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Chapter

Wipptal South Pilot Action Region: Gravity-Driven Natural Hazards and Forest Types

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Abstract

This chapter describes the Wipptal South Pilot Action Region (PAR) in South Tyrol, where forests are well recognized to play a crucial role in protecting against a variety of gravity-driven natural hazards, such as landslides, debris flows, rock falls and snow avalanches. The chapter presents the three municipalities in the PAR area in terms of socio-environmental context, gravity-driven natural hazards and forest characteristics. The presented best-practice example describes the results of a former project entitled "Waldtypisierung Südtirol" (Eng. Forest Characterization South Tyrol) that focused on a detailed description of forests in South Tyrol and the development of a handbook for foresters. It is shown that the Wipptal South PAR as being is frequently affected by a variety of gravity-induced hazards while highlighting the critical role of forest in protecting people and their properties. Appropriate forest management strategies are vital to maintain and increase tree species diversity (e.g. populating fir) and the associated protective forest function. In this context, climate change effects, such as an increasing threat of bark beetle infestation due to rising drought stress or the consequences of associated extreme weather events (e.g. storms), pose major challenges for the local forests and their protective function.

Keywords: natural hazards, forest, South Tyrol, protective forest

1. Introduction

The Wipptal South Pilot Action Region (PAR) represents one of the six study sites of the Interreg Alpine Space project GreenRisk4Alps. The area lies in the center of the Alps within the Autonomous Province of South Tyrol, northern Italy. The areal extent of the PAR includes the three municipalities of Sterzing/Vipiteno, Brenner/Brennero and Pfitsch/Val di Vizze (**Figure 1a**). Sterzing/Vipiteno is a small city with around 7,000 inhabitants lying in the southern part of the PAR at the valley bottom. The municipalities Brenner/Brennero and Pfitsch/Val di Vizze exhibit a more distinct mountainous and rural character with a population of around 2,300 and 3,100, respectively. The area was chosen as a pilot region for the GreenRisk4Alps project for the following two reasons:

- forest is well-known to play an important role in protecting against a variety of gravity-driven natural hazards

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- it directly borders the Austrian Vals/Gries PAR to the north, which allows the elaboration of cross-border similarities and differences in terms of forest management and its impact on the current natural hazard risk situation

The present chapter first introduces the PAR and its three municipalities in terms of socio-environmental context (Section 2) before highlighting the current natural hazard situation (Section 3). These more general parts are followed by the best-practice example (Section 4) that builds upon a former project entitled "Waldtypisierung Südtirol" (here translated as "Forest characterization South Tyrol").

This best-practice project focused on the characterization of forests in South Tyrol and included a spatially explicit elaboration of forest typologies and associated ideal silvicultural treatment guidelines while also paying attention to the forest protective function. The chapter is concluded by highlighting pending challenges in terms of the protective forest and its management in the PAR (Section 5).

2. PAR description

2.1 General description

The Wipptal South PAR is situated in the northern part of the Province of South Tyrol with several mountain chains crossing the area. The area refers to the upper Wipptal with the Brenner area to the north, the Pflersch Valley to the west, the Sterzing Basin to the south and the Pfitsch Valley to the east (**Figure 1b**). The upper

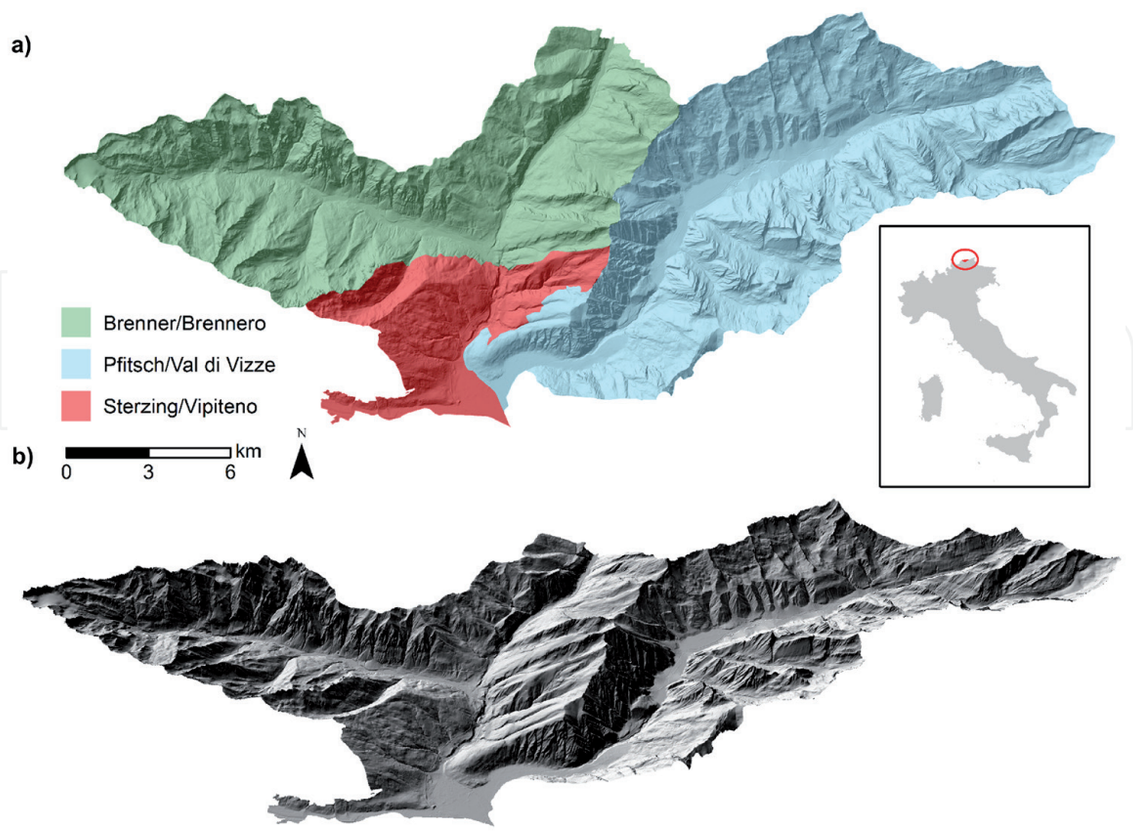


Figure 1.
The location of the Wipptal south PAR within Italy and the areal extent of the three associated municipalities (a). The 3D shaded relief image provides a visual impression of the morphology of the area (b). (data source: GeoKatalog of the province of South Tyrol – http://geokatalog.buergernetz.bz.it/geokatalog/#!).

Wipptal is part of the Eisack Valley that borders with Austria at the Brenner Pass. This mountain pass represents one of the most important strategic commercial corridors in the Alps. The Pflersch and the Pfitsch valleys are located aside the main transportation network, making them rather unspoiled and attractive for naturalistic tourism, hiking and skiing sport activities (**Figure 1b**).

In the Wipptal area, mountains span from the west, with the Stubaier Kalkberge dividing the Tuxer Alps from the Pfitsch Valley, and run transversely from the southwest to east of the Brenner line. South of the Pfitscher Joch (2,251 m), the Pfunderer Mountains form the foothills of the Zillertal Alps, where the Hochfeiler, at 3,510 m, represents the highest peak (**Figure 1b**). The area around the Hochfeiler is heavily glaciated and merges into the more strongly dissected Pfunderer Mountains, located in the high mountain region between the Pfitsch, Valser and Pfunderer valleys.

In summary, the mountainous environment characterizes considerable parts of the PAR. The prevalent high altitudinal gradients and steep slopes are essential controls for several gravity-driven processes that can rapidly displace a considerable amount of material to the valley bottoms where most of the assets, urban areas and villages are located (**Figure 2**).

2.2 Socio-environmental context

The social, economic and environmental characteristics of the Wipptal South PAR are fundamental in determining the risk associated with gravitational processes. Each change in the socio-economic situation (e.g. changing population densities at the foot slopes) or environmental conditions (e.g. climate change) can modify the natural hazard risk situation. The comprehension of such differences in the socio-environmental conditions across the PAR and their developments



Figure 2.
View of the main valley. Sterzing/Vipiteno as seen from the Elzenbaumer Wetterkreuz. (source: https://it.wikipedia.org/wiki/Immagine:Sterzing-Vipiteno_and_Elzenbaumer_Wetterkreuz.JPG; author: Fantasy; CC BY-SA 3.0: https://creativecommons.org/licenses/by-sa/3.0/legalcode; no changes were made).

contribute to a better understanding of current and future impacts related to gravity-driven natural hazard processes.

