2015	Autonomous Province of Bolzano	
PAR6 Vals/Gries am Brenner, Austria				
buildings_6.shp	Building polygons	2014	https://www.data.gv.at/	No differentiation of building types

roads_6.shp	Transportation infrastructure	2018	https://www.data.gv.at/	Combined data set with railway, forest roads, hiking trails etc.
railways_6.shp	Separate data set for railways	2014	https://www.data.gv.at/	
Ski_area_6.shp	Ski areas	2011	Land Tirol	
PAR6_Nutzung_new.shp	Mining area	2019	Land Tirol	Updated land-use data maps

Note: Shown are only the data sets that were actually used and not data sets provided by the institutions linked to the PARs. See Appendix B for overview.

Table 2. Simplified object classification scheme that was applied to classify assets potentially at risk in each PAR.

Object type	**Class 2 (high priority infrastructure)**	**Class 1 (medium priority infrastructure)**	**Not considered**
Buildings	Buildings (in general and if no building type is available)	Secondary buildings (if building type is available, e.g. sheds, buildings that are used temporarily)	
Transportation	Major roads (e.g. motorway, secondary roads) Railways	Minor roads (e.g., municipality roads)	Forest roads
Recreation		Recreational infrastructure (e.g., ski lifts and runs, golf courses, sports grounds, campsites)	Bike trails Hiking trails Protected areas
Other		Mining area	

Note: Scheme is adapted for each PAR based on the available input data and expert opinions through a validation process.

3.2 Existing protection measures

In accordance to the principles described in Section 2.3 of this report, an overview of the existing protection measures in the PARs is provided with the aim to assess the most frequently used solutions for each natural hazard. In order to gain a complete list of the existing measures despite the large differences between PARs in terms of available data, format, status and detail, three different ways of gathering, organizing and finally selecting the required data were applied, often in parallel, for each PAR:

- Collecting existing data on protection measures in PARs (Section 3.2.1);
- Collecting field data in PAR2 Kranjska Gora (Section 3.2.2)
- Selecting protection measures for the TEGRAV model (Section 3.3)

3.2.1 Existing data on protection measures in the PARs

Regarding the first method, the results show that the required information was not available for all the PARs. Data was only available (or could be gathered in the given amount of time) for three PARs and showed large differences in terms of both data format (vector or raster data) as well as level of detail. An overview of the information provided by the PARs is presented in Table 3.

Table 3. Database or data sets on existing protection measures provided by the PARs.

PAR	**Natural hazard**	**Data source**	**Year**
PAR1 Val Ferret, IT	Avalanches	http://geonavsct.partout.it/pub/geovalanghe/	2019
PAR5 Southern Wipptal, IT	Rockfall Floods and Debris flows Avalanches	http://geoservices.buergernetz.bz.it/geoserver/p_bz-geology/ows?SERVICE=WMS	2011
PAR6 Vals/Gries am Brenner, AT	Rockfall Floods and Debris flow Avalanches Landslides	Austrian Service for Torrent and Avalanche Control (WLV)	

Based on these data sets, we summarized different protection measures that are present in these three PARs by the types of hazard and protection structure, which are presented in Tables 4, 5 and 6.

Table 4. Summary of protection measures currently installed in PAR1 Val Ferret, Italy.

Natural hazard	Type of structure	n.	Info on the current state of the structures
Avalanches	Snow nets	1	/
Avalanches	Snow fences	11	/
Avalanches	? (Gradoni)	2	/
Avalanches	Tunnel	1	/
Avalanches	Deflector	1	/

Note: No information on current status of the structure were available.

Table 5. Summary of protection measures currently installed in PAR5 Southern Wipptal, Italy.

Natural hazard	Type of structure	n.	Info on the current state of the structures
Avalanches/debris flow	Catching dam	3	/
Floods and debris flow	Deviation dam	3	/
Floods and debris flow	Ditches	48	/
Floods and debris flow	Slurry walls	4	/
Floods and debris flow	Retaining walls	22	/
Floods and debris flow	Riverbank walls	19	/
Avalanches	Snow fences	2 11	/
Avalanches	Snow nets	4	/
Floods and debris flow	Paving	17	/
Floods and debris flow	? (Soffioni)	3	/
Floods and debris flow	Terreplein	19	/
Rockfall	Rock nets	23	/
Rockfall	Rock dam	1	/
Rockfall	Wall	4	/
Rockfall	Crib wall	2	/

Note: No information on current status of the structure were available.

Table 6. Summary of protection measures currently installed in PAR6 Vals/Gries am Brenner, Austria.

Natural hazard	Type of structure	n.	Info on the current state of the structures
Avalanches	Deviation dam	1	/
Avalanches	Snow fences	3	/
Avalanches	Wooden tripods	2	/
Floods and debris flow	Sediment deposition zone	7	/
Rockfall	Catching dam	2	/
Floods and debris flow	Open regulation structures	3	/
Floods and debris flow	Ground sill	4	/
Floods and debris flow	Bank protection structure	5	/
Floods and debris flow	Casing	2	/
Landslide	Drainage	2	/
Rockfall	Rockfall wall	3	/
Rockfall	Rockfall nets	2	/
Floods and debris flow	Consolidation check dam		/
Floods and debris flow	River bottom sill	2	/
Floods and debris flow	Ditch	5	/

Note: Data is not complete since up to now no data was delivered by the Austrian national railway. No information on current status of the structure were available.

3.2.2 Field survey method

For efficient torrent structural flood mitigation management, it is necessary to establish an adequate information base that enables an overview on locations and conditions of water infrastructure (Sodnik et al., 2014). However, this can be challenging due to the particular characteristic of existing databases and associated problems (Sodnik et al., 2015): first, the existing data does not match the actual field situation; second, the data have not been described accurately; third, several differing classifications for water infrastructure exist, and finally, the existing data is dispersed as there are several unrelated projects dealing with water infrastructure inventory. Therefore, in this section we describe a new, efficient and user-friendly method for collecting field data and information on existing protection measures in an area of interest, which was here applied for water infrastructure.

Design and implementation of flood mitigation measures is directed to minimize the risk and to decrease the damage caused by a natural hazard (Brilly et al., 1999). We can categorize mitigation measures considering the type of intervention into (a) structural, and (b) non-structural. Structural flood mitigation is a system for reducing the effects of floods using physical solutions, e.g. reservoirs, levees, dredging, diversions, flood proofing, etc. Non-structural flood mitigation is a system for reducing the effects of floods using non-structural measures, e.g. land-use planning (flood plain zoning), advance warning systems or flood insurance (Mikoš, 2002). Depending on the mode of operation, we can divide them into (a) active (reducing the size and duration of flood waves; e.g. accumulations, afforestation), and (b) passive (protecting against the consequences; e.g. dykes, evacuation). Overall, the basic task of torrent management is to reduce the dynamics of tractive force and/or to increase the resilience of riverbeds and riverbanks. The dynamics of tractive force can be reduced by lowering the amount of water in the stream, which can be achieved by structural mitigation measures; e.g. transverse structures such as barriers and sills. The resilience of riverbeds and riverbanks can be increased using longitudinal structures such as river training.

