IntechOpen

Best Practice Examples of Implementing Ecosystem-Based Natural Hazard Risk Management in the GreenRisk4ALPs Pilot Action Regions

Edited by Jurij Beguš, Frédéric Berger and Karl Kleemayr

Interreg
Alpine Space
EUROPEAN UNION
GREEN RISK 4 ALPS
European Regional Development Fund

Best Practice Examples of Implementing Ecosystem-Based Natural Hazard Risk Management in the GreenRisk4ALPs Pilot Action Regions

Edited by Jurij Beguš, Frédéric Berger and Karl Kleemayr

Published in London, United Kingdom







IntechOpen



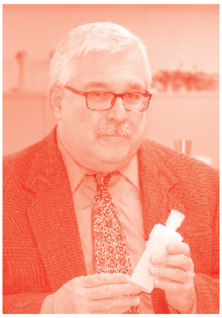







Supporting open minds since 2005







Best Practice Examples of Implementing Ecosystem-Based Natural Hazard Risk Management in the GreenRisk4ALPs Pilot Action Regions
http://dx.doi.org/10.5772/intechopen.95015
Edited by Jurij Beguš, Frédéric Berger and Karl Kleemayr

Contributors
Frédéric Berger, Benjamin Einhorn, Jessica Jarjaye, David Toe, Jean-Baptiste Barré, Sylvain Dupire, Matthias Plörer, Dieter Stöhr, Jurij Beguš, Janez Mertelj, Samo Škrjanec, Helena Eisele, Roland Schreiber, Anne Stöger, Paolo Perret, Jean Pierre Fosson, Valerio Segor, Luca Mondardini, Christoph Hintner, Stefano Terzi, Stefan Steger

Cover graphic: Roberto Baldissera, Agentur für Grafik; Martina Eller, Austrian Research Centre for Forests (BFW)

First published in London, United Kingdom, 2021 by IntechOpen
IntechOpen is the global imprint of INTECHOPEN LIMITED, registered in England and Wales, registration number: 11086078, 5 Princes Gate Court, London, SW7 2QJ, United Kingdom
Printed in Croatia

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Additional hard and PDF copies can be obtained from orders@intechopen.com

Best Practice Examples of Implementing Ecosystem-Based Natural Hazard Risk Management in the GreenRisk4ALPs Pilot Action Regions
Edited by Jurij Beguš, Frédéric Berger and Karl Kleemayr
p. cm.
Print ISBN 978-1-83969-328-1
Online ISBN 978-1-83969-329-8
eBook (PDF) ISBN 978-1-83969-330-4

Interreg
Alpine Space
EUROPEAN UNION
GREEN RISK 4 ALPS
European Regional Development Fund

Meet the editors

Jurij Beguš is currently the project manager for international projects at the Slovenia Forest Service, Ljubljana. In 1982, he completed his forestry studies at the University of Ljubljana, Slovenia, and in 2002 upgraded his studies with a specialization in forestry techniques. His professional work involves the following issues: forest roads, forest technology, forestry extension, participation in forestry, wood biomass, occupational safety in forestry operations, and forest information systems. He cooperates with several international institutions, such as the Food and Agriculture Organisation of UN (FAO) and the International Union of Forest Research Organisations (IUFRO). Besides his regular work at the Slovenia Forest Service, he has participated in over twenty international projects and several international missions around Europe.

Dr. Karl Kleemayr completed his studies in Torrent and Avalanche Control at the University of Natural Resources and Life Sciences (BOKU) in Vienna, Austria, in 1989 and worked for two years at the Austrian Service for Torrent and Avalanche Control (WLV). He then earned a Ph.D. at BOKU in 1996. His further research included finite element calculations and avalanche dynamics modeling, but during his career, he advocated for an ecosystem-based risk management approach. From 2004 to 2021, Dr. Kleemayr led the Department of Natural Hazards at the Austrian Research Centre for Forests (BFW) with great dedication and commitment. He passed away much too early in 2021 and is greatly missed by the natural hazard and protective forest community.

Dr. Frédéric Berger is a senior researcher (M.Sc. degree in Forestry and Biology Sciences, Ph.D. in Forestry and Geomatic Sciences). He has been working at INRAE since 1997 on the sustainable valorization of forest-based solutions in integrated risk management and expert assessment processes. He has developed specific research on rockfall risk (3D modeling, modeling the mechanical behavior of trees) and terrain/forest stand characterization using aerial laser scanning. He is involved in applied research on decision support systems for risk assessment and protective forests management. His disciplinary fields concern forestry and 3D rockfall modeling. Since January 1, 2020, he has been the head of the new COMPET research team. He is also an international expert on rockfall zoning and protective forest management.

Contents

Preface

An old Slovenian proverb says - all people know it all. This proverb is, in fact, the expression of the contribution of sharing experiences and knowledge for improving collective knowledge and practice. Such an approach was also followed by the idea for the "*Best Practice Examples of Implementing Ecosystem-Based Natural Hazard Risk Management in the GreenRisk4ALPs Pilot Action Regions*", which is one of the deliverables of the GreenRisk4ALPs project (hereinafter GR4A).

The GR4A project, funded by the Interreg Alpine Space program, was established to develop models, tools, and guidelines that can serve as a basis for developing decision support tools in support of risk-based protection forest management in the Alpine Space. They have been set up using scientific/practical knowledge, tested, improved, and operationally applied in the six Pilot Action Regions of the project (hereinafter PAR). These regions lie in different parts of the Alps, and each has its own characteristics. They differ in geographical, ecological, climatic, forestry, and social conditions, and in this way, they represent ideal first sample situations for testing the project products.

However, as we wanted to expand our knowledge of individual PARs, we followed the idea of presenting an example of best practice for each PAR related to ecosystem-based risk management implementation, which could be of interest for other regions in the Alpine space. The monograph is primarily intended for forestry experts, decision-makers at all levels of decision-making, and other professional public. However, we are convinced that scientists will also find interesting ideas and knowledge in it. An example of one best practice for each individual PAR is presented in the book as a separate chapter. All six chapters are combined into a monograph, which forms a complete whole. The beginning of each chapter starts with the description of the PAR, the main geographical, ecological, and social characteristics of the area covered by the PAR, and the most common natural hazards. As the project mainly deals with forests and their protective role, information on forest and forestry in the PAR are included in the text, especially in the light of protection against natural hazards. Each chapter ends with describing the example of best practice in the PAR. Best practices examples covering different areas: large-scale rockfalls modelling, environmentally-friendly construction in an area of protective forest, the mountain forest initiative program, glaciers' open-air laboratory, forest types determination, and ski tour steering concept. The idea for the monograph was given by the, unfortunately, already passed away leader of the GreenRisk4ALPs project, Dr. Karl Kleemayr, who, as a co-editor, also took an active part in its preparation. Let this book be a small contribution in memory of his rich work, and above all, thanks to him for all the efforts he has put into the project itself and especially in the development of science in protecting against natural hazards.

Jurij Beguš
Zavod za gozdove Slovenije (Slovenia Forest Service),
Ljubljana, Slovenia

Dr. Karl Kleemayr
Department for Natural Hazards,
Austrian Research Centre for Forests,
Austria

Dr. Frederic Berger
INRAE, Saint Martin d'Hères,
France

Note from the Publisher

It is with great sadness and regret that we inform the future readers of this book that the Co-Editor, Dr. Karl Kleemayr, passed away shortly before finishing the book and having a chance to see its publication. Dr. Karl Kleemayr was IntechOpen's dear collaborator and authored 1 book chapter with us in 2013 ("Management Strategies to Adapt Alpine Space Forests to Climate Change Risks").

This collaboration continued until his final days when he was acting as the co-editor of the Book "Best Practice Examples of Implementing Ecosystem-Based Natural Hazard Risk Management in the GreenRisk4ALPs Pilot Action Regions". We would like to acknowledge Dr. Karl Kleemayr contribution to open access scientific publishing, which he made during the years of dedicated work, and express our gratitude for his pleasant cooperation with us.

IntechOpen Book Department Team, August, 2021

Chapter 1

Baronnies Provençales Regional Nature Park Pilot Action Region: The Benefit of Large-Scale Rockfall Modelling for Developing Efficient Forest-Based Integrative Management of an Alpine Territory

Frédéric Berger, Benjamin Einhorn, Jessica Jarjaye, David Toe, Jean-Baptiste Barré and Sylvain Dupire

Abstract

The choice of a natural risk prevention strategy must be considered at the scale of a territory in order to take into account all its components. Since 2015, France has developed integrated natural risk management (INRM) approaches in Alpine territories. The challenge of INRM lies in the definition and implementation of innovative projects for initiating synergies with respect to natural risks while seeking to increase resilience through the new and different involvement of the territorial actors. The Baronnies Provençales Regional Nature Park is one of the pilot territories for the operational implementation of this approach, with a particular focus on forest-based solutions. For this reason it has been chosen as the French Pilot Action Region (PAR) of the Interreg Alpine Space project GreenRisk4Alps. In this article we present an example of good practice related to the benefit of large-scale rockfall risk modeling, the analysis of potential cascading effects and the added value of a territorial perspective.

Keywords: protective forest, protective function, risk plan prevention, mapping, modeling, rockfalls, forest fire, integrated natural risk management

1. Introduction

Natural risks in mountains combine multiple hazards and specific vulnerabilities, including a high dependence of socio-economic activities on transport networks (risk of isolation). These risks, which are already omnipresent, also tend to increase under the combined effect of human activities and the rapid changes in the mountain environment brought about by climate change.

The nature and diversity of the phenomena (rapid kinetics, strong impacts, unpredictability, accumulation of hazards, domino effects), but also of the vulnerabilities (material, organizational) and impact scenarios, lead to particular difficulties in terms of detection, monitoring, anticipation, evaluation and prioritization of risk situations associated with strong uncertainties.

These challenges make it difficult to take decisions concerning the choice, sizing or prioritization of interventions. These decisions must also establish a compromise between the socio-economic elements to be protected and the generally limited resources of mountain communities. Risk prevention in these territories therefore requires specific management methods that respond to these geographical particularities through approaches that are both global (multi-risk) and adapted to the local context.

For increasing the competence of the Alpine territories in terms of risk management and adaptation to climate change, it is not only necessary to mobilize a wide range of interdisciplinary scientific and technical skills, but also specific resources dedicated to the co-construction, capitalization and transfer of knowledge and practices to managers and decision-makers.

In this context, support for the development of integrated natural risk management actions, public awareness raising and enterprises is essential. Integrated multi-hazard approaches, nature-based solutions and research-action are crucial levers for the quality of life, resilience and development of Alpine territories.

The main objective of integrated natural risk management in France is to optimize risk governance at the catchment level. It targets all risk prevention levers:

- Knowledge of hazards and risks
- Recognition and optimization of nature-based solutions, particularly forestry
- Monitoring in order to anticipate an event
- Information for citizens and risk culture
- Control of urbanization by integrating local and systemic risk management into planning documents
- Reducing vulnerability
- Emergency preparedness
- Experience feedback

In 2015, the Baronnies Provençales Regional Nature Park (BPRNP) initiated a process to develop an Alpine Territory of Integrated Natural Risk Management (ATINRM, TAGIRN in French). The challenge for a TAGIRN lies in the definition and implementation of innovative projects that make it possible to initiate synergies with respect to natural risks while seeking to increase resilience through the new and different involvement of the actors in the territories in question.

One of the park's objectives is to complement the regulatory prevention of natural hazards with a more integrated and efficient approach capable of limiting the consequences of disasters from an economic, social and environmental point of view. Through this multi-risk project, the park's aim is to develop a risk culture among the population and elected representatives by implementing targeted activities according to the actions and the public. The emergence of this risk culture begins with the provision of information and knowledge of natural risks to local authorities, the local population and local associations in order to raise awareness. Indeed, the memory of risk is fading in Baronnies Provençales; therefore, the main objectives of this TAGIRN project are as follows:

- to raise awareness among the population of natural risks, in particular the risks of forest fires, falling rocks and landslides;
- to develop coordination and synergy between the actors;
- to qualitatively and quantitatively develop an integrated management of natural risks in the territory with consideration of solutions based on the forest;
- to improve knowledge and awareness of natural hazards.

This TAGIRN project also has an interregional dimension with the opportunity to network actors and state services of the Drôme and Hautes-Alpes departments and to organize meetings and exchanges on working methods concerning natural risk management. Indeed, at the beginning of the demarche, differences in the approach to risk were identified between the services, resulting in significant differences in the understanding of risk management.

The desire of the park to develop an integrated management of natural risks, based among others on nature-based solutions, and the motivation of the actors of this territory, led us to select it as the French Pilot Area Region (PAR) of the GreenRisk4Alps Interreg Alpine Space project.

As an example of good practice related to forest-based solutions (FBS) for rockfall risk mitigation, the benefit of large-scale rockfall risk modeling, the analysis of potential cascading effects and the added value of a territorial diagnosis for better wellbeing in an Alpine territory, we present in this chapter the main conclusions of our analysis.

2. Description of the baronnies provençales regional nature park PAR

2.1 General data

Crossed by the northern limit of the presence of the olive tree, which has been cultivated here since antiquity, the Baronnies are authentically Provencal. However, it is a mountainous Provence, a mosaic Provence, constantly attenuated or affirmed according to altitude and latitude.

The Baronnies Provençales are located on the borders of two large regions, two thirds in the Rhône-Alpes, in the department of Drôme, and one third in Provence-Alpes-Côte d'Azur, in the department of Hautes-Alpes (**Figure 1**). This off-center mountainous territory remains far away from the main transport routes and urban areas.