2.2.1 Population

The entire Wipptal area represents the least populated district in the Autonomous Province of South Tyrol. Five out of six municipalities and about 95% of the area of the Wipptal can be classified as highly rural due to their comparably low population density of less than 30 inhabitants per square kilometer [1]. The area experienced an increase in population after 1960, a stagnation in the 1980s and an increase again after the 1990s (this most recent increase being mainly in the municipalities of Sterzing/Vipiteno and Pfitsch/Val di Vizze). In the other municipalities, a minimal growth rate or a decline in population have been recorded. The city of Sterzing/Vipiteno has the largest population and, at the same time, the smallest area, leading to a relatively high population density of 205 inhabitants per square kilometer. Overall, the population density of the Wipptal South area is far below the national average in all municipalities, except Sterzing/Vipiteno, underlining the rural character of the landscape [1].

2.2.2 Economy

The geographical position of the PAR close to the border with Austria has always supported trade activities between the south side of the Alps and Central Europe. In this context, the Brenner Pass plays a strategic role as a corridor for the transportation of goods and for shaping the social and economic characteristics in the entire province. While the vicinity of the pass affects the distribution of the population in the valley bottoms, where facilities and means of transportation are located, it also influences the type of existing economy, with most of the population employed in services (66%), manufacturing (25%) and agriculture (9%) [1].

In this sense, the municipalities of Brenner/Brennero and Vipiteno/Sterzing represent the economic hubs for the manufacturing and service sectors, with the latter being the main urban area (6,979 inhabitants in December 2018, Provincial Statistics Institute, 2019) and having an economic fabric focusing on Alpine technologies (cable systems, snow groomers), and food products (milk-based products) [2].

Tourism in South Tyrol represents a key sector, and the area has seen a steady increase in visitation over the years. This is not only due to its geographical and climatic conditions, but also to its historical and cultural background, which create particularly favorable conditions for activities linked to tourism. In the Wipptal area, Vipiteno/Sterzing and Brenner/Brennero have the highest bed occupancy rates, while the rest of the area shows a declining rate, with potential for expanding the tourist accommodation capacity [1].

With respect to agriculture, the number of farms in the Wipptal has declined at an above-average rate over the last 15 years. This is a clear sign that agriculture in the Wipptal Valley is undergoing profound change. This has consequences for the amount of land used for agricultural purposes and the ongoing process of rural abandonment. However, in the municipality of Pfitsch/Val di Vizze, the utilized agricultural area has increased, suggesting an intensification of agriculture activities with a lower number of farms [1].

2.2.3 Land use

The city of Sterzing/Vipiteno, as the main town and district center, represents only 11% of the area of Wipptal, at 33.2km^2 [1]. The Wipptal has a below-average

proportion of artificial and agricultural land compared to the total area of the province, with Sterzing/Vipiteno having the highest proportion of artificial areas. In the context of rural communities, Pfitsch/Val di Vizze has a relatively high proportion of agricultural land, which shapes its landscapes and economic characteristics.

Due to the high altitude of the area and the mountainous topography (**Figure 1b**), however, all the municipalities in Wipptal South, except Sterzing/Vipiteno, have a below average proportion of usable agricultural land compared to the Italian mean. Such numbers, however, should be interpreted in the context of the considerable amount of high-altitude areas and extent of high forest. In particular, the municipalities of Pfitsch/Val di Vizze and Brenner/Brennero exhibit an above-average proportion of high-altitude areas without vegetation [1]. The prevalent forest situation is presented in detail in Section 4.

2.3 Climate

2.3.1 Past and current climate

The Wipptal South PAR is characterized by a climate that is heavily influenced by its alpine topography, with mountain peaks contributing to large diurnal temperature variations. The general climatic condition can be described as temperate with very cold and snowy winters and frequent cold winds coming from the Brenner Pass. Summers are generally warm with maximum rainfall precipitation and very intense localized events (**Figure 3**). The Köppen-Geiger climate classification is Dfb, meaning a warm-summer humid continental climate. The average annual temperature in Sterzing/Vipiteno was 8.6°C for the period 2001–2010, while cumulative annual rainfall was 699.1 mm over an average of 90 rainy days (data for the period 2001–2010, **Figure 3**).

The prevalent climatic characteristics, with frequent heavy precipitation events, considerable snow fall in winter and snow melting in spring and frequent freeze–thaw cycles at higher altitudes or in winter, generally favor suitable conditions for a variety of gravitational natural hazards. The projected increase in temperatures due to climate change is expected to affect the forest in the area as well as several hydrological processes related to snow melting, runoff and soil infiltration. Moreover, climate change is also affecting the number and frequency of extreme sudden events (e.g. rainstorms and snowstorms), with acute consequences for environmental conditions and potential effects in terms of natural hazards. Three of the highest daily values of precipitation, maximum and minimum temperature are reported in **Table 1**, with extreme positive values of precipitation and temperature having been recorded in the last 17 years, while minimum temperature values were recorded further in the past.

2.3.2 Future climate

Future changes in climate conditions are expected to affect forest development and the occurrence of gravitational processes in the Wipptal South area. Although climate projections are affected by a certain degree of uncertainty, they can also provide indications of what can be expected in the future. In the context of the GreenRisk4Alps project, climate scenarios for the PAR were derived from multiple models and two greenhouse gas emission scenarios (Representative Concentration Pathway, RCP): RCP4.5 (i.e. emission peak around 2040) and RCP8.5 (i.e. business-as-usual scenario). Technical details on the derivation of climate change scenarios are provided in Deliverable 1.1.1 of the project [3].

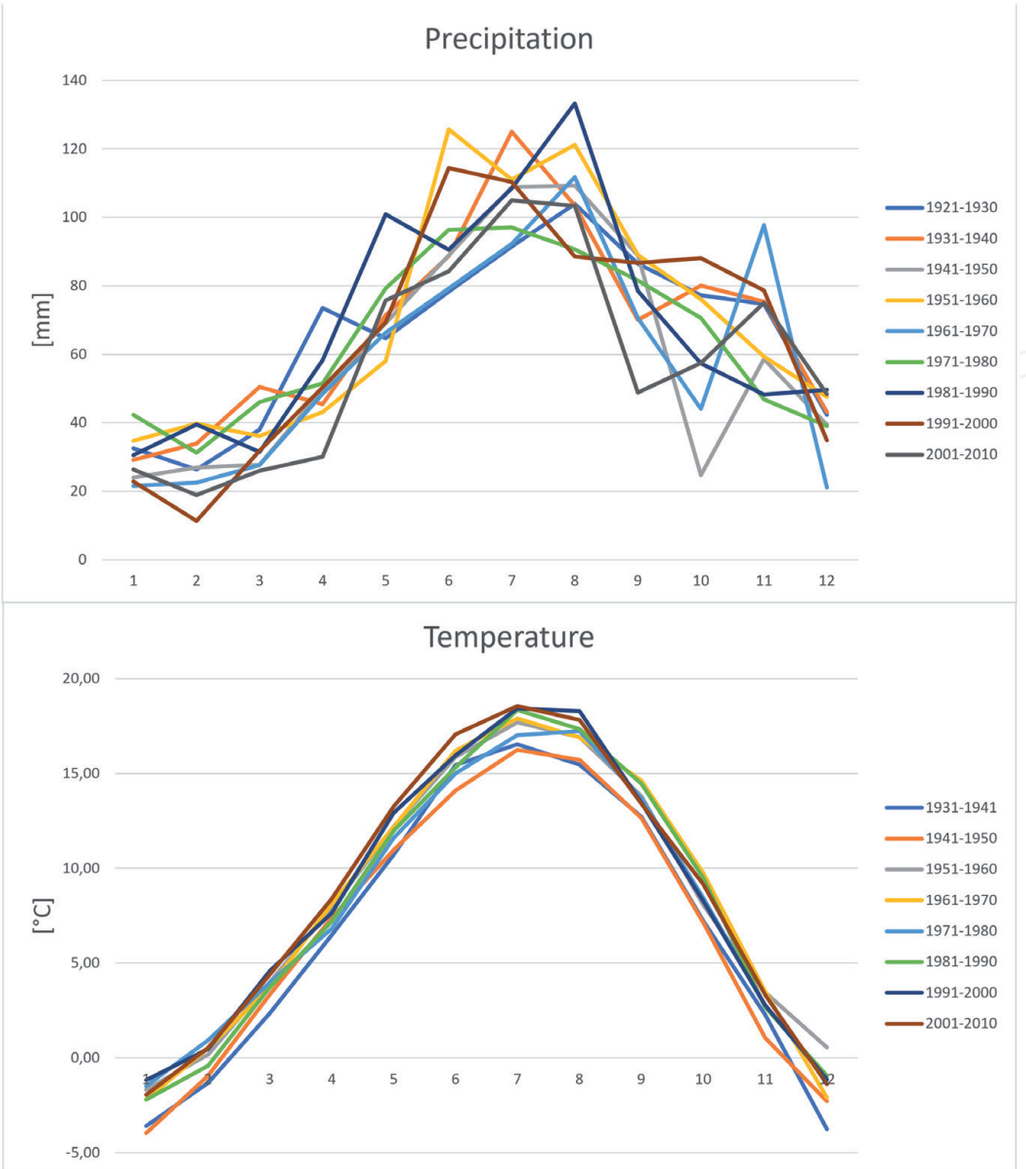


Figure 3.
Ten-year average monthly (x-axis) precipitation and temperature (y-axis) recorded at the weather station in Sterzing/Vipiteno from 1931 to 2010 (data source: http://meteo.provincia.bz.it/download-dati.asp).