In Slovenia, the inventory of water infrastructure is still being updated (Sodnik et al., 2014). The existing official databases are the (a) *Water cadaster* (slo. Vodni kataster; DRSV, 2019), which is an official record of water management, established under Water Act (2002; slo. Zakon o vodah, 2002). It consists of two basic databases; 1) water inventory, and 2) water structures inventory, divided into several sub collections. The Water cadaster includes all national water management programs, water management plans and action programs. It is publicly accessible online. The second database is the (b) *Water atlas* (slo. Atlas voda; Grili et al., 2015, Direkcija RS za vode, 2017). It is the first publicly released web browser, established on a state-owned computer cloud. It contains graphical presentations of the updated contents of the water cadaster with the information of water rights. Metadata descriptions of the RS Water Directorate are available on the Slovenian INSPIRE metadata system. In 2015, the Ministry of the Environment and Spatial Planning, due to the difficulty of data accessing and the dispersion of water management databases, prepared the project (c) *eWaters* (slo. eVode). The project includes the establishment of an online portal where data on water management is publicly accessible in one place. With the establishment of the eWaters web portal, it was expected that access to water management data would increase, which could be reflected in more efficient water management and shorter spatial planning and construction work. In 2017, the Ministry of the Environment and Spatial Planning upgraded the eWaters web portal, within which it established a long-awaited official record in the field of water management: **Water cadaster** (DRSV, 2019).

Water infrastructure is defined as 1) a structure intended for the regulation of water or which is directly affected by the water regime or 2) a structure intended for the specific use of a water or marine property. The first group of structures includes high-water embankments, dams, sills, landless reservoirs intended for the occasional retention of water, reservoirs etc., as well as water monitoring. The second group includes, in particular, pumping stations, dams, drainages and supply channels etc., including measures or devices designed to directly protect the structures from harmful effects of water. Water structures, besides objects, also include watercourses, resulting from the displacement of a natural watercourse or its arrangement, or a water reservoir created by the impoundment of running water or other encroachment on a site, if it is intended to provide public services under the Water Act (Water Act, 2002). The list of distinguished types of structures under the Water Act and a classification based on Mikoš (2012) are shown in Figure 5.

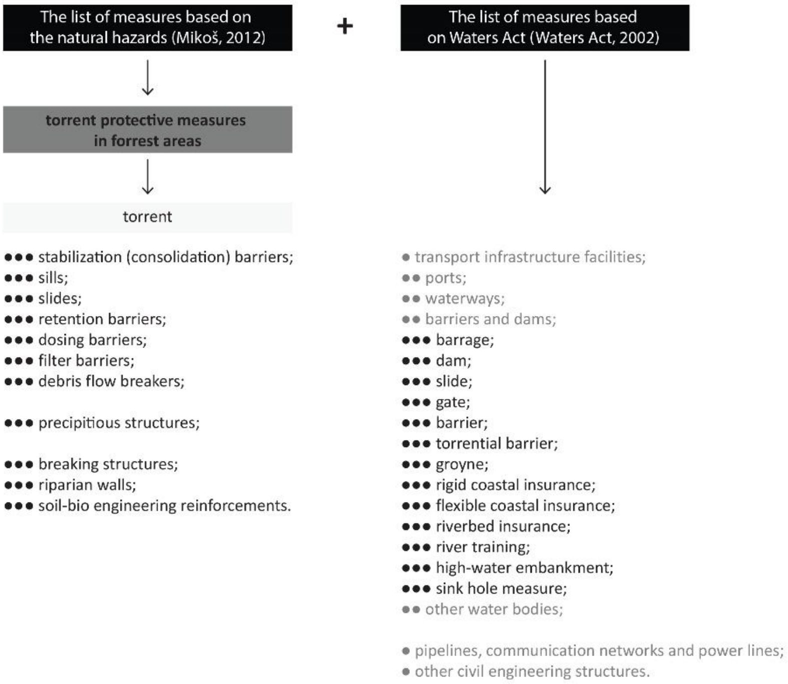


Figure 5. Classification of torrent mitigation measures for developing the Mobile GIS application is based on existing classification of types of measures (Water Act, 2002) in combination with protection measures in forest areas (Mikoš, 2012).

The “Survey 123 for ArcGIS” application was used to implement the methodology for collecting torrent structural mitigation measures in the form of point features with attributes. Each object is an autonomous record in the feature database consisting of the basic attributes, which are determined automatically: field worker (username and password required); X, Y coordinates in the Gauß-Krüger coordinate system (on longitudinal structures, the location is taken at the beginning of the object; accuracy < 10 m); altitude (in m); date (LLMMDD), time (HHMMSS); and record code. In addition, one can add other attributes and attachments (notes or photographs) to each feature. One can also create features with attributes in the ArcMap environment and upload them to the ArcGIS Online platform for further processing (changes of base map, viewing and editing options). The web map can be shared with different groups or individual users. The application can be used by several users at the same time. The application offers an authorship (information about the author/editor) and time (information about the time and date of collected/edited features) stamp option. The application can be accessed via smart phone or tablet and does not require an internet connection to store data in the field. When an internet connection is available, the data will be synchronized and uploaded to the online platform. The application is compatible with a high-accuracy GNSS receiver.

The application systematically captures representative groups of water infrastructure by guiding the user (Figure 6). It enables the user to collect large (type of a natural hazard) to small-scale information (condition of the object) by guiding the user through 11 steps to collect data about an individual mitigation measure. The basic concept of the methodology is that a user must first define the type of natural hazard (torrent) and the part of torrent (upper, middle, lower part). Second, the field worker selects a type of measure based on the classification of the water infrastructure, which was developed by combining the list of types of water infrastructures from the Slovenian Water Act (Article 44 of the Water Act, 2002; Annex 1: List of types of objects) with an overview of selected torrential protection structures in forested areas (Mikoš, 2012; see Figure 5). Then, data on dimension, material, condition, notes and photos are gathered. As mitigation measures are often constructed on steep and inaccessible areas, the actual dimensions of measures are additionally checked by using a high-resolution digital terrain model (DTM).