The remoteness and geographical compartmentalization of the Baronnies Provençales have left it on the fringes of the industrial development dynamics that prevailed in the last century. A territory forgotten by the industrialization of the 19th century, devoted to mixed farming and stockbreeding, the Provençal Baronnies have long preserved the traditional forms of rural society, punctuated, until the middle of the 20th century, by agricultural work, markets and the life of the villages. This restrictive geographical context has enabled the Baronnies Provençales to preserve particularly unspoilt biological wealth and original landscape structures associated

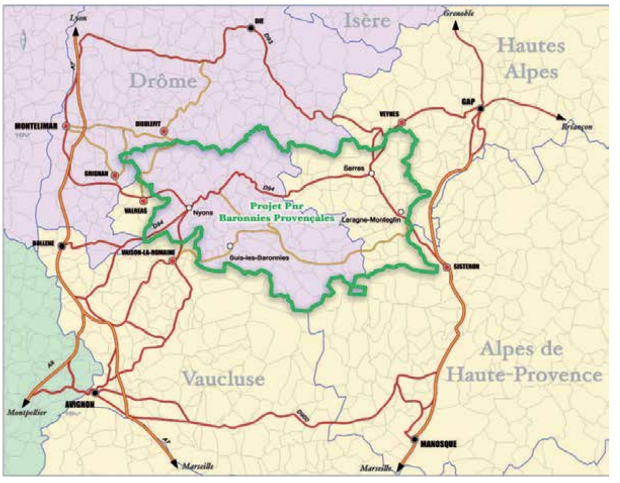


Figure 1.
Geographical scope (green contour) of the BPRNP [1].

with a great diversity of traditional production, which make this territory so distinctive and justify its recognition as a regional nature park.

The recent but marked changes in agriculture have considerably modified the landscapes and terroirs over the last few decades. Mechanization has caused many hedges to disappear. The old canals have been abandoned or replaced by sprinklers. The dry stone terraces on the well-exposed hillsides, which were used for vineyards or olive groves, have been abandoned. The forest is advancing on land covered by too few herds, and the life of men has retreated to the bottom of the valley. The land, which was once domesticated, including at high altitude, is now becoming more and more fertile, giving the region the picturesque character of a wilderness as soon as one leaves the cultivated valley bottoms.

The BPRNP is a tool at the service of the inhabitants, a responsible rural development project for an exceptional territory that we wish to preserve and also develop. It serves to find a balance between development that allows us to live better on a daily basis and the preservation of natural and cultural heritage.

Here, the fauna, flora and landscapes are protected, the built heritage is enhanced, cultural and tourist projects as well as economic development are encouraged, people meet, act together and bring their territory to life with passion.

This exceptional place of preserved nature is recognized at the national level for its rich terroir (Protected Designations of Origin, Protected Geographical Indications, red labels), its unique landscapes, built heritage (dry stone terraces, perched villages) and emblematic agricultural heritage (orchards, olive groves, lime trees, lavender, thyme, rosemary, etc.), as well as for its remarkable geology and biodiversity. There is not a single piece of land in this dry medium-sized mountain area that has not been used, valued or named by the inhabitants, from the valley bottoms to the mountain peaks. The search for land for cultivation led to the use of very steep slopes, with constructions and facilities essential to agricultural activity: terraces, sheds or shelters; water distribution networks; reservoirs; drainage galleries; etc. This medieval and agricultural heritage was gradually abandoned from the 1850s onwards, in favor of sites or land that were easier to occupy or exploit. The ways of living, occupying space and moving around transcend major administrative, historical or political boundaries, and bear witness to social and spatial similarities on which a project community can rely. In the Baronnies Provençales, Man and nature have lived together everywhere. The inherited cultivated landscapes express the skilful use of the land, a harmony of the senses. The alternating atmospheres of the interior valleys reveal this feeling, the visual richness, in mosaic, of the lavender fields, the vineyards and the orchards accompanied by their colorful and olfactory notes. If the quality of the territory is partly linked to its intrinsic characteristics, it depends for the most part on the complicity that Man has established here with nature. However, the continuity of the long process of adaptation to a rural mountain life, which has produced the rich heritage of the Baronnies Provençales, is now threatened by the devitalization of the heart of the territory. The significant aging of the population is the first worrying sign of imbalance. It calls for a proactive policy to win back the population by attracting new workers.

Uncertainties about the future of agricultural policy make the transfer of farms more fragile, especially as the current economic valuation hardly remunerates the requirements of production methods that respect the environment, biodiversity and the landscape. The construction of an economic alternative based on the recognition and enhancement of the specificities of local production is another challenge for a collective approach.

The future of agriculture in this dry mountain region cannot be conceived independently of water resource management. Under the effect of climate change, tensions may arise, particularly during summer low water periods. The search for a better balance between water abstraction and the availability of the resource is therefore an essential challenge for the organization of life in the area. An important network of rivers, which have structured the settlements and trade areas, irrigates the Baronnies Provençales. However, the regime of these rivers, which are torrential in nature, is very irregular and strongly marked by the seasons. They play a major ecological and tourist role and shape the landscape.

If the highly preserved character of the Baronnies Provençales is now becoming a factor of attractiveness, it is first for the benefit of the development of second homes. The resulting pressure on the land entails risks of imbalance in access to housing. The control of land, the development of the built heritage, the emergence of eco-construction, the development of communication technologies for the benefit of young people and the reception of new residents represent a real challenge for the territory.

The attractiveness of the area is also reflected in the development of seasonal tourism based on outdoor activities. The organization of these activities in order to optimize the economic spin-offs is a development issue, just as the control of visitor numbers in the most vulnerable natural sites is necessary to preserve the value of the natural heritage. The industrial past has had little impact on the area. Peri-urbanization remains a one-off phenomenon for the time being. The landscape of the Baronnies Provençales is therefore not polluted by heterogeneous buildings or by the proliferation of unmarked business areas.

In this geographical and socio-economic context, forest areas occupy a large part of the park. These are alternating green or white oak forests, beech forests and pine forests that can be seen as you drive through the Baronnies Provençales.

The BPRNP in a nutshell:

- Administrative headquarters: Sahune, in the Drôme department.
- Surface area: 1,818 km2.
- 152,759 ha of woodland and moorland (84.02% of the territory).
- 24 historical monuments, including 10 “listed” and 14 “remarkable” sites.

- Around 2,000 plant species.
- Over 200 animal species protected at the national or regional level.
- 10 “Natura 2000” sites.
- 33,250 inhabitants [2].
- 97 communes classified as a Park +1 associated commune.
- 2 main communities of communes and 7 gateway towns: Dieulefit, Grignan, Montélimar, Sisteron, Valréas, Vaison-la-Romaine, Veynes.
- Baronnies Provençales Regional Nature Park is a member of the network of 54 French regional nature parks. It has been classified as a regional nature park for 15 years.

2.2 The main issues and activities in dealing with natural risks

A natural risk only exists if a natural hazard threatens one or more socio-economic elements. Given this definition, for a territory, the implementation of a real integrated management of natural risks requires the establishment beforehand of a territorial analysis allowing an understanding of the main components characterizing the economic stakes and the main trends of territorial development. The LESSEM research unit (Laboratory of Ecosystems and Societies in Mountains) of the National Research Institute for Agriculture, Food and the Environment (INRAE) has developed an information system dedicated to territories (SIDDT). This information system provides users with the LESSEM “territory” database:

- Large national statistical files, “BD Communale” section.
- GIS data, “Geographic Information” section.

The functionalities and databases of this information system are constantly evolving, allowing the characterization of evolutionary trends.

The SIDDT query and consultation portal was used to carry out the first stage of the territorial analysis relating to understanding the demographic and socio-economic components of the BPRNP.

The BPRNP has a population of approximately 33,000 inhabitants. The most densely populated areas of the territory are on its eastern and western margins in the lower valleys of the Eygues, Ouvèze and Buëch rivers, with 60 inhabitants per km^2. On the other hand, the heart of the territory, which is very enclosed, is one of the least densely populated areas in France with less than 10 inhabitants per km^2 (**Figure 2**). Thus, the specific geographical context of the territory has led to urbanization that is essentially limited to the valley bottoms or the plains, with a relatively weak intra- and inter-basin road network.

In 2017, the unemployment rate in the BPRNP (**Figure 3**) was higher than the national unemployment rate (France: 9.4%). This trend continued between 2018 and 2020.

If the quality of the territory is partly linked to its intrinsic characteristics, it depends for the most part on the complicity that Man has established here with

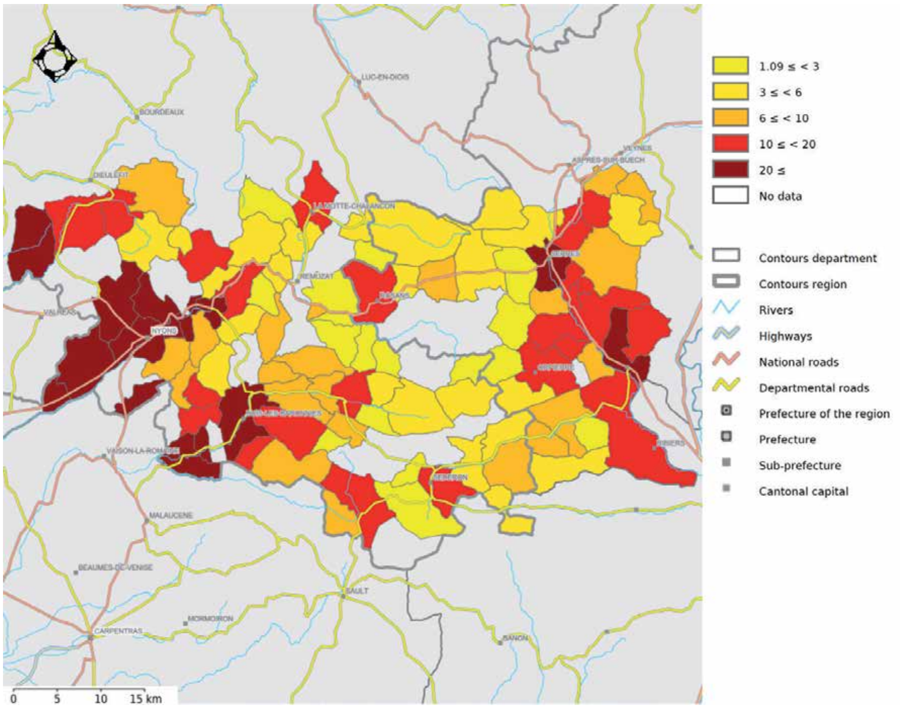


Figure 2.
Population density in 2017, inhabitants/km² [2].

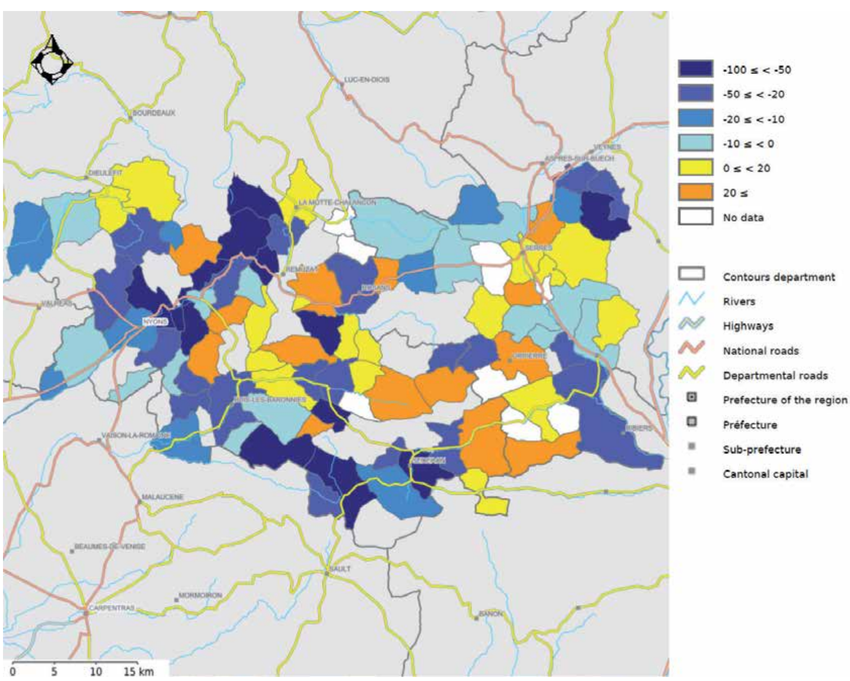


Figure 3.
Evolution of utilized agricultural land from 2000 to 2010 (%) [3].

nature. However, the continuity of the long process of adaptation to a rural mountain life, which has produced the rich heritage of the Baronnies Provençales, is now threatened by the devitalization of the heart of the territory. The significant aging of the population and high unemployment rate are the first worrying signs of imbalance. It calls for a proactive policy to win back the population by developing new economic activities and welcoming new workers.

From 2012 to 2017, the population increased by 1.93%, of which 1.03% was due to natural population growth and 0.90% to immigration. In association and since 1968, there has been a very strong upward trend in the aging of the population. The aging index (ratio of the population aged over 75 to that aged 20, expressed as a percentage) has been rising steadily since 1968. It went from 28.87% in 1968 to 84.36% in 2017 (more than tripling in 50 years!).