Date	Precipitation [mm]	Date	Max. temp. [°C]	Date	Min. temp. [°C]
2018-10-28	99.7	2013-08-03	35.5	2000-01-14	−20.6
2012-08-05	81	2015-07-05	35.1	1999-12-22	−19.9
2011-09-19	80.4	2003-08-13	34.7	1999-12-23	−19.8

Table 1.
Extreme daily precipitation and temperature values recorded at the weather station in Sterzing/Vipiteno. Precipitation records are from 1/01/1981 onward, while temperature records are from 03/12/1998 onward (data source: http://meteo.provincia.bz.it/download-dati.asp).

The results for the Wipptal South PAR clearly depict a positive trend in temperature by all models, with considerable differences between the emission scenario that foresees a peak around 2040 and the business-as-usual scenario (**Table 2**). The more uncertain analysis of precipitation projections indicates slightly wetter

	Wipptal South PAR	
	RCP4.5	**RCP8.5**
DJF	+1.7	+2.9
MAM	+1.5	+2.9
JJA	+2.2	+3.8
SON	**+2.0**	+3.6
Year	+1.8	+3.2

Table 2.
Trend in seasonal and annual mean temperature anomalies (reference 1971–2000) for the period 1950–2097. The values are expressed as °C per century. Interpretation example (in bold): Annual mean temperature variation over one century (e.g. 1951–2050) is +2°C (+1°C in 50 years). DJF: December, January, February, MAM: March, April, may; JJA: June, July, august; SON: September, October, November.

conditions for future winters, with no clear trend regarding increasing or decreasing precipitation amounts. The uncertainties involved call for a cautious interpretation of the results. Nevertheless, such outcomes are in line with existing studies on climate change across Europe and Alpine regions (see e.g. [4–8]).

In particular, the results on temperature highlight an increase in all seasons, with a yearly average of +1.8 °C for the greenhouse gas emission peak in 2040 and + 3.2 °C for the business-as-usual scenario. Although the highest increase in temperatures is expected during summers, the projected changes during winters and springs should be carefully considered due to their potential influence on snowfall and snow cover, frost conditions, run-off and soil moisture.

The models also depict seasonal changes for precipitation with generally higher yearly precipitation in the business-as-usual emission scenario (**Table 3**).

Changes in extreme precipitation conditions were also analyzed within the GreenRisk4Alps project, and further details can be seen within Deliverable 1.1.1 [3]. In summary, the derived numbers indicate a statistically significant increase in extreme precipitation for the business-as-usual emission scenario. In the case of an emission peak around 2040, the derived extreme precipitation indicators showed a lower signal and no statistical significance in most cases. Overall, the obtained results need to be cautiously interpreted, especially in case of the analysis of total precipitation and extremes (see e.g. [9, 10]).

	Wipptal South PAR	
	RCP4.5	**RCP8.5**
DJF	+	+26.7
MAM	+	+
JJA	+	+15.2
SON	+11.8	+
Year	**+8.1**	+14.1

Table 3.
Trend in seasonal and annual total precipitation anomalies (reference 1971–2000) over the period 1950–2097. The values are expressed as % per century. The trend sign (+ or -) is only reported for non-significant trends (p-value <0.05). Interpretation example (in bold): Annual total precipitation variation over one century (e.g. 1951–2050) is +8.1% (+4.05% in 50 years).

3. Natural hazard risks in the PAR

3.1 Principles of risk management

The area is regularly affected by diverse natural hazard phenomena. After severe weather periods in particular, rivers and streams can overflow their banks, hillslopes can become unstable, debris flows or snow avalanches can occur and rock walls and very steep terrain can produce rock falls. In South Tyrol, the Agency for Civil Protection deals with protecting the population from the potential negative effects of natural hazards. In summary, their integral approach to risk management builds upon the combination of four pillars for the most efficient protection of people and their belongings (cf. http://www.provincia.bz.it/sicherheit-zivilschutz/wildbach/umgang-mit-naturgefahren.asp):

- **Prevention** mainly focuses on spatial planning, including official hazard zonation, object protection (also via forests) and awareness raising.
- **Protection** activities also include the case-specific design, construction and maintenance of technical protection structures.
- **Preparedness** includes prediction, warning, emergency planning and the development of protocols in case of events.
- **Response** and **recovery** activities relate to measures after an event, such as the implementation of protocols, restoring the pre-event state, redevelopment, learning from past events and improving conditions to cope with future events.

These four risk management pillars should be considered as equally important, and one pillar should not be neglected in favor of another. The official hazard zonation of South Tyrol accounts for a variety of gravity-driven mass movement hazards (slides and falls), water-related hazards and snow avalanches (Section 3.2). For the Wipptal South PAR, these legally binding plans are currently in an advanced stage of development (status: 4th December 2020): the municipalities of Brenner/Brennero and Pfitsch/Val di Vizze are currently in phase C (technical examination), while the plan for Sterzing/Vipiteno has recently been approved (http://www.provinz.bz.it/natur-umwelt/natur-raum/planung/gefahrenzonenplan.asp).

3.2 Gravity-driven hazards

The causes of gravity-driven hazards in the PAR are manifold and controlled by a combination of diverse environmental factors. Besides the morphology of the area, the properties of weathered slope material and hydrological and mechanical effects of vegetation also influence the occurrence of natural hazards in the PAR. Anthropogenic effects also play a role in modifying the natural risk situation. On the one hand, humans frequently influence natural hazard processes due to e.g. construction activities, slope undercutting or land use practices, while on the other hand, construction and land use activities determine the exposure of assets. In the PAR, gravity-driven hazards are mainly triggered by heavy precipitation events and/or intensive snow melting (all mass movements), temperature alterations (e.g. avalanches, rock falls), mid-term weather conditions (e.g. prolonged rain, wet or snow-rich seasons) and direct human interference (e.g. construction works).

Altitudes range from less than 950 m a.s.l. in the Sterzing/Vipiteno basin to more than 3,500 m a.s.l. in the very east of the Pfitsch Valley (Hochfeiler in **Figure 1**).

This considerable elevation difference entails substantial relief energy in the PAR. In addition to altitude, slope aspect and associated shadowing effects co-determine the prevalent temperature, insolation and precipitation regimes. In fact, mean annual precipitation of around 700 mm can be observed for Sterzing/Vipiteno (**Figure 3**), while rates of more than 1,000 mm/year are prevalent for some of the mountainous areas (e.g. Pfitsch Valley).

The geology and therefore also the subsurface material properties vary across the PAR. In the Pflersch Valley, different kinds of gneisses and schists are prevalent, and carbonate rocks, such as calcareous phyllites, marbles and dolomite (e.g. Pflerscher Tribulaune), can also be found. In the Pfitsch Valley, the main rocks are landslide-prone phyllitic mica-schists, paragneisses and granite gneiss. At the Brenner Pass, calcareous phyllites and mica-schists are common. Glacial till, laid down directly by glaciers or reworked by fluvial and other processes, covers large parts of the hillslopes [11].