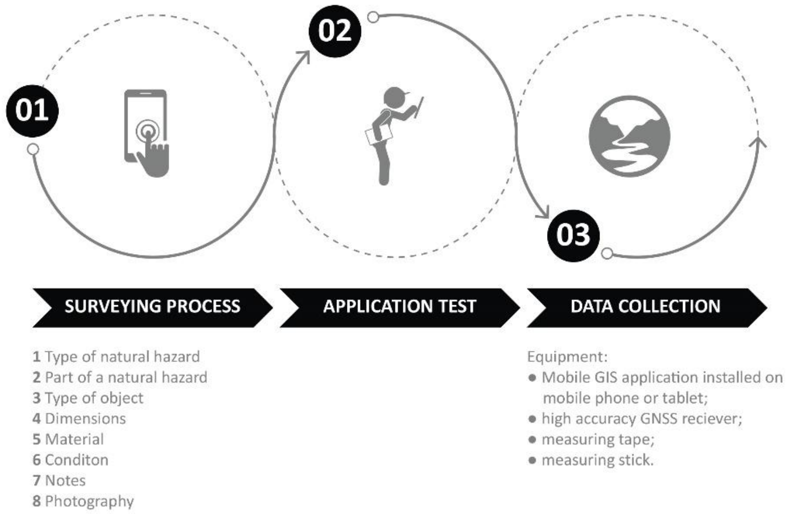
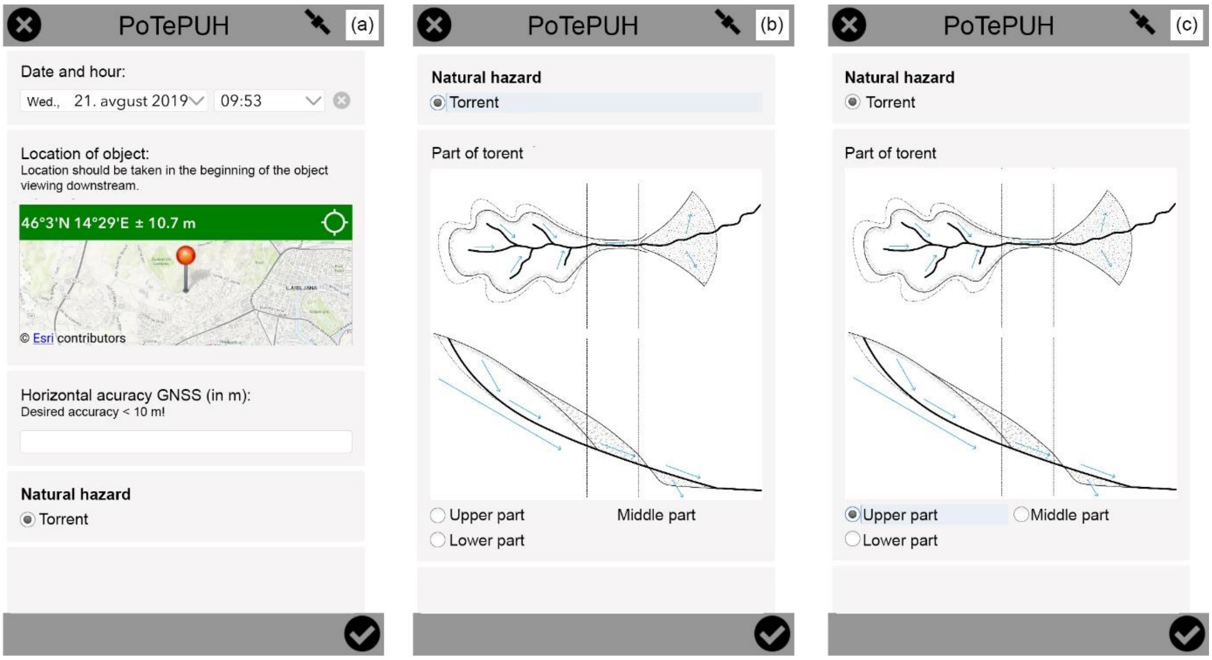


Figure 6. Conceptual model for water infrastructure data collection.

One part of a torrent area can have several types of measures. This means that each object in the original attribute table (part of torrent) is linked to multiple objects in associated tables (type of objects). Each mitigation measure has its own identification number (ID) that is linked to each part of the torrent. Some types of measures appear only on a specific part of the torrent. In practice, basic attributes are collected automatically when connecting to a high-accuracy GNSS. Afterwards, the field worker selects the type of natural hazard and the part of natural hazard (Figure 7). When choosing a part of a natural hazard, a new window pops up, where it is possible to choose measures that only appeared on the specific part of the torrent. Types of measures are divided into 2 groups; longitudinal and transverse objects with their own sub groups. In case of longitudinal measures, the presence of one or more soil-bio engineering measures can be determined. Afterwards, the dimensions are entered in the form. Then, the worker selects one or multiple materials from the listed options. The condition of a structure is determined by selecting one option on a given 3-level scale. Additional notes can be entered as text and up to 5 photographs can be recorded.



(a)

Date and hour:
Wed., 21. avgust 2019 09:53

Location of object:
Location should be taken in the beginning of the object viewing downstream.
46°3'N 14°29'E ± 10.7 m
© Esri contributors

Horizontal acuracy GNSS (in m):
Desired accuracy < 10 m!

Natural hazard
● Torrent

(b)

Natural hazard
● Torrent

Part of torent
○ Upper part Middle part
○ Lower part

(c)

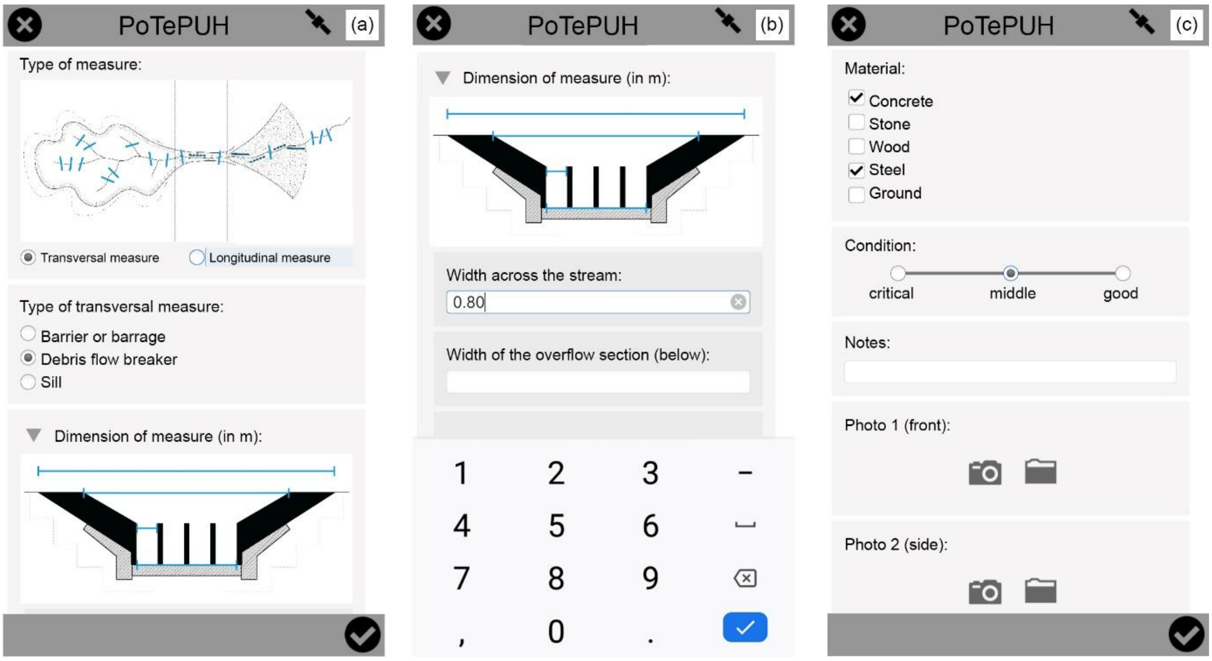
Natural hazard
● Torrent

Part of torent
● Upper part ○ Middle part
○ Lower part

Figure 7. Mobile GIS application for collecting torrent structural mitigation measures A: The process of selecting a part of a torrent area. When basic attributes are selected and the mobile device or tablet is connected to GNSS, one selects the type of the natural hazard (a) and the part of the natural hazard (b). After the part of the natural hazard is chosen (c), the types of available measures will pop-up, depending on the part of torrent.