In parallel and in line with these trends, the share of personal services equipment is clustered around the main local areas of activity and population.

These demographic and employment trends generate the strong use of the road networks in favor of outgoing flows from the park territory compared to incoming flows: for the active population, the outgoing flow is on average twice as high as the incoming flow.

In addition, during the touristic season, these flows increase due to the occupancy capacity of tourist accommodation and the outdoor activities on offer (canoeing, climbing, hiking trails, etc.). The organization of these activities to optimize economic spin-offs is a development issue, just as the control of visitor numbers in the most vulnerable natural sites is necessary to preserve the value of the natural heritage.

The evolution of agricultural activities is one of the main indicators of the evolution of the physiognomy of this territory over time (**Table 1**, **Figure 3**). Since 1979, this evolution has been negative and reflects a very strong agricultural decline. The agricultural area decreased from 50,910 ha in 1979 to 39,919 ha in 2010, a loss of 21.59% of the agricultural surface. In parallel, the forest area has increased by 1.73%.

Given the geographical, economic and social characteristics of the park, natural risks must be anticipated and managed as closely as possible to the realities of this territory. Thus, the Baronnies Provençales Regional Nature Park includes the management of natural risks in a territorial and multi-actor approach, integrating all the active forces of the territory (elected officials, technicians, local populations, economic circles and decentralized institutions).

The territory of the park is affected by the following natural risks:

- Water-related risks: flooding, torrential floods, debris flows. In particular, the development of urbanization at the bottom of valleys raises the issue of flood management linked to run-off water.

	1979–2000 (%) (reference year: 1979)	2000–2010 (%) (reference year: 2000)
Number of farms	−25.4	−22.4
Utilized agricultural land	−14.1	−8.2
Permanent grassland	−25.7	−15.7
Cropland	−11.1	−9.8

Table 1.
Evolution from 1979 to 2000 and from 2000 to 2010 of the main agricultural indicators [3].

- The risks of ground/terrain movements: landslides, rockfalls (**Figures 5** and **6**), consequences of clay shrinkage and swelling on housing.

- The risk of forest fires: Almost 70% of the park area is wooded. This characteristic, combined with the Mediterranean climate, the dry stations and a diffuse habitat, makes the risk of forest fires present. This is why all of the park's communes are classified by prefectural decree in the list of communes at risk, subject to legal obligations to clear brushwood.

- Seismic risks: since the new zoning of 22 October 2010, the communes of the park are in a low to moderate seismic zone. The damage from past tremors has been non-existent or minimal.

In terms of the consequences of these phenomena, 5% of the communes of the park have been affected by natural disaster decrees, which mainly concern floods, mudslides and land movements. In France, it is possible to be compensated for a disaster due to a natural or technological catastrophe if insurance against these risks has been taken out. However, an interministerial order (so-called natural disaster decree) must recognize the state of natural or technological catastrophe (**Figure 4**).

2.3 Forests and forestry in the Baronnies Provençales regional Nature Park PAR

In France, the July 2001 Forestry Orientation Law gives an important role to the development of a sustainable and multifunctional forest management policy, introducing the notion of territorial integration through the implementation of Territorial Forest Charters (TFC). The purpose of TFCs is "to structure a project for the sustainable development of rural areas, integrating forests more closely into their economic, ecological, social or cultural environment". In 2012, the Park drafted is first TFC for its entire territory.

Figure 4.
Example of rockfall risks in the park (photos F. Berger INRAE).

The park's forestry heritage represents an important potential lever for local development and a major challenge for sustainable development. The Forestry Charter approach is an opportunity to carry out a shared reflection with all the local stakeholders for developing a real forestry dynamic in this area.

Forest cover is substantial in the Baronnies Provençales compared to the rest of the country: the degree of afforestation is almost of 84%, i.e. around 152,000 hectares (BD forêt v2 data), which is evenly distributed. In France, the national degree of afforestation is 31%. This land use makes the forest a considerable lever for local development. However, it currently generates very little economic benefit in relation to the space it occupies.

With respect to the forest sites, according to ecological and vegetation conditions, oak forest types predominate in terms of area. The percentage share of area for the most important forest types is as follows:

- Coppice with a majority of oak sp. (43%) present on sunny slopes and/or on poor and superficial soils.
- Beech coppice (5%) on the higher northern slopes.
- Scots pine forests (19%) abound throughout the area.
- Other coniferous forests (5%), generally of Aleppo pine, are located in the most Mediterranean part of the area.
- Austrian black pine stands (5%) are widely scattered throughout the area. They constitute important massifs, mainly in communal and state-owned forests and locally in private forests. They reflect the artificial afforestation effort using Austrian black pine, generally carried out on former agricultural land colonized by Scots pine.
- Heaths and wooded moors (22%) are present on most of the slopes.
- According to the European forest types [5], the percentage share of area of the two most important forest types is as follows:
- 3.3 Alpine Scots pine and black pine forest: 22.4%
- 8.8 Other thermophilous deciduous forests: 60.7%
- The percentage share of area of the main tree species is presented in the map in **Figure 5**.

The characteristics of the Baronnies Provençales forest reflect the forestry context of the area: a young forest with low volumes, often resulting from the natural reclamation of former pastoral or agricultural areas whose soils are generally chalky and superficial. These low-value stands are composed of an abundance of pubescent oak coppice, Scots pine forests and, to a lesser extent, black pine forests. Beech forests are rarer and fir forests are almost anecdotal (**Figures 5** and **6**).

The forest of the park is essentially private: it represents 82% of the woodland and slightly more than 10,000 owners. Seventy-five percent of the forest properties are smaller than 5 hectares. Ninety percent of the private forest territory concerns properties of less than 100 ha, but 46% is occupied by properties of more than 25 ha and therefore requires a simple management plan approved by the state.

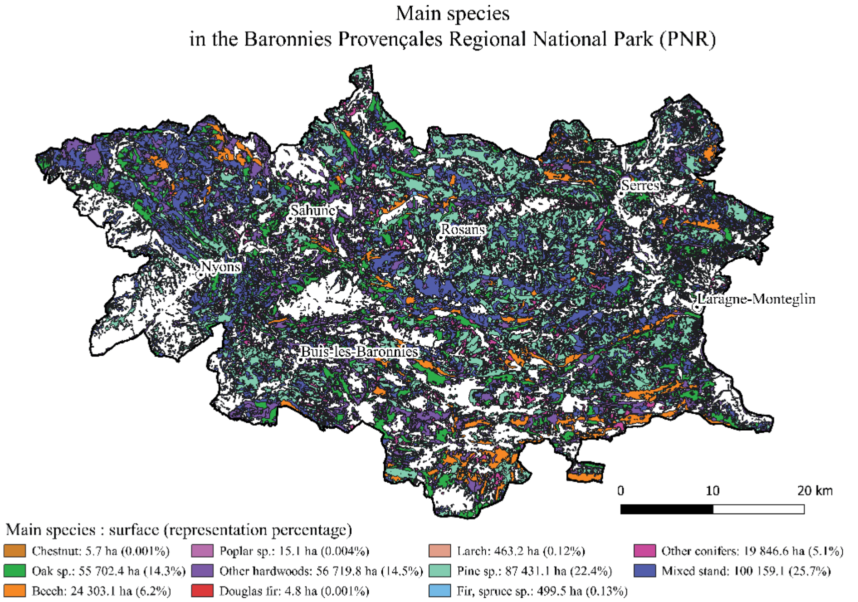


Figure 5.
Map presenting the spatial distribution of the main tree species [4].

Figure 6.
Example of residual rockfall risks below an Austrian black pine stand in the park (photos F. Berger INRAE).

Private forests are therefore relatively fragmented, which hinders the mobilization of the resource.

Public forests represent 18% of the wooded area: 56% communal and 44% state-owned. They are evenly distributed over the area.

The analysis of the national forest inventory data on the territory makes it possible to estimate the main values of wood capital. Taking all types of stands together, there are approximately 7 million cubic meters of wood. The estimation of the annual production is 240,000 m^3, but this volume should be put into perspective because more than 60% of the areas are difficult or very difficult to exploit (problems of access, quality of the stands, etc.). Most of the wood in the Baronnies Provençales is harvested in public forests, due to the quality of the roads and the stands. In private forests, the problems of access, fragmentation and the low value of the stands explain the low mobilization of timber, which is more complex to manage. Taking private and public forests together, the annual volume exploited is estimated at between 10,000 and 15,000 m^3 per year, i.e. around 5% of the annual productivity of the forests.

There are only two logging companies in the area. Twelve to fifteen companies from outside the area are involved in the process of forest resource mobilization. Some local construction and public works companies carry out part of the transport. Several factors explain this situation:

- a lack of trained workers (loggers, skidders, etc.) linked to the arduous nature of the work relative to remuneration.
- a tense economic situation in which the value of wood remains low.
- the cumbersome nature of the investment involved.
- the increasing complexity of the regulations and the handicaps of the territory (land, access, slopes), including access to cuttings (inadequate access, tonnage limitations, etc.).

Primary processing is the most worrying link in the Baronnies Provençales. In ten years, nearly ten sawmills of various sizes, located in the area or nearby, have closed. The disappearance of sawmilling condemns any possibility of local valorisation of the production in transformed products. A reflection on the installation of the first transformation units is therefore necessary to meet the needs of the second transformation. Black pine in particular is a species with very good mechanical properties suitable for construction. Traditionally, secondary processing companies used to source very unprocessed products directly from local sawmills. Today, they are turning to the use of semi-finished and technologically advanced products. At the same time, wood construction has undergone a technological leap: regulations have been refined and the quality requirements of companies are increasingly stringent. In addition, secondary processing companies (carpentry and joinery) prefer industrial products that meet precise criteria (grading, drying, etc.), which are not available locally due to the absence of modern sawing units. Finally, in the face of the craze for wood construction, the territory is faced with a deficit of carpentry companies, whereas secondary processing is a real link in the local economic development.

The main outlet for hardwoods (beech and oak) is energy wood (mainly logs). There is a significant amount of estovers. The forest communities therefore derive little benefit from their forests, preferring to focus on the social and community aspects. The almost exclusive outlet for softwoods is pulping, except for black pine for which outlets are more diversified. Wood energy in the form of forestry chips represents a promising outlet, especially since, unlike industrial wood, it can be used in short marketing channels.

3. An example of best practice: the benefit of large-scale rockfall modeling for developing efficient forest-based integrative management of an alpine territory

The preservation and enhancement of the role of forests in mitigating natural hazards is essential in strategies to protect inhabitants and economic activities in mountain areas. In order to avoid the catastrophic consequences generated by the alteration or even disappearance of forest cover, it is first necessary to locate the forests that play a role in protection against hazards.

With the exception of the risk of forest fires, the Baronnies Provençales Regional Nature Park had not carried out any assessment of the ecosystem service of protection against natural risks provided by the forest ecosystems present on its territory. Due to the masking effect of the forest cover and the lack of exhaustive mapping of the potential of phenomena in the absence of any forest vegetation, this protective service was either unknown or considered to be present throughout the territory.

In view of this observation, and the models developed by INRAE and its Alpine Territory for Integrated Natural Risk Management approach, the park asked the COMPET research team from the INRAE Centre in Grenoble to deploy its tools to carry out the first territorial assessment of the ecosystem service of rockfall risk protection in BPRNP forests.

The main aspects of the methodology, associated tools and results are presented in the following chapters.

3.1 The ROCK-EU-mapping model

Spatial models are effective tools for determining rockfall source, transit and deposit areas, and can be used for recognizing areas at risk due to rockfalls. Based on such models, a harmonized method for mapping rockfall protective forests for the entire Alpine Space (AS) has been developed by the consortium of the Interreg Alpine Space project RockTheAlps (#462). The innovative model Rock-EU-Mapping has been so developed.

Rock-EU-Mapping enables the large-scale identification of forests that could potentially play a role in protection against rockfall hazards. This model is relevant for providing studies on a regional scale or for a mountain massif. The calibration and validation of the methodology [5] was carried out using a database gathering information on past rockfall events. This database (2,812 events at the date of the model calibration) was initiated in the framework of the Interreg Alpine Space project RockTheAlps and is updated regularly. On 1 January 2021, 6,116 past events were registered in this database, and a new calibration of the model is scheduled for December 2021.

Spatial input data were chosen to be homogeneous over the whole Alpine Space and in open access. They were taken from two main sources: The European Union's Copernicus Earth Observation Program and OpenStreetMap. Relief and topography were obtained from EUDEM v1.1, which is a digital elevation model (DEM) available in raster format for Europe at a 25 m spatial resolution. Land and forest cover were extracted from Corine Land Cover (CLC) 2018. CLC is produced by visual interpretation of high-resolution satellite imagery. It is available in shapefile (vector layer of polygons) format with a minimum mapping unit of 25 ha. Water surfaces and rivers were obtained from OpenStreetMap contributors in shapefile format and used also to develop the classification of soil types (needed for defining soil rebound coefficients). Human assets (buildings, roads and railways) were extracted in shapefile format from OpenStreetMap contributors locating different topographical information over the world. Using all these input data, the model simulates the propagation of rocks along the slope on a rasterized digital terrain model by successive sequences of free flights in the air and rebounds on the slope surface. Rebounds are directly calculated using a classical rebound model [6].

The detection of block release areas is based on the use of slope thresholds. The parameters required to compute the rebound are derived from 7 soil classes which are defined from the land use map and specified according to elevation, slope and information on human assets, water surfaces and rivers.