3.3 Landslides of different movement types

Natural hazard inventories provide an overview of the spatial distribution of past events. In the basin area of Sterzing/Vipiteno, flooding and associated hydrological processes are the main natural hazard. **Figure 4** highlights that the hilly and mountainous areas surrounding the area of Sterzing/Vipiteno are prone to a variety of gravity-induced processes. Due to their mountainous character, the municipalities of Brenner/Brennero and Pfitsch/Val di Vizze frequently

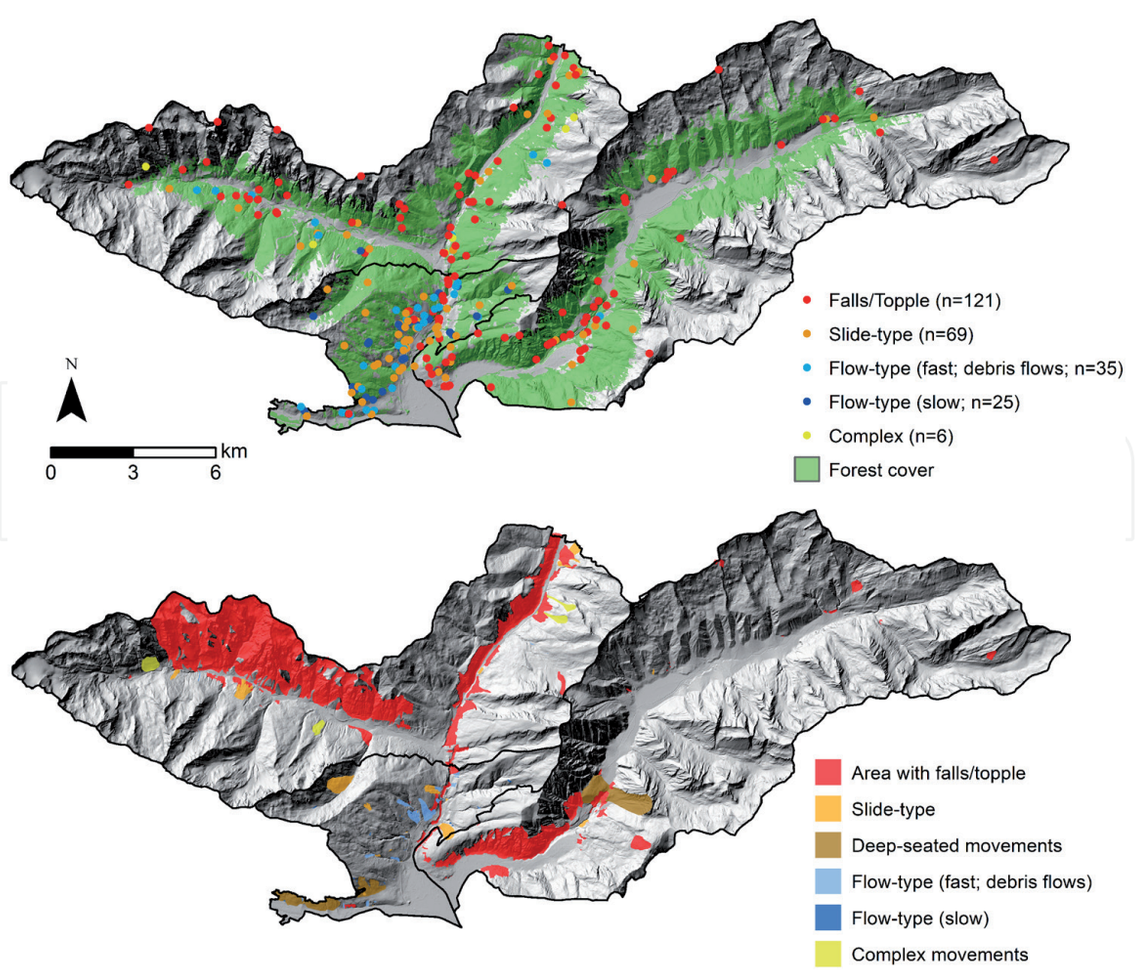


Figure 4.
Point and extension information for different landslides types. (data source: GeoKatalog of the Autonomous Province of South Tyrol – http://geokatalog.buergernetz.bz.it/geokatalog/#!).

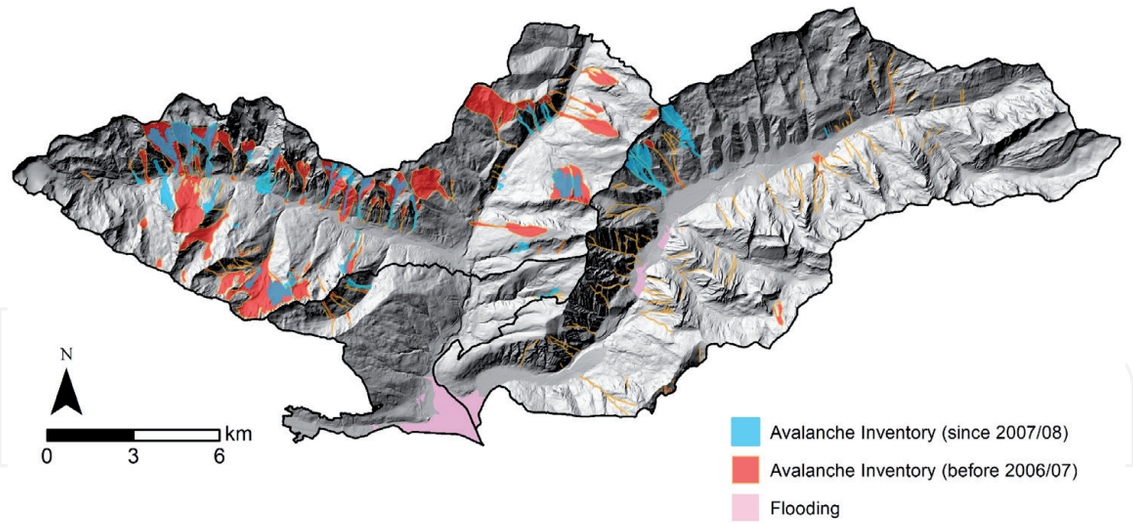


Figure 5.
Snow avalanche inventory of the area (light blue and red) and flooding area (light red). (data source: GeoKatalog of the province of South Tyrol – http://geokatalog.buergernetz.bz.it/geokatalog/#!).

experience gravitational mass movements, such as landslides, rock falls, debris flows and snow avalanches (**Figures 4** and **5**).

The official Italian database for landslides (IFFI: Inventario dei Fenomeni Franosi in Italia) provides an overview of registered past events. For the PAR, the available point information depicts the initiation zones of different landslide types (**Figure 4**). Even though this information was registered with high positional accuracy, it should be noted that it mainly portrays instabilities that caused damage or induced an intervention by the local authorities. Thus, landslides that did not cause damage or pose a risk were usually not registered [12]. For the PAR, 121 landslides of the fall-type movement (mainly rock falls) and topples are registered. In particular, the south-exposed very steep parts of the Pflersch valley, the lower parts of the Pfitsch Valley and the upper part of the Eisack valley are well-known to be prone to rock fall processes. Landslides of the slide-type movement are characterized by a downslope movement of earth and debris on a distinct (planar or rotational) sliding



Figure 6.
Buildings in the area affected by debris flows in 2012 (source: © Provinz Bozen Südtirol, Abteilung 30).

surface. A high portion of the 69 inventoried slide-type movements were registered on the western lying hillslope in the municipality of Vipiteno/Sterzing. In total, 60 flow-type movements, which are mainly related to the prevalent channel system, were registered. In this context, it should be emphasized that many hydrological processes in the area, such as channelized debris flows, are not registered in the IFFI dataset, but in an inventory called ED30 (not shown in the maps). Complex movements consist of a combination of several movement types. Six of these movements are inventoried for the PAR. A very interesting geomorphic feature in the PAR is the impressive catastrophic rock-slope failure between the villages of Afens and Ried in the Pfitsch Valley (cf. deep-seated movement in the Pfitsch valley; **Figure 4** bottom). The catastrophic slope collapse was dated with a minimum age of 11,290 ± 500 years before present and its masses cover around 0.9 km^2. This massive mass movement completely dammed the Pfitsch River, leading to the development of a considerable backwater lake (11 km^2). The lake area dried up after a devastating outburst. The flat and wide valley floor upstream of this mass is a silent witness of this impressive event and represents the former bottom of the lake [13].

3.3.1 Example of a severe debris flow event

The heavy weather event in August 2012 exemplarily highlights the potential consequences of gravity-induced hazards in the PAR. On 4 August 2012, a series of storms hit the Upper Isarco Valley, particularly the middle and lower part of the Pfitsch Valley. On this day, cumulative precipitation values between 14 h00 and 22 h30 summed up to more than 80 mm in large parts of the area. Almost all of the side streams suffered debris flows, and the Rio di Vizze River recorded significant flooding that included a considerable amount of sediment. Damage to infrastructure was very serious, and the entire Pfitsch Valley remained isolated for a long time. Unfortunately, two people lost their lives due to the debris flows. **Figure 6**



Figure 7.
Technical measure against debris flows upstream of the buildings in **Figure 6**. *The site was visited during a GreenRisk4Alps field trip in June, 2019 (source: © S. Cocuccioni).*

depicts the accumulation zone of one of the debris flows in the area. The restoration works were carried out quickly and several technical mitigation works have been finalized (**Figure 7**). Besides the events in the Pfitsch Valley, a major event (flooding with extensive bedload transportation) was also registered at the Riesenbachl in Sterzing, causing damage to infrastructure, buildings and vehicles.

3.4 Snow avalanches

The Agency for Civil Protection manages the snow avalanche inventory for South Tyrol. **Figure 5** highlights that snow avalanches are common on the hillslope sides of the PAR. The threat posed by snow avalanches to infrastructure and buildings is considerably reduced in the PAR by a variety of protection measures. The widespread forest on the lower lying hillsides provides crucial protection against snow avalanches. For particularly prone areas or at high altitude sites, technical measures such as snow bridges and avalanche nets are common.