For each measure, the dimensions in meters are determined (Figure 8). Dimension width across the stream represents the largest transverse dimension of the measure (measured on the visible part of the water infrastructure without the foundation). The thickness of the water infrastructure represents the maximum transverse width of the measure (measured on the visible part of the water infrastructure). The level of the object means the difference between the highest point of width of the overflow section (below) and the lowest point of the object. The deposit length is the area where, due to the inflow of river material, gravel and sand eventually accumulates. In case of an overflow section, the listed dimensions can be chosen: thickness of the overflow section (below), thickness of the overflow section (above) and height of the overflow section. The dimensions of the overflow section are the dimensions of the overflow area of the water infrastructure. Width (below) represents the largest transverse dimension of the overflow section below. Width (above) represents the largest transverse dimension of the overflow section above. Height means the difference between the highest and lowest points of the overflow section. Further dimensions of elements on transverse measure can be chosen (options: the length of stilling basin, the depth of the river pool, the level of the final sill).

In the case of longitudinal structures and the presence of soil-bio engineering measures, the following option can be chosen: presence of soil-bio engineering (SB) measures, dimensions of longitudinal structures (in m), type of SB measure, material, trees and bushes. The mobile GIS application allows to determine the presence (YES) or absence (NO) of soil-bio engineering measures on longitudinal objects. If a soil-bio engineering measure is present, the dimensions: length, width and type of the measure are determined.



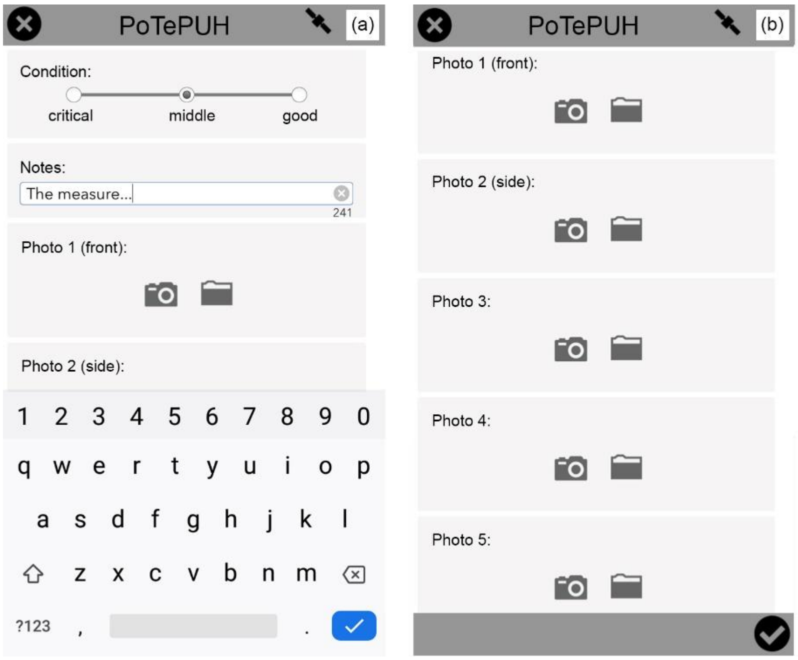
(a)
Type of measure:
● Transversal measure ○ Longitudinal measure
Type of transversal measure:
○ Barrier or barrage
● Debris flow breaker
○ Sill
Dimension of measure (in m):

(b)
Dimension of measure (in m):
Width across the stream: 0.80
Width of the overflow section (below):

(c)
Material:
☑ Concrete
☐ Stone
☐ Wood
☑ Steel
☐ Ground
Condition: ○ critical ● middle ○ good
Notes:
Photo 1 (front):
Photo 2 (side):

Figure 8. Mobile application for collecting torrent structural mitigation measures B: After the type of measure is selected (a), the dimensions are entered (in m) (b), and the material is selected from predefined options and the condition is determined, based on a 3-level scale for each individual element of water infrastructure (c).

Determining the condition of the structures is more difficult. The evaluation is based on the degree of visible damage and the assessment of material overuse (Figure 9). Therefore, a 3-level scale was established: critical (damage to the structure is very common and visible on more than 40%), medium (individual structural damage is visible or the material is worn on more than 40% of the structure surface), good (no visible damage; and no sign of worn construction materials). The system allows the user to enter notes and to add additional information and features, that are not covered by the system. The user can take up to 5 photographs that are saved as attributes in the attribute table. It is recommended to take photos from different angles with a measuring stick captured in the photograph, so that the results are comparable. It is important to take photos of each individual damage for later analysis, since the collection of attributes is adjusted to most common input parameters. Notes are optional and are dedicated to save additional terrain observations. The acquired data is transferred to an online database where it can be processed and presented graphically (e.g., interactive graphs and maps).



Condition:
○ critical ● middle ○ good

Notes:
The measure...
241

Photo 1 (front):

Photo 2 (side):

Photo 1 (front):

Photo 2 (side):

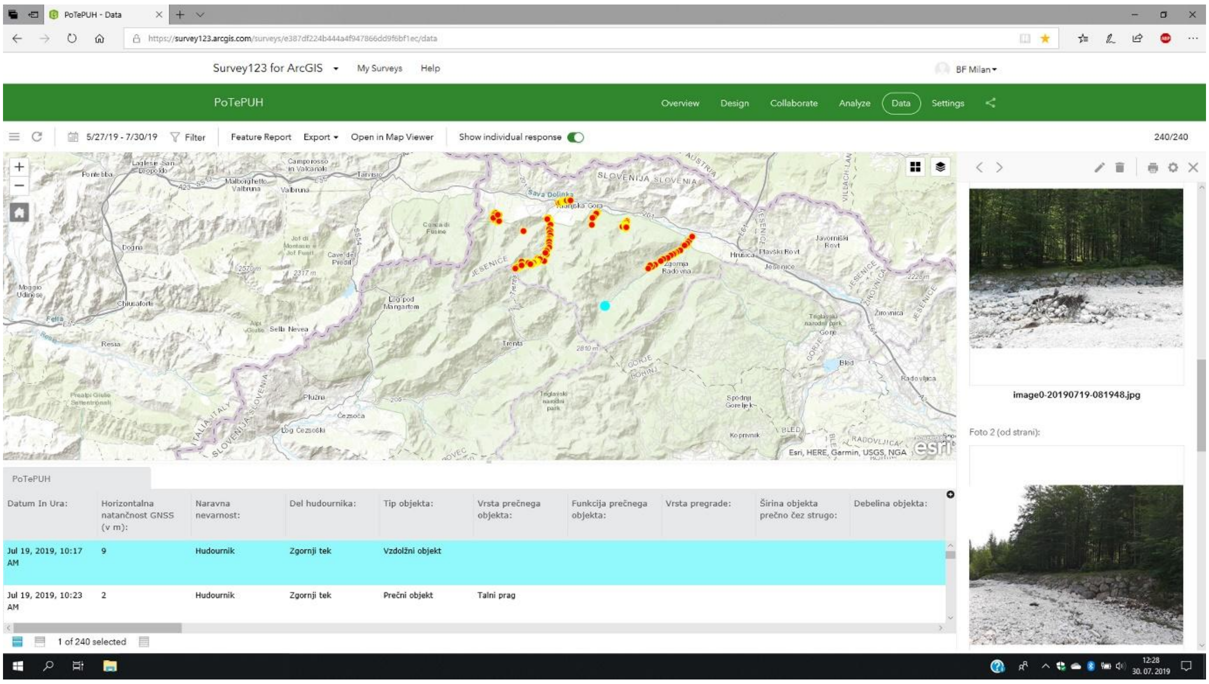
Photo 3:

Photo 4:

Photo 5:

Figure 9. Mobile application for collecting torrent structural mitigation measures C: The system allows the user to enter notes (a) and to take up to 5 photographs (b). When the surveying process is completed, the data is submitted to an Online platform, which enables further data processing.

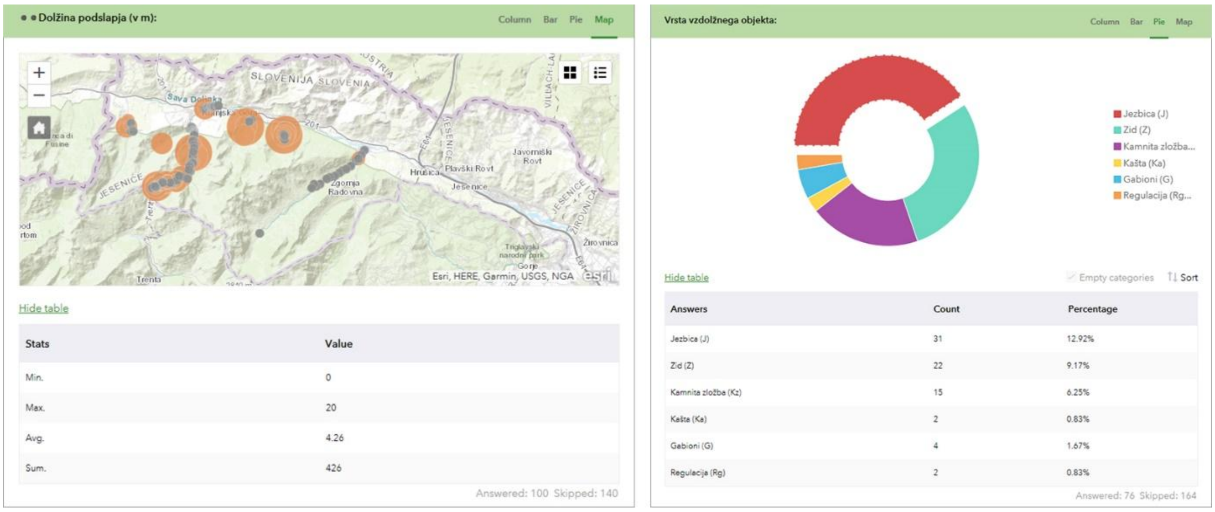
The application was used to collect water infrastructure data to be added to the torrent database of PAR2 Kranjska Gora, Slovenia (Figures 10 and 11).



PoTePUH

Datum In Ura:	Horizontalna natančnost GNSS (v m):	Naravna nevarnost:	Del hudournika:	Tip objekta:	Vrsta prečnega objekta:	Funkcija prečnega objekta:	Vrsta pregrade:	Širina objekta prečno čez strugo:	Debelina objekta:
Jul 19, 2019, 10:17 AM	9	Hudournik	Zgornji tek	Vzdolžni objekt					
Jul 19, 2019, 10:23 AM	2	Hudournik	Zgornji tek	Prečni objekt	Talni prag				

Figure 10. Locations of torrent mitigation measures within GR4A PAR2 Kranjska Gora recorded by using a Mobile GIS application.



Stats	Value
Min.	0
Max.	20
Avg.	4.26
Sum.	426

Answered: 100 Skipped: 140

Answers	Count	Percentage
Jezbica (J)	31	12.92%
Zid (Z)	22	9.17%
Kamnita zložba (Kz)	15	6.25%
Kašta (Ka)	2	0.83%
Gabioni (G)	4	1.67%
Regulacija (Rg)	2	0.83%

Answered: 76 Skipped: 164

Figure 11. The online inventory platform of water infrastructure enables data browsing and processing.

The field methodology for surveying water infrastructure protecting against the impacts of torrents is an efficient tool for field surveying. Compared to other manual methods, it can save time and also reduces the probability of transcription errors. The data are available and ready to further use immediately after field surveying. The accessibility of collected data is simple as data is saved in a standard vector format (shapefile; name.shp). The tool is flexible, i.e. it can be applied for basic as well as more detailed surveying, depending on the needs of the final user. The platform can be used on smart phones and tablets, with a potential for participatory use. The application provides an overview of the obtained data in the ArcGIS Online platform, which enables various queries and graphical outputs.

In order to collect comparable data among different torrents, the user should be aware of following issues:

- *Definition of part of a natural hazard:* Torrent processes are complex systems with large diversity in sediment and flow regimes depending on the part of a torrent. Usually, the amount of deposited sediments is quantified to provide basic information for planning mitigation measures (Hübl, 2018). However, specific measures appear more often on certain torrent parts.
- *Choice of function of measure*: Depending on the part of natural hazard and the amount of sediment, measures have a specific function; however, sometimes a single measure has multiple functions.
- *Measurements of dimensions*: Measurement errors can occur mainly due to the difficult access to some parts of torrents. Only the visible part of a structure is measured. However, it must be considered that each measure has a foundation, which enlarges the dimensions up to 1 m or more on each side.
- *Condition of measures:* Determining condition is more difficult and subjective. The evaluation is based on the degree of visible damage and the assessment of material overuse. The worker evaluates the condition based on a 3-level scale.
- *Photographs*: Taking photographs is important during field surveys. The condition of measures is additionally documented and can be evaluated again.
- *The use/non-use of external GNSS receiver*: The accuracy of the location may not be suitable when recorded by smart phones or tablets with a built-in GPS, and a poor accuracy may affect the validation procedure. Additionally, high uncertainty may be introduced, when several field workers are using different accuracy GNSS receivers.
- *Challenges for field surveying*:
- Field surveying may be sometimes dangerous and special attention should be given to the safety of field workers (e.g. the use of helmets, gloves, and proper footwear). Attention must

be taken on steep, inaccessible and fluctuating slopes and during river crossings where there is a danger of falling. When surveying wide torrents, only one shore should be surveyed at a time.