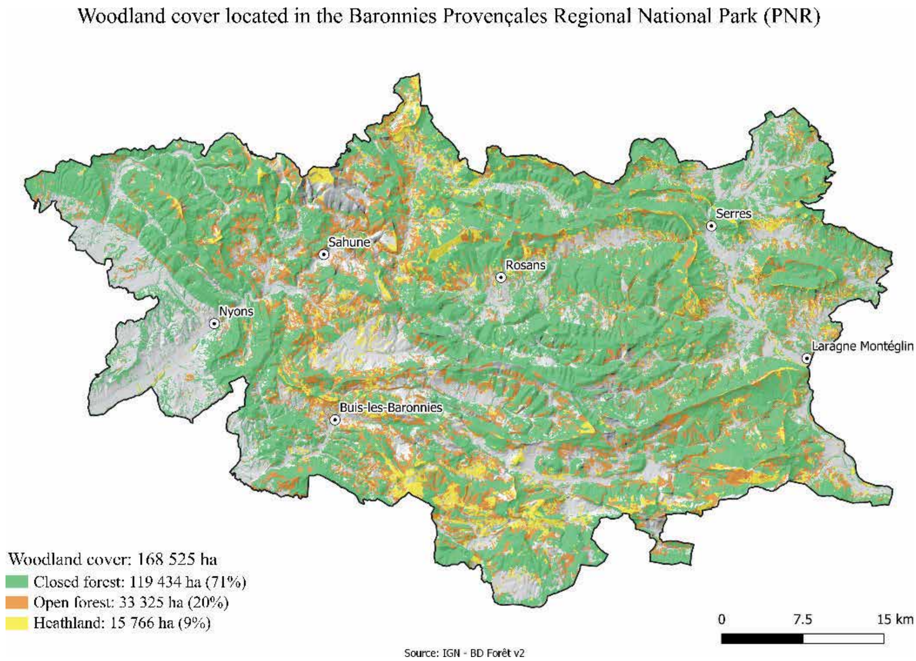


Figure 7.
Woodland cover of the Baronnies Provençales regional Nature Park [7].

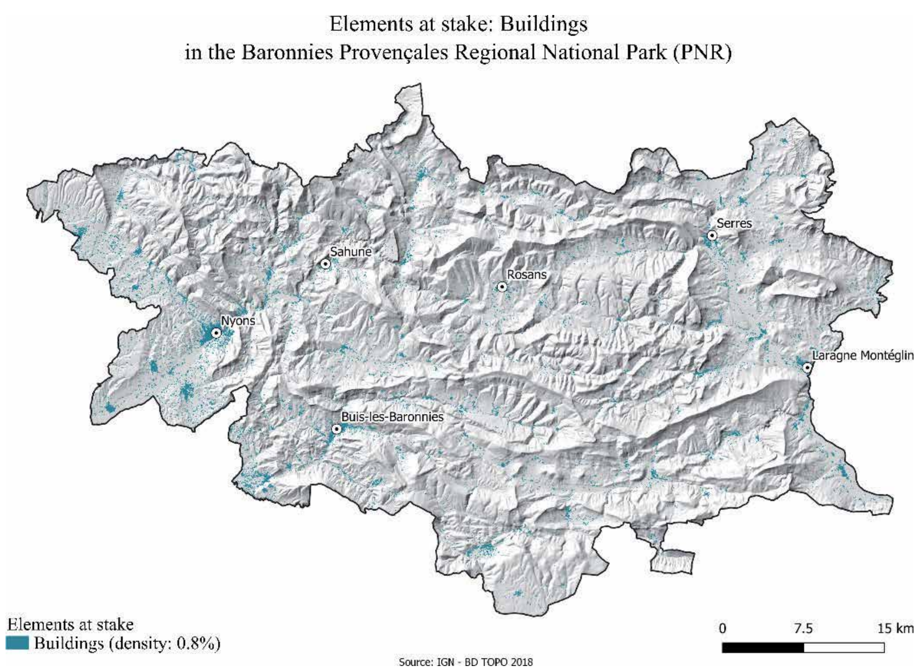


Figure 8.
DEM and building locations in the Baronnies Provençales regional Nature Park [8].

Since these first works, the model has been calibrated for the French territory to use a French DEM and OSO data, both with a resolution of 10*10 m. OSO is the national scale map (Metropolitan France) of land cover in 30 classes, with a resolution of 10*10 m and an annual update frequency. The data used are a series of multi-temporal optical images at high spatial resolution (Sentinel-2 type, but also in the future SPOT-6/7, or even Pleiades).

Figures 7–10 present the main input parameters of the model.

In addition to these three main categories of elements, the park also requested the consideration of orchards and vineyards as important elements of the economic activities within its territory.

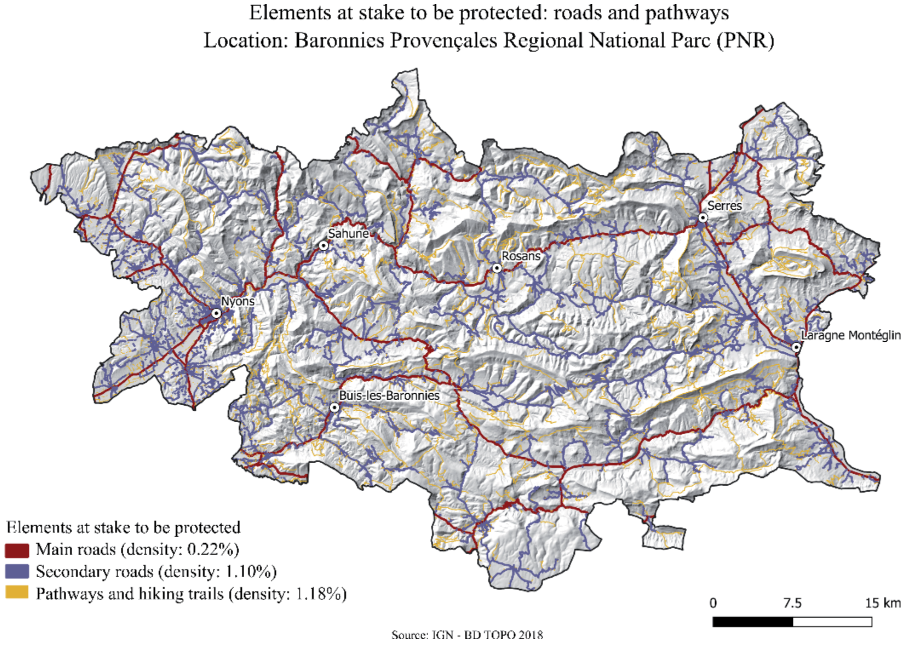


Figure 9.
Road network in the Baronnies Provençales regional Nature Park [9].

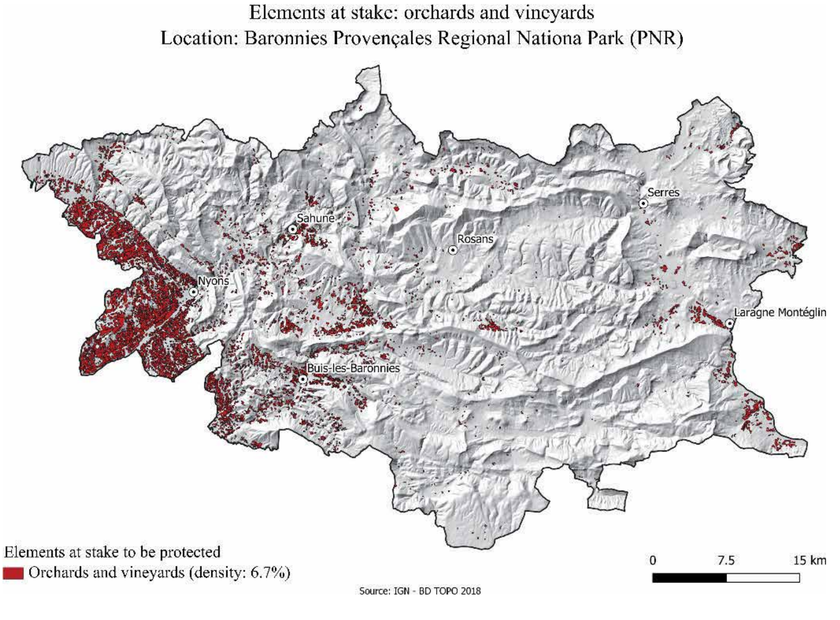


Figure 10.
Orchards and vineyards in the Baronnies Provençales regional Nature Park [10].

All these input data are automatically processed by the ROCK-EU-Mapping model in order to provide a map of the forest areas offering a potential protection role against rockfall risks. Two classes of slope values are used for defining potential release areas: 28° to 42°, corresponding to foothill conditions, and greater than 42°,

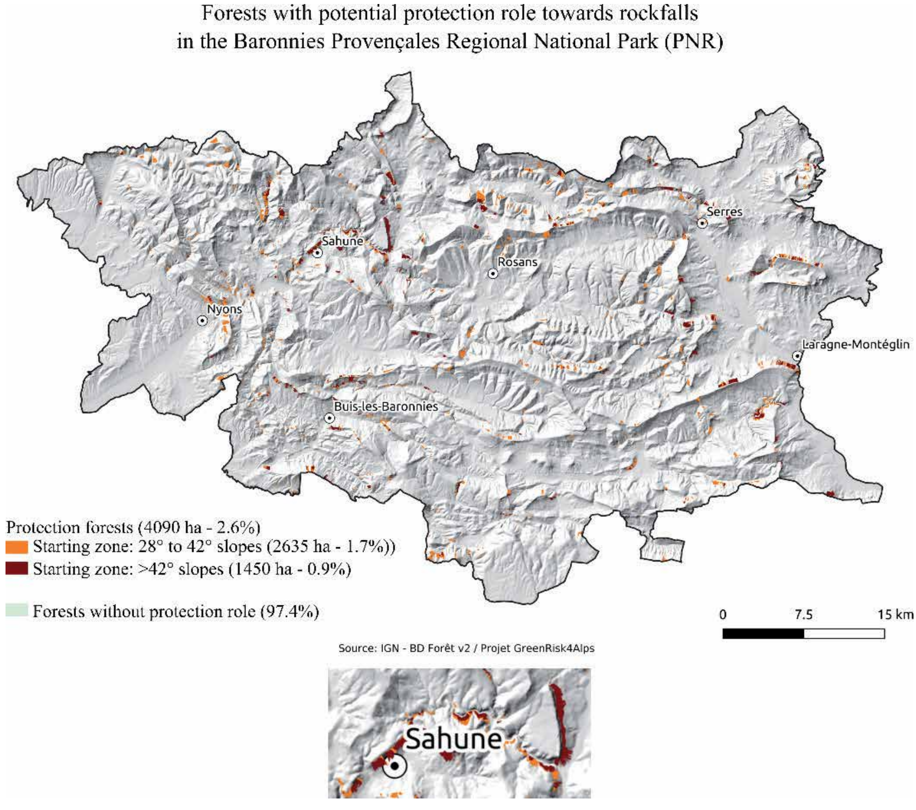


Figure 11.
*Forests protecting against rockfall risks in the Baronnies Provençales regional Nature Park with a blow-up of the Sahune area (***Figure 12***) [11].*

Figure 12.
Example of the protective effect of thermophilous deciduous forests in the Baronnies Provençales regional Nature Park (photos J. Jarjaye).

corresponding to mountain and cliff conditions. According to the geographical and topographical conditions of the park, all the results obtained for slopes greater 28° have to be considered.

Therefore, forests protecting against rockfall risks represent only 2.6% of the park's woodlands. The main element endangered by rockfall risks is the road network. As such, these forests are one of the actors, but not the main ones, of the policy of securing the transport routes in this territory. This analysis allows this ecosystem service, which had been largely overestimated by forest managers, to be put in its proper place (**Figures 11** and **12**).

3.2 Assessment of accessibility to logging machines in protective forests

Identifying and characterizing the conditions of access to forest resources are strategic points for their sustainable and multifunctional management. This issue of accessibility is all the more important for protective forests as it determines their maintenance and management strategies.

In order to fulfill these two objectives, INRAE developed the Sylvaccess model in 2015. This model is designed to automatically map the accessibility of forests with the three main logging techniques currently used in France: skidder, forwarder and cable yarder. The model is based on spatial information and specific parameters of each logging technique. It can also integrate physical or environmental obstacles in the analysis. The outputs of the model can be used for many applications ranging from forest management and planning of logging operations to the comparison and selection of new forest road projects.

The Sylvaccess model requires different layers of geographical information. The three layers necessary for its operation are as follows:

- A digital terrain model (DTM) in raster format. The resolution of the DTM determines the resolution that the model uses for all processing.

- The forestry access network. This data is a vector of polylines. It lists all the public roads in the network, forest roads (accessible to timber trucks) and forest tracks (only accessible to logging machines). A specific field in the attribute table, previously filled in by the user, allows the model to automatically distinguish between these three types of service. The quality of processing depends on the completeness of this layer. Careful preparation of this information is therefore important. Before processing, the model checks the connection between the forest service and the public network. If errors are detected, it returns a warning message and a GIS layer for locating possible problems.

- The forest area. This data is a vector of polygons. It allows the model to identify forest areas. In France, BD Forêt v2 provided by the IGN is a source of information adapted to the analysis scale.