4. The project "Forest Characterization South Tyrol": best-practice example for the Wipptal south PAR

The project "Waldtypisierung Südtirol" (further referred to as "Forest Characterization South Tyrol") represents the best-practice example for the PAR. Within Section 4, we first present the aims and the background associated with this project. Section 4.1 describes forest types at the level of the South Tyrol Province and one example from the best-practice handbook. The different sections under 4.2 are also based on the abovementioned project but are dedicated to the Wipptal South PAR. In this context, the forest type distributions (Section 4.2.1) and the forest history and former management in the PAR (Section 4.2.2) are presented. Section 4.3 highlights the protective forest in the PAR and related silvicultural measures.

The results of this project are summarized in two freely accessible books (Volume 1 and Volume 2 as pdfs in German or Italian) and can be downloaded under the following link: http://www.provinz.bz.it/land-forstwirtschaft/wald-holz-almen/studien-projekte/waldtypisierung-suedtirol.asp). The main aims of this project were to:

i. determine the potential natural forest types in South Tyrol

ii. provide an ecological description of forest types in terms of location (terrain forms and altitudinal levels), geology, soil, nutrient and water balance, and vegetation

iii. provide a silvicultural characterization of forest types with regard to tree species selection, forest management and forest regeneration methods

iv. summarize the results in a practice-oriented ecological handbook and representation of the forest types on a map at a 1:25,000 scale with possible indications for associated natural hazard processes

The objective of producing a scientifically sound and at the same time practicable handbook required a thorough examination by all staff members involved in the project. The developed silvicultural guidelines were intended to set a broader framework for forest management within which sustainable actions are possible.

The handbook was designed to provide foresters with a decision-making tool for the selection of tree species and associated forest management practices. The main target group of the handbook is therefore forestry personnel.

From a methodological viewpoint, stratification procedures were applied to derive forest site units based on a comprehensive geo-ecological model. This model integrates spatial information with the prevalent geology and associated substrates, the morphology of the area (slope angle, aspect terrain forms) as well as climatic information related to altitudinal belts. The forest site units were subsequently validated by means of detailed field surveys. To characterize the forest types in detail, literature and the practical experience of local forest experts were also included (**Figure 8**).

The aim of the associated workshops was to account for the local experiences of foresters in silvicultural management and to consider their expertise when developing the associated recommendations. Based on the selected forest sites, the current forest management was discussed, and potential challenges were elaborated. During the workshops, the developed handbook was first introduced in order to facilitate its later use. The silvicultural discussion also led to the development of a common glossary. When preparing the workshops, attention was paid to known silvicultural problem areas. The selection of the locations for the workshops was then based on multiple criteria, such as the representative forest type, homogeneousness and accessibility of the site, and the forest function. During the workshops, previously collected and prepared site and stand characteristics served the groups as a basis for their work. The results of the individual groups were discussed together and then translated into statements that were generally considered valid for the entire forest type. This allowed the incorporation of local specificities and experiences into a practice-oriented ecological handbook (see Section 4.1 for an example). The handbook was intended to not only facilitate the silvicultural treatment of the individual forest types, but also indicate their ecological importance and possible natural hazards.

4.1 Forest types in South Tyrol and handbook example

Half of the province of Bolzano/Bozen is covered by forests, for a total of 356,188 ha of forests. Due to this large forest area, management practices are particularly important for supporting its many protective, productive, social and ecological functions. In particular, 99% of the forested area is subject to hydrogeological provincial law restrictions [14] limiting and defining territorial and forest interventions (e.g. deforestation, soil movements) that can negatively affect slope stability and the water regime.



Figure 8.
Workshop participants develop silvicultural treatment strategies for many forest types (source: © C. Hintner).

Most of the forest area in the province of Bolzano/Bozen is covered by subalpine spruce (25.8%), followed by mountain spruce (19%), mixed beech and fir (15.4%) and Swiss pine (13.1%), as reported in **Figure 9**.

The practice-oriented ecological handbooks first provide an overview of the ecological classification for the forests of South Tyrol, which is based on the regional climate, the predominant forest types and differences in altitudinal belts. The different growth areas of South Tyrol are described in detail. The following forest type catalog characterizes the prevalent forests based on both ecological and silvicultural aspects. The results of the silvicultural and site analysis, the outcome of interviews in forest stations and discussions during workshops were incorporated into the description of each individual forest type. In addition to the forest type map in **Figure 9**, forest types can also be determined by means of a forest type key. This key has a logical structure, whereby the forest type is mainly determined by three input variables: site group, altitudinal gradient and substrate group.

For example, the comprehensive forest type catalog contains several sub-categories and among them a category called "subalpine spruce forests". This subcategory in turn contains a detailed elaboration of eleven individual forest types, such as "subalpine high shrub spruce forest" (Adenostylo alliariae-Piceetum). Each specific forest type is presented concisely (two pages) using easily comprehensible text and graphs (**Figure 10**).

For instance, such a forest is predominantly present on north-exposed slopes, on rather steep terrain (> 40°) and at altitudes above ~1,500 m.a.s.l. The general appearance of this type is then described in a short text block. The geology and soil development are shown and describe that this forest type predominantly develops over carbonate–silicate mixed rocks and clay-rich weathering limestones or marls as well as on loose sediments from these rocks with nutrient-rich, medium- to deep-textured calcareous brown soil or calcareous brown loam. The following section entitled silvicultural evaluation highlights accompanying forest types, forest productivity, formation and forest development. Furthermore, the specific forest

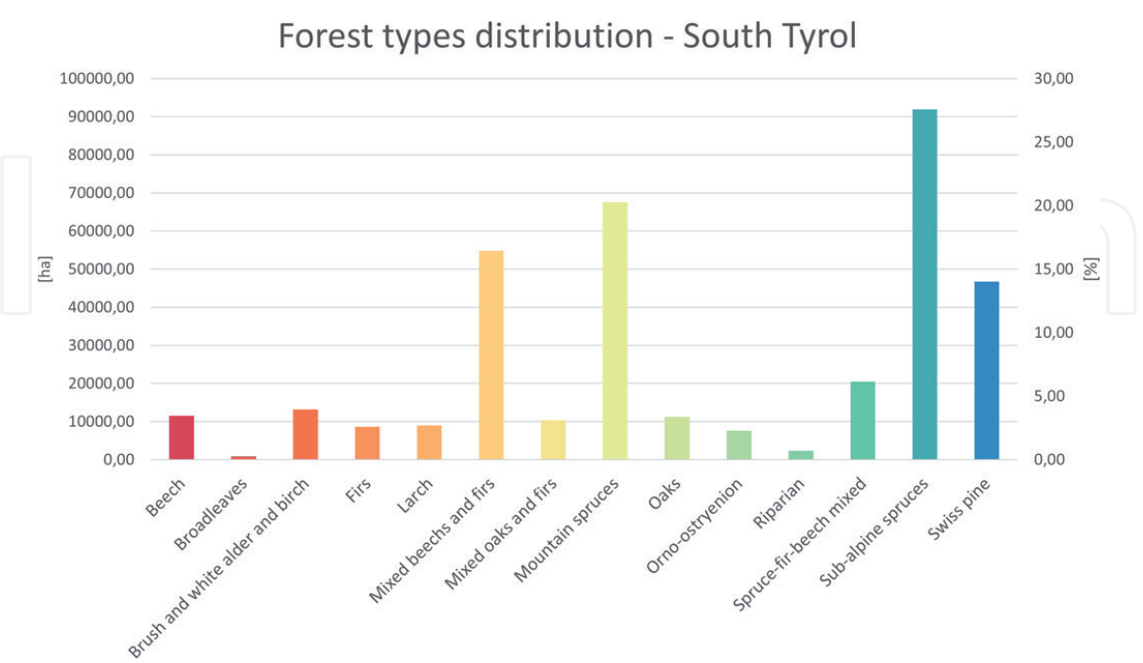


Figure 9.
Areal extent of forest type distributions and percentage of total forested area in South Tyrol (provincial forest type classification, data source: GeoKatalog of the province of South Tyrol – http://geokatalog.buergernetz.bz.it/geokatalog/#!).