The main advantages that were identified during the development of the mobile GIS application are:

- *Data traceability*: After field surveying, the data is labelled with the name of the field worker, which enables the traceability of data origin and provides the possibility for later data verification.
- *Limited classification*: By developing the methodology for the mobile GIS application, we used existing classification types of measures (Water Act, 2002) and combine them with protection measures in forest areas (Mikoš, 2012) to create a comprehensive and simple procedure for collecting such data. However, the methodology represents one of several classifications, which should be further optimized.
- *A complete database on water infrastructure*: Developing mobile GIS applications for field surveys provides a standardized methodology for collecting data on torrent protection measures. A complete and harmonized database is created, which adds to existing databases information on dimension, material, condition, and notes and photographs.
- *Use for other natural hazards*: The presented methodology can be adapted for surveying protection measures against other natural hazards, e.g. snow avalanches, landslides and rockfall.

A new methodology for surveying torrent mitigation measures has been developed as a “Survey 123 for ArcGIS” mobile application. The method is efficient and user-friendly to collect data and attributes on measures in different parts of torrents, which can be used for further analysis (e.g. economical validation).

3.3 Protection measures for TEGRAV

Based on the information collected with the different methodologies described above, it was possible to select from the existing protection measures a “short list” of solutions to be included in the TEGRAV model (Table 7).

Table 7. List of measures selected for the TEGRAV model and their basic description.

N.	Measure	Location	Process	Typology
1	Technical release control	Release area	Avalanche	Grey
2	Artificial release system	Release area	Avalanche	Avoidance
3	Rockfall net	Transit/runout area	Rockfall	Grey
4	Debris net	Transit/runout area	Soil slope failures	Grey
5	Crib wall	Release area	Soil slope failures	Grey
6	Retention dam	Transit/runout area	Multi-risk	Grey
7	Afforestation	Both	Multi-risk	Green
8	Protection forest rehabilitation	Both	Multi-risk	Green
9	Road closure	Transit/runout area	Multi-risk	Avoidance
10	Building relocation	Transit/runout area	Multi-risk	Avoidance
11	Building evacuation	Transit/runout area	Multi-risk	Avoidance
12	Construction ban	Transit/runout area	Multi-risk	Avoidance
13	Early warning system	Transit/runout area	Multi-risk	Avoidance

We then defined for each of the listed measure the features and their economic valuation. This assessment will be performed based on the classification presented in Section 2.3 (direct costs, indirect costs, benefits and avoided damages), and is the main output that the TEGRAV model will provide for each measure. Table 8 shows how the economic components of each measure will be calculated, according to their typology, location, natural hazard process and features.

The information presented in Table 8, both the measure list and the definition of their economic components, constitutes the basic framework of the TEGRAV model. The model will match the structure defined above with the actual values of construction costs, asset value, forest management costs, etc. collected for all the countries and regions of the AS in order to provide site-relevant economic values. This second data collection, to be performed at large scale, will be achieved in the following months of the project and will constitute, together with the detailed description of the TEGRAV model, the core of the Activity A.T3.3.

Table 8. List of the economic components of each measure selected for the TEGRAV model.

		Direct cost					
N.	**Measure**	**Construction/ implementation**	**Maintenance**	**Dismantling**	**Indirect cost**	**Avoided damages**	**Benefits**
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

4 Summary and outlook

The present report summarizes the spatial and non-spatial data on existing elements at risk (potentially endangered assets) and protection measures that were provided by the institutions responsible for each PAR, and further analyzed to be employed in WPs1 to 3.

It was found that collecting and compiling such data is not an easy task since much of the data is not publicly available or does not have the required quality and/or depth of information. For example, information on building types (e.g. residential buildings, industrial and commercial buildings, sheds, and buildings that are not occupied all year round etc.), which are crucial for a thorough risk analysis, were only available (or could only be gathered in the available amount of time and with the available resources) for PAR5 Southern Wipptal. For PAR3 Oberammergau/Ettal, some classification could be applied but only based on land-use categories and not on actual building footprints (see Appendix A), which were not available for this PAR. This lack of information on building types is mainly due to data privacy regulations or requires a lot of data editing and processing of several more or less complete data sources (see Perzl et al., 2014). Furthermore, comparisons with current orthophotos have also shown that most of the available data is not up to date. However, we agreed on a simple classification system for building, transportation and recreational infrastructure, which were separated into two categories (high priority and low priority infrastructure, see Table 2), so that results from WPs1 to 3 can be compared between all PARs.

Gathering information on exiting protection measures was even more challenging than compiling infrastructure data. In the given amount of time, we were only able to gather some data for three PARs, but even that data is incomplete; however, it was sufficient to select a “short list” of solutions that will be included in the TEGRAV model. Where no such data exists, we demonstrated a method to collect it in the field by using a “Survey 123 for ArcGIS” application. For this project, it was applied to collect spatially-explicit data on torrent structural mitigation measures in the form of point features and related attributes, which can then be fed into a database. This method could also be applied to other structural protection measures against, e.g. avalanches or rockfall, where sufficient data is not available. The advantage of this method is that information on the current status of a structure can be recorded in the field based on simple predefined attributes. These attributes can then be updated regularly by subsequent field surveys guaranteeing a continuous status update.

To summarize, based on the compiled data:

1) forests with a direct object protection function were identified by linking natural hazard process models to the existing infrastructure (see Section 2.1),
2) a regional spatially explicit assessment (exposure assessment), which uses the natural hazard and forest protective effects modelling results will be carried out (see Section 2.2),
3) a more detailed spatial analysis in selected hotspots will be conducted (see Section 2.2),
4) an overview of the current practices in risk mitigation, which are already in place, provides input for the “Rapid Risk Appraisal” (see Section 2.2), and
5) a short list of existing protection measures for the TEGRAV model was prepared (see Sections 2.3 and 3.3).

References

Brilly, M., Mikoš, M., Šraj, M., 1999. Vodne ujme. Ljubljana, Univerza v Ljubljani, Fakulteta za gradbeništvo in geodezijo, 186 str.

Cardona, O.D., van Aalst, M.K., Birkmann, J., Fordham, M., McGregor, G., Perez, R., Pulwarty, R.S., Schipper, E.L.F., Sinh, B.T., 2012. Determinants of risk: exposure and vulnerability. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. [Field, C.B., Barros, V., Stocker, T.F., Qin, D., Dokken, D.J., Ebi, K.L., Mastrandrea, M.D., Mach, K.J., Plattner, G.-K., Allen, S.K., Tignor, M., Midgley, P.M., (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK; New York, NY, USA, 65-108. https://www.ipcc.ch/site/assets/uploads/2018/03/SREX-Chap2_FINAL-1.pdf

Direkcija, RS za vode. 2017. Atlas voda. Portal E-vode. https://gisportal.gov.si/portal/apps/webappviewer/index.html?id=11785b60acdf4f599157f33aac8556a6. (Accesed: June 2019)

DRSV, 2019. Spletni programi in storitve. http://www.dv.gov.si/si/spletni_programi_in_storitve/ (Accesed: 19 August 2019)

Grilj, T., Cunder, M., Kogovšek, P., Kregar, M., Štravs, L., 2015. eVode, Atlas voda in LIDAR – novi javno dostopni in brezplačni sistemi za dostop do podatkov s področja upravljanja voda. Ljubljana, Urbani izziv, posebna izdaja, 4 str.