The Sylvaccess model is a useful diagnostic and decision-making tool for forest managers and public decision-makers. It allows the identification of accessible forests with the main logging methods and the comparison of different alternatives during service projects. The results are summarized in the form of a map of logging methods. This map can be used as a basis for the planner and manager to plan the felling and silviculture to be carried out, which is of a different nature depending on the chosen exploitation mode [12]. The Sylvaccess model can be downloaded at https://sourcesup.renater.fr/projects/sylvaccess/.

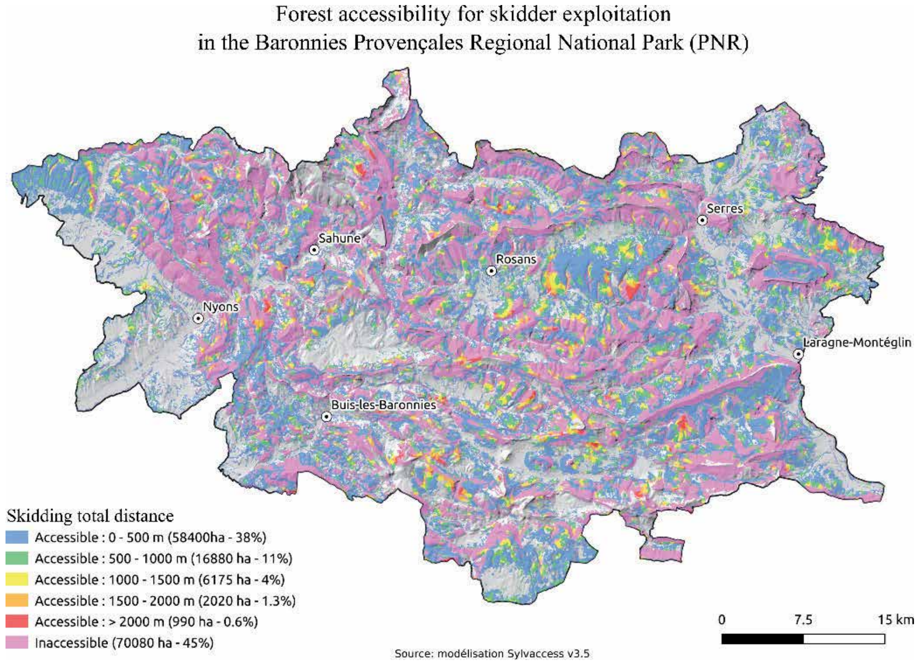


Figure 13.
Forest accessibility for skidder exploitation in the Baronnies Provençales regional Nature Park [13].

It is governed by the CeCILL license, which is subject to French law and respects the principles of free software distribution. Any forest manager, private or public, is able to use it free of charge for his own needs.

This model has been applied to the entire territory of the park. The first result confirms the difficulties in accessing forest areas. Sixty-two percent has a skidding distance longer than 500 m. This result confirms the impression of the local managers who considered in the first approach that more than 60% of the forest is difficult to access.

The second result is that 73% of the forest protecting against rockfall risks is not accessible to forestry equipment. This highlights the fact that protective forests are located in extreme topographical conditions, which makes them inaccessible to foresters even on foot (**Figures 13** and **14**).

3.3 Assessment of accessibility to fire fighting and rescue vehicles in protective forests

The dryness of the climate, the aerology and the type of forest species make the Baronnies Provençales an area that is highly exposed to the risk of forest fires. All the communes are classified by prefectural decree in the list of communes at risk, subject to the obligation to clear brushwood. As a result, the territory has several management documents such as the Departmental Plans for Forest Fire Defense (FFD). With regard to these documents, the fire risk hazard and the level of FFD equipment are precisely known. However, none of these documents spatializes the areas that are actually accessible from the forest road network. This question of the accessibility of protective forests is crucial for assessing the sustainability of this function in a territory where the risk of forest fires is high. A forest fire can effectively nullify this function and force managers to implement civil engineering techniques as a replacement. Knowing the location and accessibility of protective forests, firefighters can then build an adapted intervention strategy for these forests.

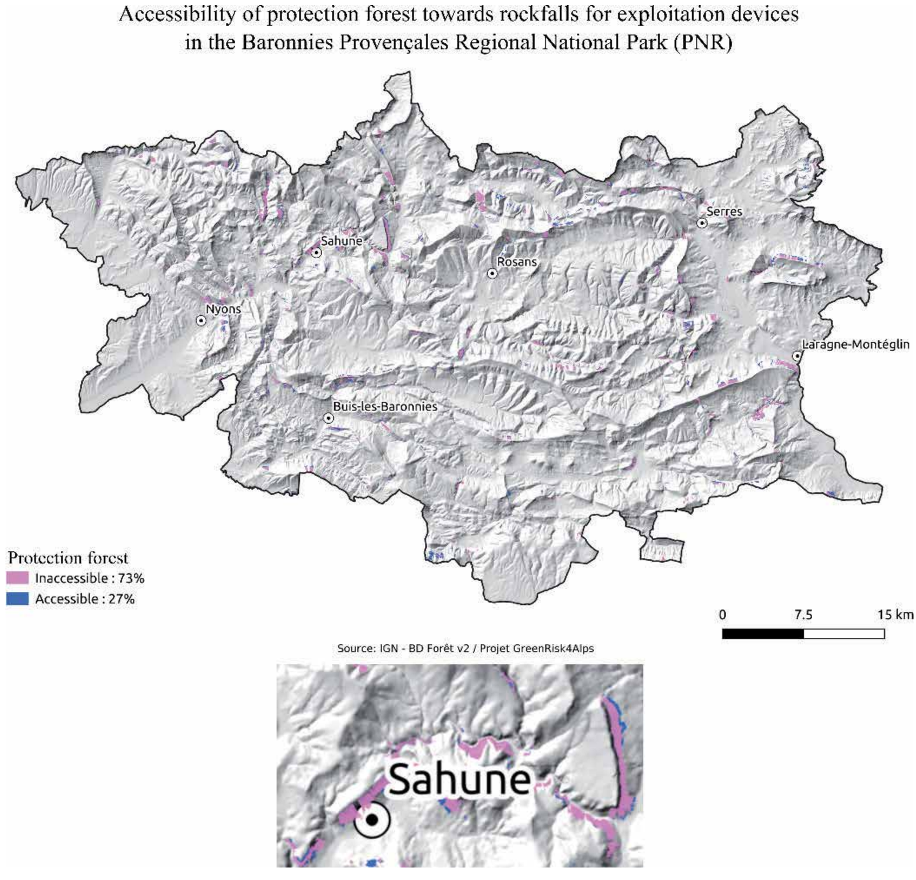


Figure 14.
Accessibility of forest protecting against rockfall to exploitation devices in the Baronnies Provençales regional Nature Park with a blow-up of the Sahune area [14].

Within the framework of the Interreg Alpine Space project GreenRisks4Alps, Sylvaccess has been adapted to the context of the accessibility of forest areas to fire fighting and rescue vehicles. The first prototype of the Fireaccess model was developed and tested on the territory of the Baronnies Provençales Regional Nature Park.

This new model makes it possible to identify and map forest areas that are accessible to land-based firefighting equipment (**Figures 15**–**17**).

The key result is that, based on a distance threshold of 100 m from both sides of a forest road or track, 74.8% of the forest is mainly inaccessible to classical land-based fire fighting vehicles (**Figure 18**). Another way of calculation is to evaluate the density of the forest surface accessible from a road or track. This density is calculated using a base of 100 ha. With this indicator, 71.4% of the forest has an accessibility density of less than 50% (for a forest area of 100 ha, less than 50 ha is accessible). These two results converge, underscoring the potential consequences of a forest fire in this territory if air-based equipment cannot be used.

Combining the map of the rockfall protective forests with the map of the accessible forest density to terrestrial based firefighting devices reveals that 59% of these forests have an accessible density of less than 50%. The difference with the previous result presented is due to the location of these protective forests close to the road networks that they are protecting.

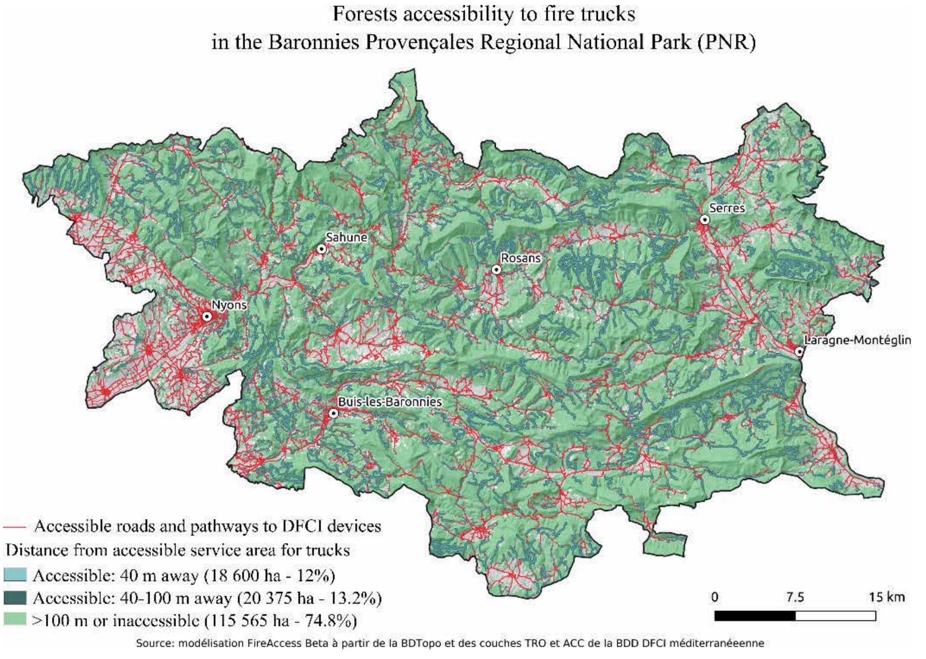


Figure 15.
Forest accessibility to terrestrial based firefighting devices in the Baronnies Provençales regional Nature Park [15].

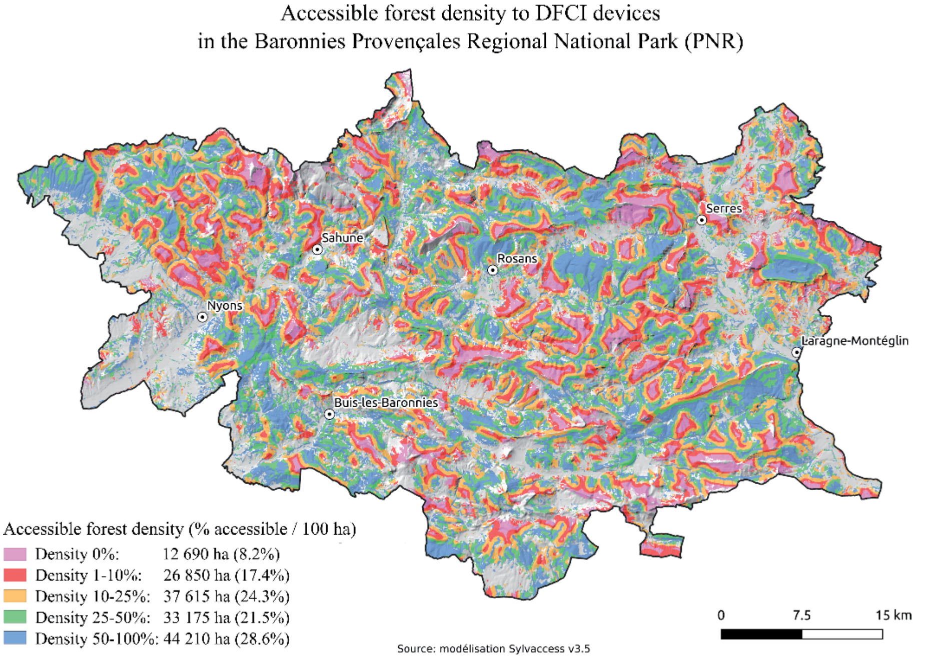


Figure 16.
Accessible forest density to terrestrial based firefighting devices in the Baronnies Provençales regional Nature Park [16].

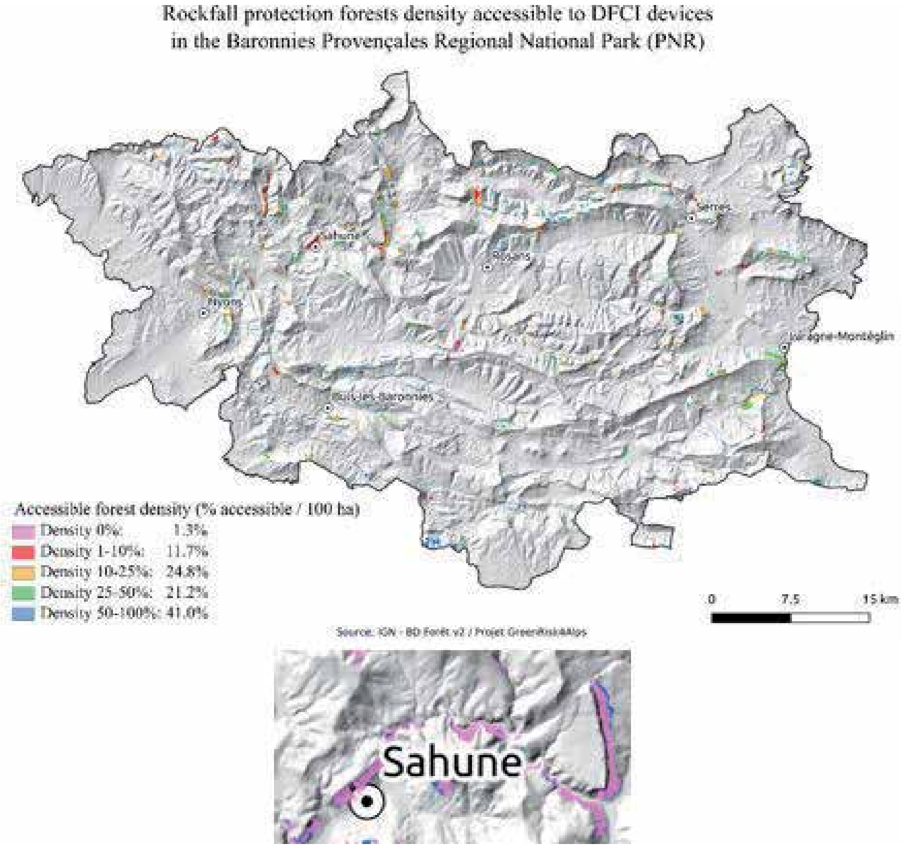


Figure 17.
Rockfall protection forest density accessible to terrestrial based firefighting devices in the Baronnies Provençales regional Nature Park with a blow-up of the Sahune area [17].