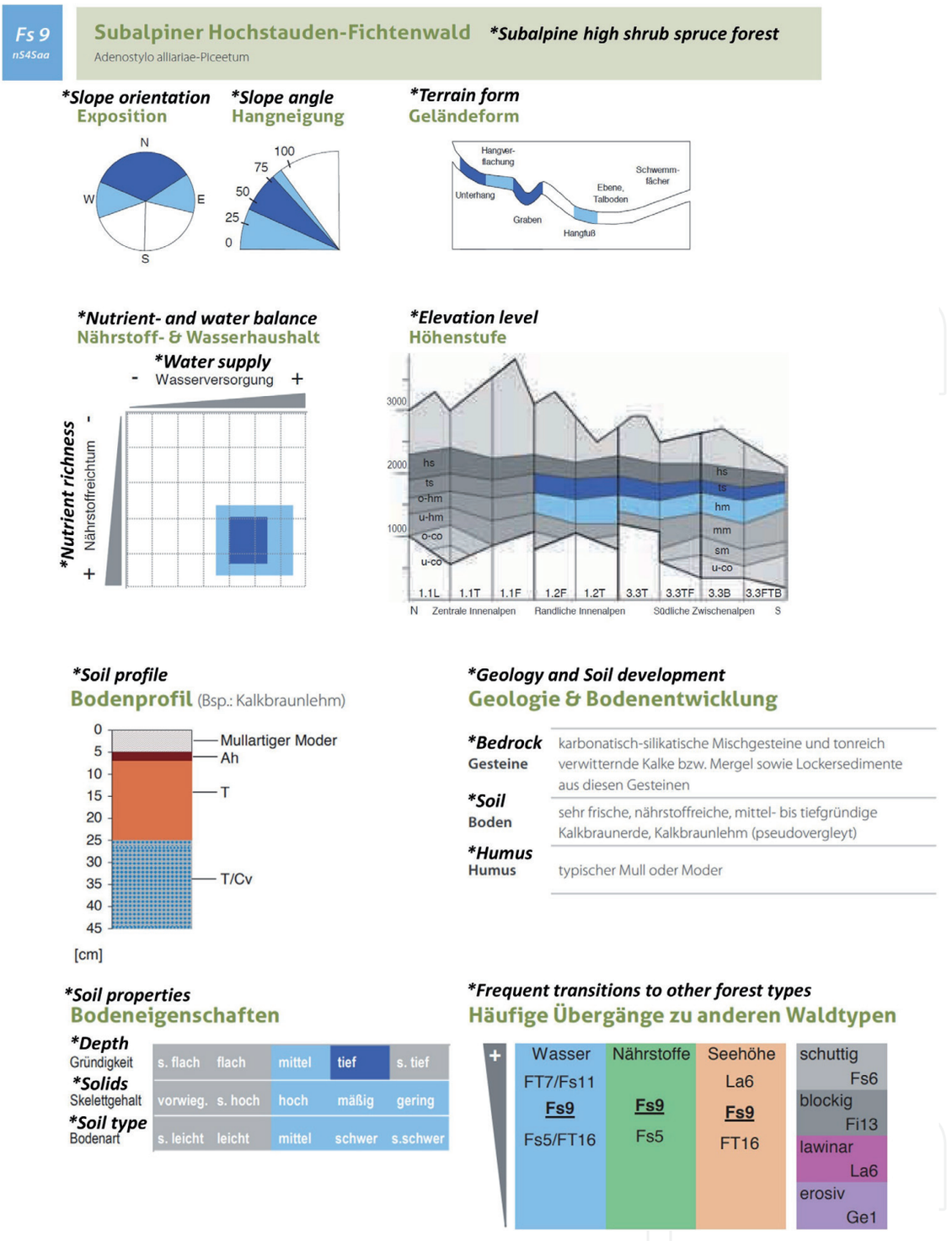


Figure 10.
*Example of the representation of one specific forest type (Adenostylo alliariae-Piceetum) from the original handbook (volume 1). For this figure, the main categories were translated into English (marked with *). For details refer to the text below.*

functions are also highlighted and show that this forest is usually a *"commercial forest with protective functions, especially against landslides, floods, snow movement and rockfall."* The last text block focuses on recommendations for its silvicultural treatment and provides recommendations for natural regeneration and forest management. It should be noted that this example should only provide insight into the extent of detail included for the many identified individual forest types that are presented in the handbook.

4.2 Forest characterization for the PAR

4.2.1 Forest type distributions

The Wipptal South PAR area is characterized by extensive forested areas, most of which are sub-alpine and mountain spruce forests. Larch forests in montane and sub-alpine locations extend over large areas from Gossensass/Colle Isarco via Sterzing/Vipiteno to the southern slopes around Mauls/Campo di Trens, in the Pfitsch Valley to Kematen/Caminata as well as from Gossensass to Hinterstein (**Figure 11**). The distribution coincides well with the extent of the calcareous shales on which these forest types were anthropogenically created due to their suitability for grazing and mowing (larch meadows). On the other hand, natural juniper-larch forests are covered with numerous dry plants on sunny steep slopes above limestone slates. Larch also dominates the dwarf-shrub-rich stands in high sub-alpine and steep and shady areas together with mountain pine. In the lower, high-montane level (up to 1,300 m), a steppe heath pine forest grows on steep sunny sides at a similar location, and an earth sedge pine forest grows on the marble stock near Mauls/Campo di Trens. While in the Sterzing/Vipiteno basin, there are also dry grassland and shrubs with sedge bushes, and in the rest of the area, larch and spruce forests are mostly widespread. In the Pflersch Valley, pine forest stretches from the bottom (1,230 m) to the orographic limit at 1,600 m above sea level, with pine receding in favor of spruce as the valley narrows. Swiss stone pine only appears locally in the inner Pfitsch above Stein and on the N-S ridges north of Zinseler and Hühnerspiel. This is partly due to the Swiss stone pine fault area above limestone slate, and partly to clearing activity and the use of alpine pastures in subalpine areas.

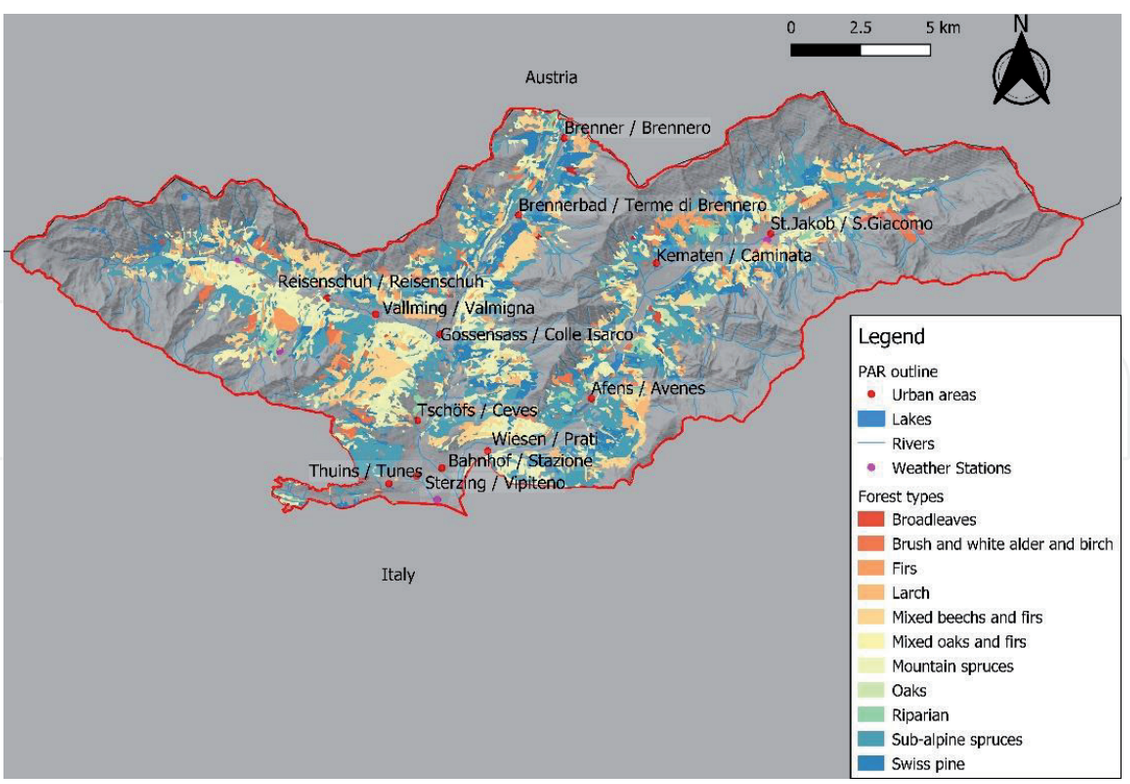


Figure 11.
Wipptal south PAR area and location in South Tyrol with a visualization of the main forest types according to the European environmental agency (EEA) forest categories and types, weather stations, urban areas, lakes and rivers. (data source: GeoKatalog of the province of South Tyrol – http://geokatalog.buergernetz.bz.it/geokatalog/#!).