Hübl, J., 2018. Conceptual Framework for Sediment Management in Torrents. Water 10(12), 1718.

Intergovernmental Panel on Climate Change (IPCC), 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. [Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., et al., Eds.]; Cambridge University Press: Cambridge, UK; New York, NY, USA.

Kleemayr, K., Teich, M., Perzl, F., Hormes, A., Markart, G., Plörer, M., 2019. Schutzwald-Definitions-Matrix. Bundesforschungszentrum für Wald (BFW), Institut für Naturgefahren, Innsbruck. Published online https://www.alpine-space.eu/projects/greenrisk4alps/downloads/poster/poster_grfa_schutzwald_deutsch.pdf

Mikoš, M., 2012. Kako se varovati pred hudourniki in masnimi tokovi v gozdnem prostoru? Varovalni gozdovi: Presoja naravnih nevarnosti, načrtovanje in gospodarjenje, Zbornik razširjenih povzetkov s predavanj, 53 – 55.

Pellicani, R., Van Westen, C. J., Spilotro, G., 2012. Assessing landslide exposure in areas with limited landslide information. Landslides, Springer Verlag Berlin Heidelberg. DOI 10.1007/s10346-013-0386-4.

Perzl, F., Den Outer, J., Rössler, M., 2014. GRAVIPROFOR – Schutzwaldkulisse in der forstlichen Raumplanung. Methodik – Datengrundlagen für die Modellierung von Waldflächen mit Lawinen- und Steinschlag-Objektschutzfunktion. Projektsbericht im Auftrag des Bundesministeriums für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft im Rahmen der Technischen Hilfe des österreichischen Programms LE 07-13 mit Unterstützung von Bund, Ländern und der Europäischen Union. Teilbericht. V2. Zahl: BMLFUW-LE.1.3-7/0020-II/5/2012.

Promper, C., 2014. Spatial and temporal development of landslide risk- a contribution to risk management in the context of global change. University of Vienna, PhD thesis, 125 pp.

Promper, C., Glade, T., 2016. Multilayer-exposure maps as a basis for a regional vulnerability assessment for landslides: applied in Waidhofen/Ybbs, Austria. Natural Hazards 82(S1), 111-127.

Sodnik, J., Kogovšek, B., Mikoš, M., 2014. Vodna infrastruktura v Sloveniji: Ali vemo, kaj moramo vzdrževati? 25. Mišičev vodarski dan 2014: 8 str.

Sodnik, J., Martinčič, M., Mikoš, M., Kryžanowski, A., 2015. Are Torrent Check-Dams Potential Debris-Flow Sources? Engineering Geology for Society and Territory 2, 6 str.

United Nations, 2015. Sendai Framework for Disaster Risk Reduction 2015–2030 (SFDRR).

Water Act, 2002. Uradni list Republike Slovenije 67, 2, 114 str.

WEP-R, 2012. Waldentwicklungsplan. Richtlinie über Inhalt und Ausgestaltung – Fassung 2012. Erstellung: Singer, F., Starsich, A., Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft (BMLFUW), Wien.

Appendix A: Infrastructure data processing

Infrastructure PAR1 Val Ferret:

Buildings

- Fabbricati – source: http://geoportale.regione.vda.it/download/
    - Manually removed eleven protection installations east of the settlement of Courmayeur

Transport data

- Class 2: Strada Statale', 'Strada Comunale' (data set: grandi_impianti)
- Class 1: non-tarmac roads
- There is no railway line in the PAR

Recreational

- One golf course (class 1)
- No ski areas or lifts within PAR

Infrastructure PAR2 Kranjska Gora:

Buildings

- All from layer *buildings_2*

Transport

- Class 2: layer *roads_2*: 'highway' and 'regional road'
- Class 1: layer *roads_2*: 'city or local road', 'local road', 'public road' and city or local road for assembly
- There is no railway line in the PAR

Recreational

- Ski area (source: *ski_trails2.asc*)
- No camp sites or other recreational areas provided

Notes:
- Roads, DTM and ski area did not have a coordinate system assigned. Buildings were projected to Webmercator, thus assumed the other files were too and assigned that coordinate system – then re-projected all files to utm_32n

Infrastructure PAR3 Oberammergau:

Settlement

Landuse layer:
Class 2:
objart" = 'AX_FlaecheBesondererFunktionalerPraegung' OR "objart" = 'AX_FlaecheGemischterNutzung' OR "objart" = 'AX_IndustrieUndGewerbeflaeche' OR "objart" = 'AX_Wohnbauflaeche'
Class 1:
"objart" = 'AX_Friedhof' OR "objart" = 'AX_SportFreizeitUndErholungsflaeche' OR "objart" = 'AX_TagebauGrubeSteinbruch'

Transport data

- Class 2: railway line, roads (wdm: 1301-motorway, 1303-Bundesstrasse, 1305-Landesstrasse, Staatsstrasse) – removed two tunnel segments
- Class 1: roads wdm 1307-municipality road

Recreational

- Lifts (Schwebebahn)
- Recreational areas in Landuse map (bike park)

Infrastructure PAR5 Wipptal South:

Buildings

Composed of two datasets of the Autonomous Province of Bolzano:

1. Technische Vektorgrundkarte (VGK)
    - released in 2007, based on interpretation of aerial imagery from up to 1999.

Class 2:

- 06075000 residential building
- 06070350 military building
- 06075200 public building
- 06075400 industrial/business building,

Class 1:

- 06090200 swimming pool
- 06076200 farm building
- 06071000 abandoned building
- 06210600 sports grounds
- 06071200 baracks
- 06076000 service building technology networks
- 06075600 churches
- 06075800 service building (e.g. cable car station, hydrowpower station)
- 06071400 building currently being constructed

2. Gebäudekataster

- As of 17-July-2019
- Original data for 10 Katastralgemeinden
- ..parcel_poly_shp contains land parcels --- attribute field PT_FABB whether the polygon is a building or not
- Pre-processing:
    - Combined the four-municipality polygon parcel information into one feature class
    - Extracted polygons classified as buildings
    - All buildings are assigned Infrastructure class 2 (since no further differentiation possible)

Transport

- Classified as follows:
- Class 2: motorway, primary roads (Staatsstrasse, Landesstrasse) and railway line
- Class 1: secondary roads (Gemeindestrasse, Gemeindestr. in Landesinstandhaltung) and tertiary roads (Güterwege für LKW, Güterwege für Traktoren)
- Data Source: Autonomous Province of Bolzano