Figure 18.
Example of trees left across the slope. Debarking may be necessary to avoid phytosanitary problems (photos F. BERGER INRAE).

4. Conclusion

The main objective of this work was to produce and transfer the necessary and sufficient cartographic data to enhance the rockfall risk protection service of the forest heritage in the integrated natural risk management approach of the Baronnies Provençales Regional Natural Park. This objective answered the desire to develop a territorial intelligence as a response to the societal demand for the improvement of the prevention of natural risks by better taking into account the functions offered and the services rendered by the forest ecosystems. The general objective was to carry out the first territorial assessment concerning all the parameters for qualifying the forest ecosystem service of rockfall risk protection.

The first stage of the territorial assessment was to identify and understand the socio-economic factors explaining the development of this territory. From this first analysis, it emerged that the road network and the maintenance of its practicability are the two most important issues. Not only does this network ensure the proper economic functioning of the territory, it also represents access routes for intervention and rescue vehicles to fight forest fires.

The second step allowed the identification and display of the forest sectors protecting against rockfalls. The use of a trajectographic simulation model greatly facilitated this mapping work. Thanks to this approach, it was possible to carry out a concerted and harmonized action for the whole of this territory, freeing it from communal boundaries. In the end, it was found that only 2.6% of the park's forest area is capable of performing this protective function. Given the importance of the risk of forest fires, which affect the entire territory (remember that 84% of the territory is forested!), the management of this ecosystem service is not a priority action due to its low representativeness in the park's territory and is secondary to forest fire protection. This is especially true since only 25% of the forests protecting against rocky hazards are accessible to fire service vehicles. For the first time in France, the information produced by large-scale simulations makes it possible to prioritize the forest fire defense intervention sectors according to the presence or absence of the ecosystem service of rockfall risk protection.

All of the park's communes are classified by prefectural decree in the list of communes at risk, subject to legal obligations to clear brushwood. As such, there is a potential conflict of objectives between fire and rock protection forestry. Given the very low rate of forests with a rockfall risk protection function and their accessibility to land-based DFCI equipment, this management conflict does not really exist. For these forests, the management compromise is very simple:

The obligation to clear brushwood is imposed according to the distance of the forest stands from the objects.

It is possible to cut down trees and leave them in place provided that:

- The trunks on the ground are lopped off and the branches are removed from the site.
- The trunks on the ground must be positioned at an angle of 30° to the contour lines.
- The height of the obstacles thus created must be at least equal to the largest dimension (a projectile is characterized by its shape and its three dimensions: width, height, length) of the largest rock projectile present on the site.

If necessary, it is possible to use the trees present as supports for a rockfall protection net. If this solution is chosen, it is necessary to carry out a 3-dimensional trajectographic study to define the mechanical characteristics of this structure.

The main conclusions of this forestry territory analysis have been integrated into the integrated natural risk management approach of the Baronnies Provençales Regional Nature Park (a first in France) and will be included in its forestry territory charter when it is revised. More specifically, they will feed into two main objectives:

- Enhancing natural and human assets.
- Designing sustainable forestry development based on solidarity.

In this respect, they demonstrate the contribution of large-scale modeling work to decision-making and to the development of a genuine territorial intelligence based on the display of the ecosystem service of protection against natural hazards. Very often and unfortunately, awareness of this service is only raised when the forest cover disappears. These tools therefore offer the possibility of anticipating the consequences of forest cover change.

The issue for decision-makers now is the recognition of forest-based solutions in natural hazard prevention policies, but that is another story to follow.

Acknowledgements

Finally, we would like to thank everyone who contributed to the production of the materials used for the drafting of this text.

Author details

Frédéric Berger[1*], Benjamin Einhorn[2], Jessica Jarjaye[3], David Toe[4], Jean-Baptiste Barré[5] and Sylvain Dupire[6]

1 INRAE, Saint Martin d'Hères, France

2 PARN, Saint Martin d'Hères, France

3 SMBP, Sahune, France

4 SNCF, Chambéry, France

5 IGE, Saint Martin d'Hères, France

6 Sylvalab, Barraux, France

*Address all correspondence to: frederic.berger@inrae.fr

References

[1] Syndicat Mixte des Baronnies Provençales, 2012 : []. Charte Forestière de Territoire des Baronnies Provençales. https://www.ofme.org/documents/actualite/201207/CFTBaronniesProvencales-DocumentFinal.pdf

[2] INRAE- research unit LESSEM -Computer development and database: F. Bray & A. Torre. Geographic data source: INSEE, démographie – la population 2017. Completion date: March 2021

[3] INRAE- research unit LESSEM -Computer development and database: F. Bray & A. Torre. Geographic data source: AGRESTE, SCEES, RGA 2010 Communal. Completion date: March 2021

[4] INRAE- research unit LESSEM -Computer development and database: P. Favier. Geographic data source: IGN BDforêtV2. Completion date: March 2021

[5] European forest types, Categories and types for sustainable forest management reporting and policy, European Environment Agency EEA Technical report No 9/2006

[6] Dupire, S., Toe D., Barré J.-B., Bourrier F., Berger F., 2020. Harmonized mapping of forests with a protection function against rockfalls over European alpine countries. Applied geography, Elsevier, 2020, 120, pp.102221. ff10.1016/j.apgeog.2020.102221ff. ffhal-02519495v2f

[7] Bourrier, F., Berger, F., Tardif, P., Dorren, L., Hungr, O., 2012. Rockfall rebound: Comparison of detailed field experiments and alternative modelling approaches. Earth Surface Processes and Landforms 37 (6), 656-665.

[8] INRAE- research unit LESSEM -Computer development and database: S. Dupire and P. Favier. Geographic data source: IGN BD forêt V2. Completion date: March 2021

[9] INRAE- research unit LESSEM -Computer development and database: S. Dupire and P. Favier. Geographic data source: IGN BD topo 2018. Completion date: March 2021

[10] INRAE- research unit LESSEM -Computer development and database: S. Dupire and P. Favier. Geographic data source: IGN BD topo 2018. Completion date: March 2021

[11] INRAE- research unit LESSEM -Computer development and database: S. Dupire and P. Favier. Geographic data source: IGN BD topo 2018. Completion date: March 2021

[12] Dupire, S., Bourrier, F., Monnet, J.M., Berger F., 2015. Sylvaccess : un modèle pour cartographier automatiquement l'accessibilité des forêts. Revue forestière française, AgroParisTech, 2015, 70 (2), pp.111-126. ff10.4267/2042/57902ff. Ffhal-01255892

[13] INRAE- research unit LESSEM -Computer development and database: S. Dupire and P. Favier. Geographic data source: IGN BD topo 2018. Completion date: March 2021

[14] INRAE- research unit LESSEM -Computer development and database: S. Dupire and P. Favier. Geographic data source: IGN BD topo 2018. Completion date: March 2021

[15] INRAE- research unit LESSEM -Computer development and database: S. Dupire and P. Favier. Geographic data source: IGN BD topo 2018. Completion date: March 2021

[16] INRAE- research unit LESSEM - Computer development and database:

S. Dupire and P. Favier. Geographic data source: IGN BD topo 2018. Completion date: **March 2021**

[17] INRAE- research unit LESSEM -Computer development and database: S. Dupire and P. Favier. Geographic data source: IGN BD topo 2018. Completion date: March 2021

Chapter 2

Oberammergau Pilot Action Region: Mountain Forest Initiative (BWO)

Helena Eisele, Roland Schreiber and Anne Stöger

Abstract

Natural hazards caused by climate change pose a permanent threat to the inhabitants of the Alpine Space. In addition to technical protection measures, forests are very often the key to permanent and cost-effective protection against these hazards. In the Mountain Forest initiative (BWO) of the Bavarian state government, launched more than 10 years ago, suitable measures for the preservation of protective forest are discussed and, if possible, decided by consensus in on-site round tables with all involved interest groups. Only a functioning interaction between the different actors in the Alpine Space will contribute towards the set objective of integrating forests and ecosystem services in risk governance and balancing the numerous interests, demands and costs. Using the example of the Oberammergau Pilot Action Region (PAR), the process and implementation of the BWO is presented against a background of more than 10 years of experience. At the beginning, the identification of stakeholders and the overall goal and expectations of the participatory process (technical issues, trust and community building) is clarified. After a detailed actor analysis, the moderated participatory process is described.

Keywords: protective forest, natural hazards, Mountain Forest Initiative, round table, participatory process, stakeholder involvement, risk governance, actor analysis

1. Introduction

Several factors contributed to the decision to select the Municipality of Oberammergau as a PAR within the GreenRisk4Alps project. The municipality is located in the Ammertal Valley on the Ammer River, which gives the municipality its name. The river has its source in the Ammergau Alps south of Oberammergau. The Ammergau Alps, with an area of about 30 x 30 km, are a mountain group of the Northern Limestone Alps, about 75% of which are located in Germany (Bavaria) and 25% of which are located in Austria (Tyrol) (see **Figure 1**). The forests in the region protect the municipality and its infrastructure from various natural hazards, especially from the Große Laine Torrent and partly from rockfalls and avalanches. These facts are the basis for the immense importance of the establishment, management and maintenance of protective forests, with their typical challenges.

Figure 1.
Ammergau Alps [1].

For more than 10 years, the region has participated in the Mountain Forest Initiative (Bergwaldoffensive, BWO), which is part of a broad Bavarian state government program combatting climate change. In the defined BWO projects, measures for the maintenance and adaptation of forests are established to maintain the protection function of forests in the face of climate change. One important part of the BWO is the involvement of forest owners and local stakeholders in order to consider their interests and ensure the broad agreement of society.

2. Description of the Oberammergau PAR

The Oberammergau PAR is a municipality in the Upper Bavarian district of Garmisch-Partenkirchen and is located 90 km southwest of Munich (see **Figure 2**). The municipality has an area of 30 km^2 and a population of about 5,500 inhabitants and is located in the Ammergau Alps Nature Park. The area was declared a nature park by the Bavarian State Ministry for the Environment and Consumer Protection on July 27, 2017 and covers an area of 227 km^2. Its tasks are comprehensive and range from nature conservation and landscape management, with the aim of protecting biodiversity, climate and resources, among other things, to recreational opportunities, sustainable regional development and education in sustainable development.

Only about one kilometre from the village center is Kofel, a striking hilltop that can be seen from afar and offers a variety of hiking trails. In addition to numerous mountain biking and hiking opportunities, the region is also well-known for winter tourism, with a wide network of cross-country ski trails and family-friendly as well as more challenging downhill runs.

Figure 2.
The village of Oberammergau and surrounding area [2].

Figure 3.
The passion play [3].

Oberammergau is also an attractive destination for various tourist groups. It has gained particular recognition for its Passion Festival, which takes place every 10 years and features locals as performers (see **Figure 3**).

Its history began almost 400 years ago when the plague ravaged Oberammergau. To put an end to the misery, the people of Oberammergau vowed in 1633 to perform the Passion and Death of Christ every ten years, provided no one else died of the plague. The first Passion Play was performed in 1634.

2.1 Forest and forestry in Bavaria

Forestry in Bavaria follows the "Bavarian Way" of integrative forest management. The guiding principle here is to "protect and benefit over as large an area as possible." With this approach, the diverse services of the forests are considered in a balanced and locally adapted manner. In Bavaria, more than 50% of forests are privately owned, while state-owned forest accounts for about 30% (see **Table 1**) [4].

Although beech sites actually predominate in Bavaria as well, the leading tree species is still spruce, which is more or less due to a historically determined approach to forest management.

Today, foresters and forest owners consistently create stable mixed stands of deciduous and coniferous species that are adapted to the respective location.

Ownership	Percentage share (%)
Private forest (distributed among about 700,000 forest owners)	54.2
Corporate forest (mainly communal forest, i.e. forest owned by municipalities or cities)	13.5
State forest (forest of the Free State of Bavaria, managed by Bayerische Staatsforsten AöR under the legal supervision of the Bavarian Forestry Commission)	30.1
Federal forest (Forest of the Federal Republic of Germany, mostly forest on training grounds of the German Armed Forces)	2.2

Table 1.
Distribution of ownership in Bavaria [5].

A look at the Bavarian Alps shows that about half of the area – around 260,000 hectares – is covered with forest. As the 2012 Federal Forest Inventory revealed, the forest in the mountains is older and has larger reserves per hectare than the forest in the lowlands. With a share of 68%, coniferous species predominate in mountain forests.