Compared to the whole province of Bozlano/Bozen, the Wipptal South PAR is characterized by a lower percentage of Swiss pine forests, which account for 3.1% of the PAR forest area. Moreover, some particular species do not occur in the PAR, such as beech, Orno-ostryenion and spruce-fir-beech mixed forest. While mountain spruces are still widespread, the share of mixed beech and fir forest is lower (8.7%) than in the whole province (15.4%). Nevertheless, the share of larch woods and brush and white alder and birch is larger (8.1% and 8%, respectively) compared to that in the whole province (2.5%) (**Figures 12** and **13**).

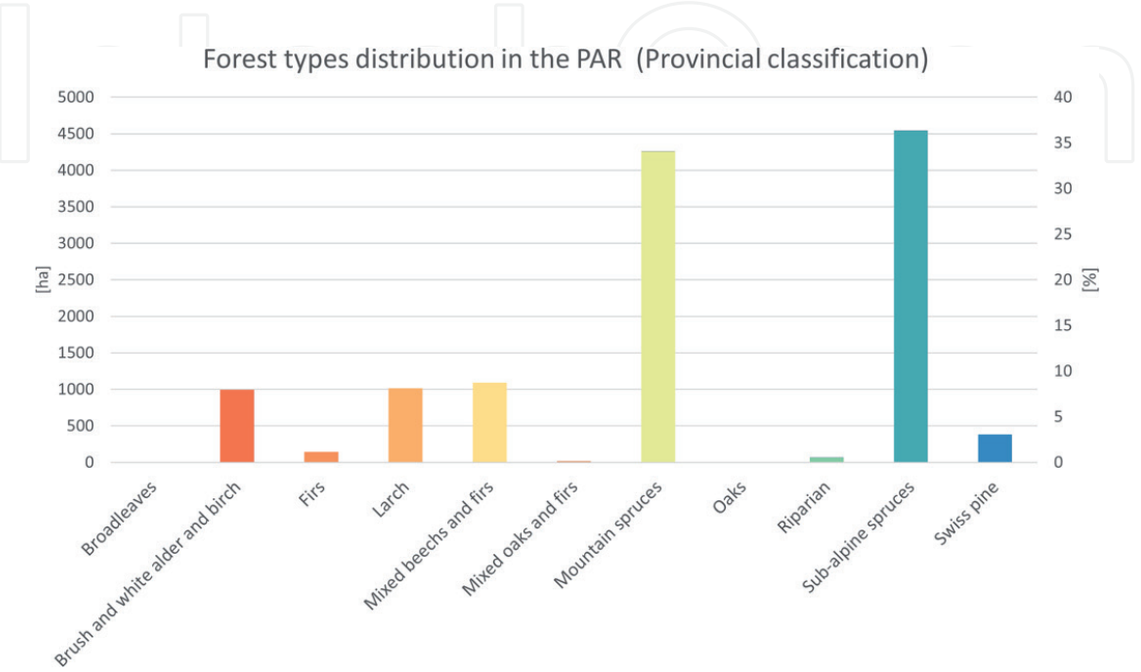


Figure 12.
Areal extent of forest type distributions and percentage of total forested area in the Wipptal south PAR according to the data presented in **Figure 11** *(provincial forest type classification, data source: GeoKatalog of the province of South Tyrol – http://geokatalog.buergernetz.bz.it/geokatalog/#!).*

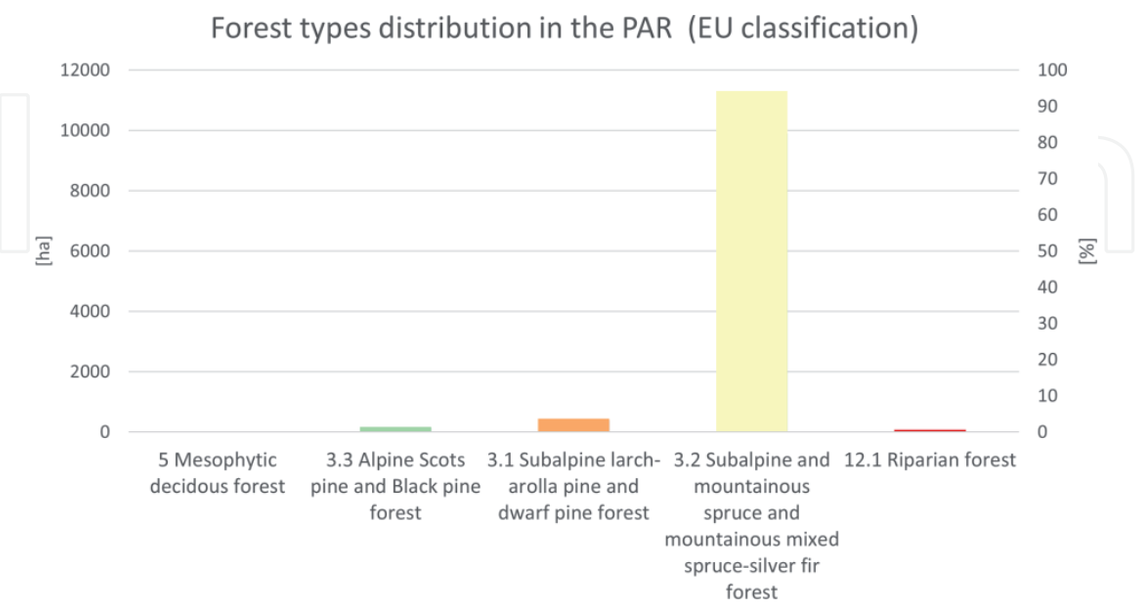


Figure 13.
Areal extent of forest type distribution and percentage of total forested area in the PAR (EU forest type classification, data source: GeoKatalog of the province of South Tyrol – http://geokatalog.buergernetz.bz.it/geokatalog/#!).

The soil in the area is formed over carbonate-rich rocks (mica marble, calcareous slates, green rocks) to calcareous brown soils with a much more demanding ground vegetation of nutrient-indicating herbs and tall perennials. At such sites, larch has been establishing itself as the predominant tree species. With the exception of a few individual finds, no fir trees occur due to the climatic conditions. Green alder bushes cover slopes and ditches on the shady side, more common in the Brenner area and the inner Pfitscher Valley. Deciduous forests with predominant ash, gray alder (occasional sycamore maple) are limited to sliding ladders on the lower slopes. The Eisack and Pfitscher streams are partly covered with gray alder floodplains. On the Pfitscher Bach near St. Jakob, there is also an occurrence of lavender willow meadows with German tamarisk.

4.2.2 Forest history and former management in the PAR

In the Middle Ages, considerable mining activities took place in the Sterzing/Vipiteno area, formerly the largest mining area in Tyrol. However, the altitude, lack of wood and water were a hindrance, and mining activity was soon abandoned. The Gossensasser Bergordnung of 1427 specifically mentioned the use of forests for the extraction of coal. Although wood burning was strictly prohibited, forests were not protected by these regulations. Many other directives were issued in 1460, 1502 and 1511 in an attempt to regulate the felling of wood for sale, coal burning, cutting and construction timber, although the effect of the laws was little to no forest protection [15, 16]. New regulations in 1527 tried to limit pitch and resin extraction, which was particularly damaging to forests, and smelters were strictly forbidden to cut green wood while there was still a drought. It was generally stipulated that only old trees could be cut down with limitations on the cutting of forests to be converted into pastures [17].

During times of need in the 19th century, the forests in Pfitsch/Val di Vizze were once again severely decimated, and from 1847, when "forest purification" took place (forest was returned by the state to the communities), a period of uncontrolled use followed throughout the Wipptal. Frequently, "plundering forests" were created through the use of the strongest trunk with a subsequent cattle drive. From 1875 to 1877, the drainage of the Sterzing/Vipiteno area and the Wiesner part of the moss was carried out, with the remaining riparian forests being converted to cultivated land [18–20].

Livestock breeding and pasture farming also had an impact on the forest. Wooden fences were erected to limit the forest and alpine pastures. The pasture areas were often extended with cattle driven into cut clearings with the forest reduced to create pre-alpine and alpine pastures. In 1515 and 1527, for example, the Sterzing forestry administration opposed the conversion of clear cuttings into permanent pastures [21]. In many cases, forest grazing rights are no longer exercised today [22]. Similarly, the large mountain meadows in Pfitsch (e.g. "in der Schnagge" and on the "Birchmahdern") have not been mown for some time [23]. In Pfitsch, where the proportion of private forests is very high, the timber industry has always had some importance as a source of income, and the proportion of farms owning forest and selling timber is above the average for the Wipptal. Although there were occasional sales of timber to other countries, most of it was processed for local use, as the supply of timber from the Pfitscher Hochtal was very difficult before the construction of the road [20, 24]. The forest of the Pflersch Valley is predominantly in the hands of interested parties [22, 25].