Recreational

- Ski runs
- Lifts
  (Note: there are no campsites or golf courses – at least not in the official data)
  Source: Autonomous Province of Bolzano

Infrastructure PAR6 Vals/Gries:

Buildings

- Class 2: All in buildings_6.shp

Transport data

- **Class 2:**
  "STRKAT" = 'Autobahn' OR "STRKAT" = 'Bahnlinie - hochrangig' OR "STRKAT" = 'Landesstraße B' OR "STRKAT" = 'Landesstraße B - Brücke' OR "STRKAT" = 'Landesstraße L' OR "STRKAT" = 'Landesstraße L - Brücke' OR "STRKAT" = 'Autobahn - Brücke' OR "STRKAT" = 'Autobahn - Nebenanlagen', 'Autobahn - Rampe mit Brücke' und 'Autobahn - Rampen'

- **Class 1**:
  "STRKAT" = 'Örtliches Straßennetz' und ‚Wirtschaftsweg‘

Recreational

- Class1: Ski area

Land use – other

- Mining area

Appendix B: Originally provided PAR assets data sets

GreenRisk4ALPs ASSETS DATA Overview

Data content	**Data set name**	**Data format**	**Data time (year)**	**Source (open access, data owner, etc.)**	**Additional information/comments**
PAR1 Val Ferret, Italy					
municipality border	border_1	.shp	2018	Fondazione Montagna sicura	
roads	roads_1	.shp	2005	Aosta Valley Autonomous Region	Data are extracted from topographic vector map (2005), codice_det (3 classes): Strada Statale, Strade Sterrate, Strada Comunale
buildings	settlements_1	.shp	2005	Aosta Valley Autonomous Region	Data are extracted from topographic vector map (2005), only footprints, no types
land use	land_use_1	.asc		Aosta Valley Autonomous Region	Based on CORINE land cover, 3 digit codes
ski trails	ski_trails_1	.shp		Aosta Valley Autonomous Region	
hiking trails	hiking_trails_1	.shp		Aosta Valley Autonomous Region	
protected areas	prot_areas_1	.asc		Aosta Valley Autonomous Region	Values are explained in catalogue
golf course	golf_course_1	.shp	2019	Fondazione Montagna sicura	Scale: 1:5.000
PAR 2 Kranjska Gora, Slovenia					
municipality border	border_2	.shp	2018	Statistical office of Republic Slovenia - https://www.stat.si/gis/Baza.aspx?lang=en	
roads	roads_2	.shp	2018	The surveying and mapping authourity of The Republic Slovenia http://www.e-prostor.gov.si/brezplacni-podatki/	Attribute ATR1: 9 categories
buildings	building_2	.shp	2018	see above	Only footprints, no types
land use	Land_use_2	.shp	2018	Ministry of agriculture, forestry and food of Slovenia - http://rkg.gov.si/GERK/	14 categories like forest, water, built-up land
ski trails	ski_trails_2	.asc	2018	PISO portal for Kranjska Gora https://www.kranjska-gora.si/sl/info/zemljevidi	Incomplete data: no data on Biathlon trails, cross country ski trails etc.
hiking trails	hiking_trails_2	.asc		The surveying and mapping authourity of The Republic Slovenia http://www.e-prostor.gov.si/brezplacni-podatki/	
protected areas	prot_area_2	.asc	2018	Ministry of the Environment and Spatial Planning – Slovenian Enviromental Agency https://www.geoprostor.net/piso/ewmap.asp?obcina=KRANJSKA_GORA	
cultural heritage	cult_her_2	.asc	2018	PISO portal for Kranjska Gora https://www.geoprostor.net/piso/ewmap.asp?obcina=KRANJSKA_GORA	Undefined spatial reference
real estate prices	real_estate_2	.asc	2018	see above	Units are in €/m²
other - tourist points	other_tp_2	.asc	2018	The surveying and mapping authourity of The Republic Slovenia http://www.e-prostor.gov.si/brezplacni-podatki/	Added paragliding start (paragliding_2). Data was collected in 2018.
PAR3 Oberammergau/Ettal, Germany					
municipality border	LVG_Gemeindegrenzen_WGS_1984	.shp			

roads	6_strasse	.shp			3 categories: 1303, 1305, 1307
railways	6_Bahn	.shp			Includes railways and ski lifts, objart: 42014=railway, 53005=ski lift
land use	7_landusemap	.shp			No building footprints, but land-use categories
economic areas	6_industriegebiet1	.shp			Extracted from 7_landusemap
bike trails	7_mountainbike_trail	.shp			
hiking trails	7_hiking_trail	.shp			
protected areas	7_SPA_grenze, 7_nsg, 7_naturpark, 7_ffh	.shp			4 data sets! outlines of areas with different status of protection
cultural heritage	7_landschaftspr_denkmal, 7_bodendenkmal, 7_baudenkmal	.shp			3 data sets! outlines of areas with different heritage status
mountain bike trails	7_bike_trail	.shp			
PAR4 Parc des Baronnies; France					
municipality border	Extent_Baronnies_WGS84, baronnies_park_perimeter	.shp			baronnies_park_perimeter
roads	Road	.shp			
railways	Railway	.shp			
buildings	industrial buildings, light_buildings, remarkable_building, undefined buildings	.shp			4 data sets!
other infrastructure	airfield_runway, sports_ground, tank	.shp			3 additional data sets of other infrastructure
land use	departement_26, departement_05	.shp			2 data sets in OSO
protected areas	zps1905, sic1905	.shp	2015		2 data sets: special protected areas; protected areas
PAR5 Southern Wipptal, Italy					
municipality border	municipality_5, par_outline_5	.shp	2011	http://geokatalog.buergernetz.bz.it/geokatalog/#!, © Autonome Provinz Bozen/Provincia autonoma di Bolzano (http://geoportal.buergernetz.bz.it/geodaten.asp)	
roads	transp_5	.shp	2010	see above	
railways	transp_5	.shp	2010	see above	
buildings	buildings_5	.shp	2008	see above	
land use	cad_parcels_5	.shp		see above	
bike trails	transp_5	.shp	2010	see above	
hiking trails	transp_5	.shp	2010	see above	
ski lifts	lifts_5	.shp	2005	see above	
ski areas	skislopes_5	.shp	2005	see above	

PAR6 Vals/Gries am Brenner, Austria					
municipality border	municipalities_6	.shp	2017	Land Tirol (Abt. Geoinformation) (contract/agreement)	
roads	roads_6	.shp/.asc	2018	https://www.data.gv.at/	Combined data set with railway, forest roads, hiking trails etc.
railways	railways_6	.shp/.asc	2014	https://www.data.gv.at/	
buildings	buildings_6	.shp/.asc	2014	https://www.data.gv.at/	Only footprints, no types
land use	zoning_6	.shp	2014	https://www.data.gv.at/	Only for building areas
protected areas	prot_areas_6	.shp	2012	https://www.data.gv.at/	

Note: Listed are the data sets that were originally provided by the institutions linked to the PARs. These data sets may differ from data sets reported in Table 1 since for PARs 1, 5 and 6, additional data was gathered during data processing.