Spruce alone, which has one of its natural distribution centers in the Alpine region, accounts for 58% of the forest structure. Fir ranks second among coniferous species with about 7%, followed by the pine with 2%. Larch and Swiss stone pine play only a minor role in the Bavarian Alps [5].

The predominant deciduous tree species in the Bavarian Alps is beech, with an area share of about 19%. Sycamore maple and ash, both of which are deciduous tree species, together take up about 10%. The remaining 3% is distributed among other deciduous tree species such as rowan, hackberry, alder, birch and willow (see **Figure 4**).

Originally, half of the mountain forest in the montane zone between 700 and 1,400 meters above sea level consisted of spruce and about 20 to 25% each of beech and fir. The other mixed tree species accounted for about 5 to 10% of the forest structure. Because of the extreme climatic conditions in the high mountains, trees grow much more slowly in the Alps than in the lowlands. Mountain forests, with an average age of 101 years, are older than lowland forests, with an average age of 83 years. With about 420 solid cubic meters of stock per hectare, the average wood stock in mountain forests is about 6% higher than the Bavarian state average. For many decades, wood utilisation has been significantly below the increment [6].

Of the 260,000 hectares of mountain forest, around 60% fulfil priority protection functions and are specially protected by the Bavarian Forest Law (BayWaldG). The preservation of intact protective forests or their restoration is therefore a forestry and socio-political task of high priority.

In 1986, the Bavarian Forestry Administration surveyed the condition of protective forests in all forest ownership types and derived from this the first long-term overall plan for protective forest restoration in the Bavarian Alpine region. Since then, the plan has been updated at regular intervals and adapted to the latest findings [6].

Protective forests are considered to be in need of rehabilitation if their functional capability is clearly impaired and this cannot be restored within the framework of regular forest management.

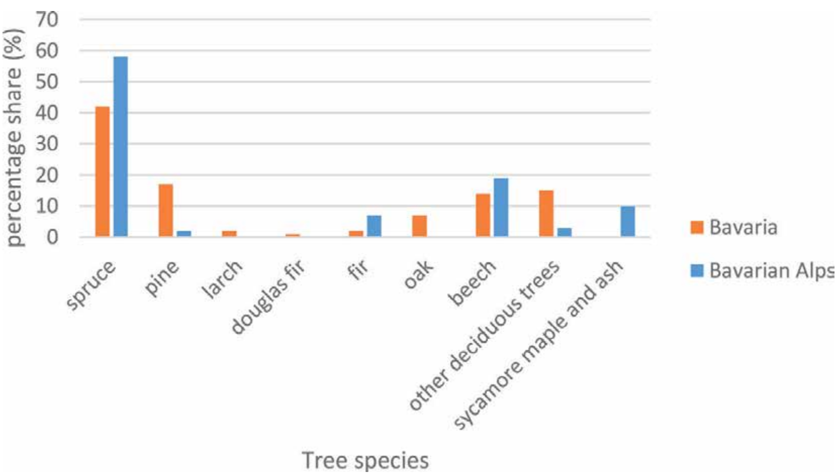


Figure 4.
Tree species distribution in Bavaria and the Bavarian Alps [5].

This applies above all to

- thinned protective forests without sufficient regeneration;
- overaged protective forests (average age over 200 years without sufficient regeneration and more than one third of decaying, dying or dead trees in the upper layer);
- protective forests damaged by storms, bark beetles, shearing damage or declining vitality;
- protective forest regeneration that is not capable of development due to high browsing damage or grazing load.

Currently, there are 1,190 rehabilitation areas in the Bavarian Alpine region with a total area of about 14,000 hectares. This corresponds to about one tenth of the total protective forest area. Mainly due to storm damage and subsequent bark beetle calamities, their extent has increased by about 1,200 hectares since the first planning in 1986. Almost 40% of the rehabilitation areas are of special importance for object protection and therefore have a very high priority [6].

Since the redevelopment measures usually have to be coordinated on a large scale and with other measures, the redevelopment sites have been grouped into redevelopment areas. They include, for example, the sum of the redevelopment sites of a mountain flank with avalanche protective forest above a federal road or a village or all redevelopment sites in a torrent catchment area. At the level of the development areas, necessary accompanying measures such as large-scale hunting and wildlife management concepts are coordinated.

Bavaria's mountain forests are habitats for cloven-hoofed game species, such as red deer, roe deer and chamois, as well as some rare game species that are not hunted. De-spite different habitat requirements, their habitats overlap, especially in the forest area. In order to reduce game damage in sensitive protective forest areas to a tolerable level, hunting management must consistently aim for adapted game populations of the three cloven-hoofed game species.

The Bavarian Hunting Act stipulates that impairment of proper agricultural, forestry and fishery use by game are to be avoided as far as possible. In particular, hunting should enable the natural regeneration of tree species appropriate to the location, essentially without protective measures [6].

2.2 Forest and forestry in the Oberammergau PAR

Since the Ammergau Alps were once royal hunting grounds, much of the region is still forested today. Forests with a high proportion of spruce cover 60% of the 3,000 ha PAR area; many of these are over-aged forests. The Private Forestry Association owns 1,800 ha, and the remaining part belongs to the Bavarian State Forests.

The centuries-old traditional use of parts of the Alpine area as forest pasture (see **Figure 5**) have created many species-rich and valuable habitats [7]. At the same time, however, the conversion to open land is said to have considerable disadvantages for the protective function of the forests against rockfall, mudflows and erosion due to the inhibition of regeneration by treading and browsing (see **Figure 6**). Therefore, the forests in the respective areas play a particularly important role as object protective forests. The separation of forest and pasture in areas exposed to grazing is therefore a declared political goal and also part of the Mountain Forest Initiative [8].

Figure 5.
Resting cattle in mountain forest [9].

Figure 6.
Forest pasture [10].

Forest diversity ranges from the peat-forming alder forest of the moraine and grey alder-spruce forest in the flysch, to mixed mountain forests, some of which are little influenced by forestry, to xerothermic carbonate pine forest on the west- and south-facing steep slopes. Subalpine spruce forests are found on the ridges.

Absolute rarities in Bavaria are thermophilic mixed forests of summer lime. Their occurrence in the Bavarian Alps and their composition there are still very insufficiently researched [11].

The last forest inventory for the private forest was carried out in 2006. According to it, the proportions of the main tree species are as follows (see **Table 2**).

Timber harvesting is complicated by steep and rocky slopes and low road density, which can result in increased stock buildup (average 478 m^3/ha).

2.3 The main problems regarding natural hazards in the PAR

The Alpine region will be particularly affected by climate change. Not only will rising temperatures change growing conditions, floods, storms and avalanches are also likely to increase, giving forests an increasingly important role in their protective function.

In the PAR, dolomite and flysch play a major role from a geological point of view, which in part leads to dry, barren but also landslide-prone soils that are not very suitable for purely agricultural cultivation. With about 1,500 mm of annual precipitation, Oberammergau is among the regions with the highest precipitation in Germany.

In Oberammergau, rockfalls, mudflows and floods pose challenges, and flood protection structures require high maintenance costs. The flood damage potential in settlements is quite high (see **Figure 7**), and the protective forest fulfils an important protective function.

The Große Laine Torrent, which in the past repeatedly caused damage during storms and heavy rain, represents a particular hazard potential.

As early as the middle of the 18th century, attempts were made to protect settlements against water masses by means of structural measures. However, the existing flood protection is not sufficient to discharge a major flood without damage.

Repairs have already been carried out since 2010. In addition, the construction of a larger debris barrier took place in 2015 (see **Figures 8** and **9**), as well as the creation of a partial drainage of the floodwater by means of a drainage channel [13].

However, these measures are associated with immensely high costs in the millions of euros and go hand in hand with a functioning mixed mountain forest that can fully develop its protective potential. This is because the forest not only protects against rockfalls and avalanches, but it also has a delaying effect on water runoff and snowmelt in the spring, reducing the risk of flooding [12].

The loss of the forest would lead to a significant challenge for the safety of settlements near the Große Laine. Therefore, the main challenges are as follows:

- Große Laine Torrent with a large catchment area and high risk/damage potential for the city Oberammergau; flood peaks cannot be drained; 332 flood protection structures.

Tree species	Percentage share (%)
Spruce	80.3
Silver fir	1.7
Beech	7.9
Special deciduous trees	7.4
Alder	1.2

Table 2.
Distribution of tree species in the PAR.

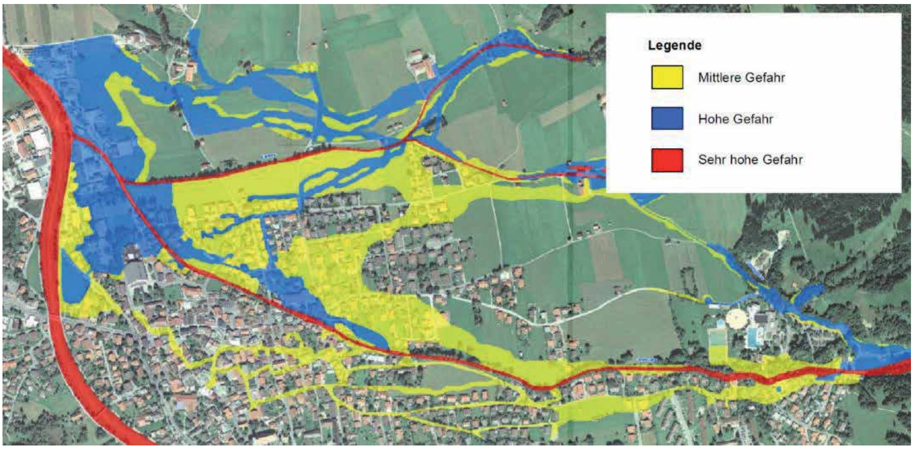


Figure 7.
Hazard zone map of the Große Laine torrent in Oberammergau [12]. Legend: Yellow – Medium risk; blue – High risk; red – Very high risk.

Figure 8.
Looking downstream at a construction site with a drainage channel on the right [12] (firma Hubert Schmid).

Figure 9.
View of the completed barrier structure. A driftwood rake can be seen in the background on the left [12].

- Rockfall and debris flow potential on the Schaffelberg and in the Graswang Valley.

- Sites are mostly geologically unstable and sensitive to erosion.

Sixty percent of the pilot action area in Oberammergau is covered with mostly tall, pure spruce. Game and hunting management is in the hands of forest owners, resulting in excessive red deer/roe deer populations causing calamity areas (stripping damage by red deer (see **Figure 10**)).

Spruce stands have been converted into mixed mountain forests since the invention of the round table (Mountain Forest Forum) by the Mountain Forest Initiative. Some silvicultural measures have been tested in Oberammergau in research projects, such as thinning to stabilise forest stands, planting, reorganisation of hunting grounds, redesignation of forest and pasture areas (see **Figure 11**).

Figure 10.
Stripping damage by red deer [14].

Figure 11.
Growing protective forest [15].

On the other hand, challenges remain in Oberammergau and include the improved involvement of local actors and the integration of the Mountain Forest Panel into the participatory development process of the Ammergau Alps Nature Park.

3. Best practice description

Almost 60% of Bavaria's mountain forests in the Alps are protective forests. These forests are increasingly endangered by climate change. Bavaria has increased its efforts to preserve multifunctional mountain and protective forests with a broad package of measures, as described in the following chapters.

3.1 Mountain Forest initiative (BWO) program

The BWO is a part of a widespread program of the Bavarian state government to combat climate change. According to the Mountain Forests Protocol of the Alpine Convention, the implementation of the BWO is put forward together with concerned stakeholders. Since 2008, the Bavarian state government has financed the BWO with about 2.5 million euros annually. The measures of the BWO are specially designed for private and communal mountain forests, where the size of the single properties is usually very small.

The central parts of the BWO are the so-called BWO projects. These are specially identified areas with an elevated risk of degradation due to climate change. In these areas measures for the maintenance and adaption of forests are established with the input of different forest owners. Examples of such measures are the planting of adapted tree species, tending with the special aim of supporting adapted tree species, natural regeneration, logging with cable crane or building new forest roads (see **Figure 12**) [16].

Local forest authorities plan the individual measures and put them into action together with the forest owners. Bringing together different owners increases efficiency and reduces costs. A project manager of the local forest authority is responsible for the BWO project from planning until completion and is the contact person for forest owners and stakeholders.

In addition, the process of integral planning participation is an important part of the program. Therefore, all concerned persons have the possibility of bringing in their ideas from the beginning of the selection of the project region and during the planning process until the implementation of individual measures. In general, a so-called BWO advisory board is founded for BWO projects. The members of the advisory board differ in each project area. Generally, they consist of politicians, deputies of the forest owners, local authorities and other organisations (e.g. hunters, farmers, conservationists). We regard the BWO advisory board as the central factor of the success of the BWO.

In addition to BWO projects, several other actions are part of the BWO as a program for the adaption of mountain forests to climate change:

- Adapted seed sources: Forest regeneration, whether natural or artificial, is based on the utilisation of forest genetic resources (i.e. seeds). The selection of suitable forest reproductive material has assumed new importance both because trees are long-lived species and because rapid climate change will have an impact on the environmental conditions of trees as they grow and mature.