4.3 Protective forest in the PAR and related silvicultural measures

Forests are well-known to influence several types of these hazard types, and available data on object protective forest indicates that forests play a paramount

role in protecting people and assets, such as settlements and infrastructure. The prevalent site protective forests also provide protection to nature and different ecosystems (e.g. soils, plants). The spatial designation of protective forest indication areas (**Figure 14**) is based on the community Initiative Interreg III Austria-Italy 2000–2006. These maps provide a general overview of where the current forest in the PAR protects people, settlements and infrastructure (object protective forests) or the ecosystem (soils, plants, site protective forests) against rock falls, snow avalanches and debris flows.

A large part of the forest in the area (around 50%) in the PAR can be considered as protective forest, with 19% object protective forest and 31% site protective forest (**Figures 14** and **15**). This comparably high number is not surprising considering that gravitational hazards are common in the area and forests are mainly located on hillsides (**Figure 4a**). **Table 4** highlights the share of site and object protective forest for each municipality of the area in detail.

The main focus in the silvicultural management of protective forests is to maintain their protective function. According to the South Tyrolean Forest Act [26], every tree must be identified by the forest authority before felling. During the timber display, the foresters come into contact with the forest owners and can thus also give them silvicultural advice. In this way, the protective forest function can optimally be taken into account in the management procedures. In order to maintain the protective effect, the forest has to be managed in a continuous, near-natural way. If a protective forest is not used for a longer period, the forest may no longer fulfill its protective function.

Many forested areas in the Wipptal, especially in the communities of Brenner/Brennero and Pfitsch/Val di Vizze, fulfill an essential protective function against snow movements and avalanches. In such forests, management aims to ensure that the forests do not become over-aged and that regeneration approaches are present over the entire area. If logging is carried out, no extensive use should be made in the fall line. At slope gradients of greater ~70%, the gap length in the fall line should be less than 50 m to prevent the onset of forest avalanches.

The situation is similar for rockfall protective forests. Here, similarly, the gap length in the stand has a great influence on the protective effect, since falling stones

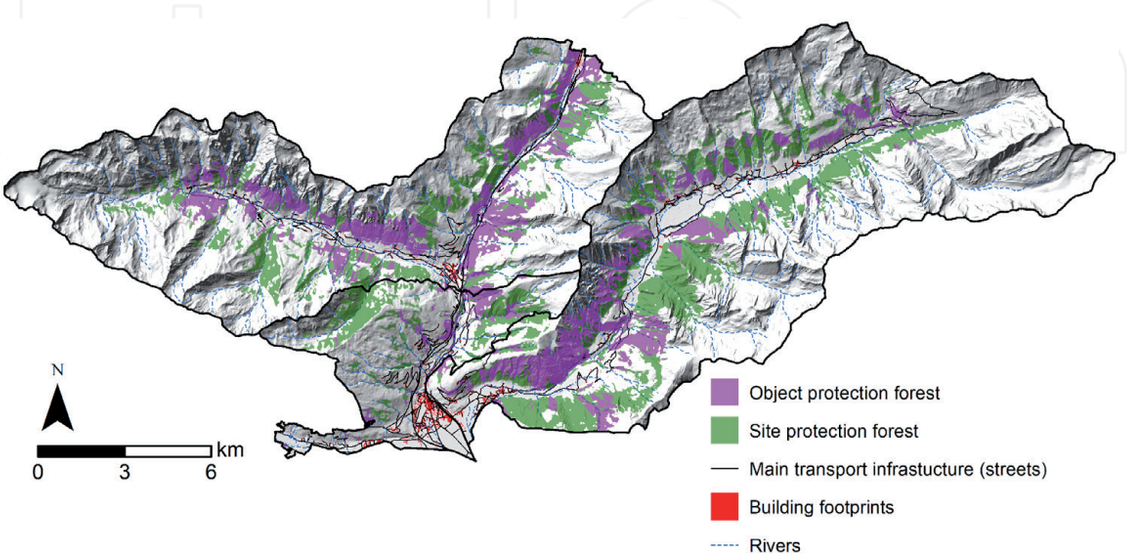


Figure 14.
Protective forest map for the Wipptal south PAR according to the south Tyrolean protective forest indication map (data source: GeoKatalog of the province of South Tyrol – http://geokatalog.buergernetz.bz.it/geokatalog/#!).

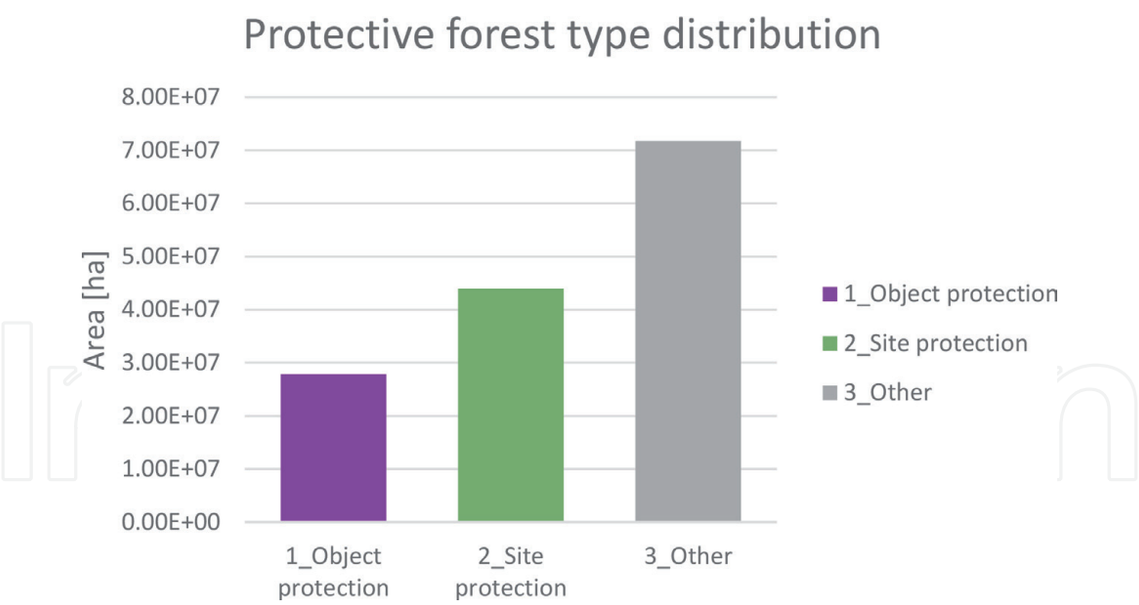


Figure 15.
Protective forest type distribution in Wipptal south according to the south Tyrolean protective forest indication map. Note that the class "other" was derived as the difference between the total forested area and the protective forest types, i.e. object and site (data source: GeoKatalog of the province of South Tyrol – http://geokatalog.buergernetz.bz.it/geokatalog/#!)

Municipality	Site protective forest	Object protective forest
Brenner/Brennero	66%	32%
Sterzing/Vipiteno	43%	10%
Pfitsch/Val di Vizze	74%	26%

Table 4.
Proportion of site and object protective forest by municipality.

may reach their maximum speed after only 40 m of track length. During timber display, care is taken to avoid large uses in the fall line.

In both rockfall protective forests and avalanche protective forests, slash-like uses across or diagonally to the fall line are considered particularly suitable. It is important to ensure that the slit-like openings are not too wide so as not to diminish the protective forest function.

Stand maintenance is of great importance in protective forests. In order for the trees to achieve good individual stability, they must not grow up too densely. Young growth with a large number of trunks must therefore be vigorously thinned already in the thickening stage. In order to stabilize pole woods and to improve the structure, the formation of rotations is recommended in the protective forests of the subalpine altitudinal zone.

5. Conclusion and some challenges

The chapter highlighted the critical role of protective forest in the natural hazard prone PAR. In this context, future challenges are expected as a consequence of climate change. It is assumed that the prevalent spruce tree species might become more prone to bark beetle infestation due to increasing drought stress. Therefore, it is particularly important to focus on tree species diversity to ensure a future protective function. The fir tree species in the Wipptal, for instance, is of great relevance

in this context. Investigations in the area have shown that the potential of fir is high on many sites and particularly on shady hillslopes. Currently, however, fir trees are often absent because of the former extensive use of wood. From a forest management perspective, red deer populations also restrict the successful natural regeneration of fir. If fir is to be promoted in the Wipptal Valley in the future, the red deer population must be controlled.

The current low timber price, as a result of damaged due to the recent storm events, also has an unfavorable effect on the protective forest in the PAR. As a result, there is currently no incentive for forest owners to carry out small-scale harvesting in protective forests. It is expected that if the price of wood does not rise in the near future, more measures and subsidies from the public sector will be required to maintain the functioning of the protective forest.

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