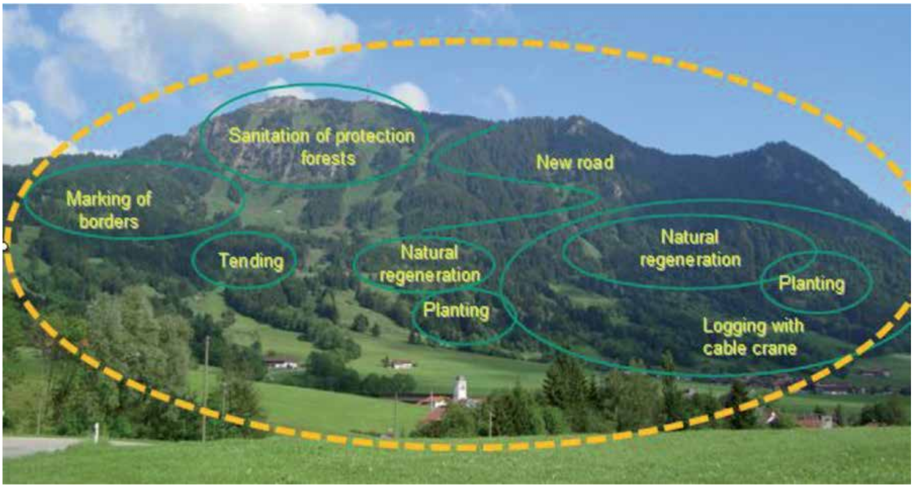


Figure 12.
Schematic picture of a BWO project in the Bavarian Alps.

This is especially pertinent for the Alps because global warming will impact mountain areas in a particularly severe way, posing a very serious threat to Alpine forests. Adaptation to these novel environmental conditions is nearly impossible without genetic diversity. Therefore, the Bavarian Office for Forest Seeding and Planting (ASP) has established a project to identify site-adapted seed stands in the Bavarian Alps and to secure an adequate supply of seeds of high genetic quality.

- Information on mountain forest sites: Whereas there are existing detailed forest site maps for the lowlands of Bavaria, for a long period no such maps existed for the Alpine region. As part of the BWO, together with partners in Austria, the project WINALP – "Forest Information System for the Northern Alps" (www.winalp.info) developed intermediate-scale maps of the potential natural forest vegetation for the Northern Calcareous Alps, which are based on the ecological gradients of temperature, soil reaction and soil moisture. The project was financially supported by the European Fund for Regional Development (EFRE) within the "INTERREG Bayern – Österreich 2007–2013" program.

- Research: Although research findings show that the Alpine region will be increasingly affected by climate change, there are many questions associated with the effects of climate change on forests. Therefore, in the frame of the BWO, Bavaria has also intensified research on the effects of climate change on forests. For example, the INTERREG co-financed projects SICCALP and STRATALP dealt with the effects of loss of humus in a succession of wind-throws in the Northern Calcareous Alps.

With the BWO, Bavaria is increasing its efforts to preserve multifunctional forests in the Alpine region. It is expected that it will help to preserve mountain forests as areas for recreation, biodiversity, wood supply and other ecosystem services for the coming generations [16].

One BWO project is located and being implemented in the GreenRisk4Alps PAR of Oberammergau.

3.2 Stakeholder involvement in the Oberammergau PAR in the framework of the project

Many actors inside and outside the forestry sector intervene in forest management, as societal demands are manifold. Whereas forest-based sectors are interested in meeting the current and future market demands for wood, increasing needs for other ecosystem services in the Alpine Space must be met as well. Only a functioning interaction between the different actors in the Alpine Space will contribute towards the set objective to integrate forests and ecosystem services in risk governance and balance the numerous interests, demands and costs.

As described in deliverable D T2.1.2 "Report GR4A SNA concept" [17], the involvement of stakeholders leads to better solutions through joint learning, i.e. innovations, innovative approaches and measures [18]. The importance of a participatory approach in the planning phase of forestry activities leads to greater public acceptance of policy decisions and provides an inclusive platform for constructive discussion. These aspects are even more important when dealing with forests and their management due to the multitude of conflicting interests and demands related to them [19, 20].

Figure 13.
"Round table" excursion [21].

3.2.1 Identification of the goals of the participatory process

Although the overall framework of the stakeholder involvement might be known, concrete and clear objectives of the participatory process must be clarified at the be-ginning. Besides the technical issues to be discussed during the round tables (see **Figure 13**), other important aspects also have to be considered. These include the following:

- Trust building between

  a. local actors and public officials and

  b. neighbouring municipalities

- Community building: creating shared collective goals

Thus, communication between different interest groups has been fostered continuously.

3.2.2 Identification of actors and stakeholders

Before starting the participatory process, it was necessary to identify the relevant and important stakeholders in the PAR. For the Oberammergau PAR, the following groups are considered to be important for the success of the process:

- Governmental actors / district: regional forest office (government), regional watershed authority, regional nature conservation authority, regional hunting authority

- Ammergauer Alps Nature Park: Nature Park Manager, Tourism Manager

DOI: http://dx.doi.org/10.5772/intechopen.99015

- Environmental NGOs
- Actors of the communities of Oberammergau and Ettal: municipalities of Oberammergau and Ettal, land use actors, hunters, recreational users of the nature park

3.2.3 Actor analysis in the PAR

3.2.3.1 Initial conditions

With respect to Oberammergau and Ettal, there are two municipalities involved. Both municipalities are part of the district of Garmisch-Partenkirchen. Natural hazard management is not a new topic in the area; since 2009, the BWO has encouraged the improvement of the protection function of mountain forests.

For many years, a major topic in Oberammergau has been the torrent & flood management of the Große Laine Torrent and the improvement of protection measures in recent years. Another topic has been the rock fall and debris flow potential at Schaffelberg and the Graswang Valley.

3.2.3.2 Objective

The objective of the actor analysis was the provision of social data to prepare and support the participation process focusing on the development and preservation of a safe and liveable regional Alpine living space in the region. The participation process is expected to enable the intermunicipal implementation of measures in the long run.

3.2.3.3 Approach

During the interviews with selected experienced actors in the PAR (mayors, regional forest officials and nature park officials), the important stakeholders and participants of the round tables are identified in a "snowball-system". The interviews are complemented with data from a literature analysis.

The following questions should be answered during the process:

- Which stakeholders are involved in natural (hazard) management?
- What is the characterisation of each stakeholder (organisation, group or person).
- Which goals are most vigorously pursued?
- What are the concerns regarding (joint) nature (hazard) management?
- With whom do they work together or with whom do they have conflicts?

The main goal of this approach is not a mere scientific exploration but the preparation of the social process in the region. The participants of the GR4Alps round tables should start the process together with a joint project briefing at the first event ("Proactive" rumours must be avoided") [22].

3.2.4 Starting the participatory process

The process started with a kick-off event, which was announced well ahead of time in an invitation letter sent to all identified stakeholders from both municipalities. They were informed about the topics to be discussed to achieve a common understanding of the following process. An external moderator accompanied the process to ensure that it was as productive and constructive as possible and to summarise the results for the participants.

The introductory work with actors from Ettal and Oberammergau led to a common objective: to identify the different types and intensity of use of the natural areas in the municipality and the added value of cooperation.

3.2.5 Expectations of the organisers

With the round tables, the initiators expected that in the short and medium term, existing local knowledge gaps concerning risk management would be closed, the available risk mitigation programs would be improved and the involvement of and exchange between local stakeholders would be fostered by this initiative. Furthermore, the Mountain Forest Panel of the BWO and the participatory development process of the Ammergauer Alps Nature Park would be merged into a visible perceived institution.

4. Conclusion

Due to its location in the Ammergau Alps, Oberammergau has been confronted with the topic of protective forest and protective forest management for years. Not least because of the perpetual challenge of potential flooding of the Große Laine River. Mechanical shoring is of immense importance in this context. However, the use of forest-based support is also of great importance, and the management of the protective forest has played a major role for years. This is also demonstrated by the state-funded Mountain Forest Initiative, which aims to protect mountain forests against climate change by involving multiple stakeholders. This is done most effectively on the ground with so-called round tables, joint excursions, talks and discussions. The GreenRisk4Alps project has now been able to draw on these many years of experience. This experience was complemented by a social network analysis, which identified the goals of the participation process and the actors and stakeholders in order to then target local knowledge gaps on the topic of risk management, improve existing risk reduction programs and promote the involvement of and exchange between local actors through this initiative.

Acknowledgements

We would like to thank Markus Hildebrandt and Felix Miller from the Office of Food, Agriculture and Forestry in Weilheim for their support as reviewers.

Author details

Helena Eisele*, Roland Schreiber and Anne Stöger
LWF, Freising, Germany

*Address all correspondence to: helena.eisele@lwf.bayern.de

References

[1] Bild Ammergauer Alpen: Von Flodur63 - Eigenes Werk, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=83016543

[2] http://www.kulturverein-oberammergau.de/media/images/kulturverein_oberammergau-large.jpg

[3] https://i.ytimg.com/vi/fX0ot1jZEmY/maxresdefault.jpg

[4] Geschichte des Waldes in Bayern - StMELF

[5] Wald in Zahlen - Fakten über Bayerns Wälder - StMELF

[6] Schutzwald - Der Wald bewahrt vor Naturgefahren - StMELF (bayern.de)

[7] https://www.anl.bayern.de/fachinformationen/beweidung/6_2_wald.htm

[8] https://www.waldwissen.net/de/waldwirtschaft/nebennutzung/agrarische-waldnutzung/geschickter-umgang-mit-der-waldweide

[9] https://www.anl.bayern.de/fachinformationen/beweidung/pic/6_2_1_fleckvieh_550.jpg

[10] https://almen-und-berge.de/pics/wanderungen/Waldlichtung%20 20200913-1373.jpg

[11] https://www.naturpark-ammergauer-alpen.de/Waldlandschaft/Waldvielfalt

[12] Wasserwirtschaftsamt Weilheim, Alpine Naturgefahren, Hochwassserschutz Oberammergau - Wasserwirtschaftsamt Weilheim (bayern.de)

[13] https://www.merkur.de/lokales/garmisch-partenkirchen/oberammergau-ort29187/arbeiten-zum-hochwasserschutz-an-grossen-laine-in-oberammergau-sollen-im-herbst-2021-starten-13834955.html

[14] na.hessen.de

[15] Private picture by Felix Miller

[16] Die Bergwaldoffensive (bayern.de)

[17] d-t2.1.2-report-gr4a-sna_concept_20190327-1-.pdf (alpine-space.eu)

[18] Carayannis, E. G., Campbell, D. F. J. 2010. Triple Helix, Quadruple Helix and Quintuple Helix and How Do Knowledge, Innovation, and Environment Relate to Each Other? International Journal of Social Ecology and Sustainable Development, 1(1), 41-69.

[19] Blanc, S., Lingua, F., Bioglio, L., Pensa, R., Brun, F., Mosso, A., 2018. Implementing Participatory Processes in Forestry Training Using Social Network Analysis Techniques. Forests 9, 463. doi:10.3390/f9080463

[20] Kleinschmit, D., Pülzl, H., Secco, L., Sergent, A., Wallin, I., 2018. Orchestration in political processes: Involvement of experts, citizens, and participatory professionals in forest policy making. Forest Policy and Economics, Orchestrating forest policy making: Involvement of scientists and stakeholders in political processes 89, 4-15. doi:10.1016/j.forpol.2017.12.011

[21] https://www.allgaeuer-zeitung.de/cms_media/module_img/2477/1238883_1_azarticledetailteaser_Copy_of_Gruenten_Bergwald074a_5fb405160edab.jpg Logo BWO: https://www.stmelf.bayern.de/wald/publikationen/198878/index.php

[22] Aurenhammer, P., 2015: Network analysis and actor-centred approach - A critical review. Forest Policy and Economics 68 (2016) 30-38

Chapter 3

Val Ferret Pilot Action Region: Grandes Jorasses Glaciers - An Open-Air Laboratory for the Development of Close-Range Remote Sensing Monitoring Systems

Paolo Perret, Jean Pierre Fosson, Luca Mondardini and Valerio Segor

Abstract

The Val Ferret valley (Courmayeur, Aosta Valley, Italy) was included as a Pilot Action Region (PAR) of the GreenRisk4Alps project since it is both a famous tourist location and a high-risk area for all types of mass movement processes. Typical natural hazards that endanger this PAR are debris flows and avalanches, sometimes connected to ice collapses from the glaciers of the Mont Blanc massif. Thanks to the steep sides of the valley and widespread alluvial channels, these events can reach the valley floor, where public roads, villages and touristic attractions are located. This article presents the main challenges of natural hazard management in the Val Ferret PAR, as well as the role of forestry and protective forests in the Aosta Valley Autonomous Region. As an example of good practice, the monitoring systems of the Planpincieux and Grandes Jorasses glaciers are presented. Recently, these glaciers have become an open-air laboratory for glacial monitoring techniques. Many close-range surveys have been conducted here, and a permanent network of monitoring systems that measure the surface deformation of the glaciers is currently active.

Keywords: Val Ferret, protective forest, Mont Blanc, Aosta Valley, monitoring, glacial hazards, remote sensing

1. Introduction

Courmayeur (1,224 m asl) is a small mountain town located in the Aosta Valley Autonomous Region, in northwestern Italy. It is a famous tourist destination whose fame and history are largely related to the presence of the Mont Blanc massif, which is one of the most renowned attractions in the Alps. Two glacial valleys, the Val Veny to the west and the Val Ferret to the east, run parallel to the massif. Every year, these valleys become the holiday destination of thousands of tourists (more than 350,000 in 2019), and amongst them are many climbers and hikers who are drawn to this

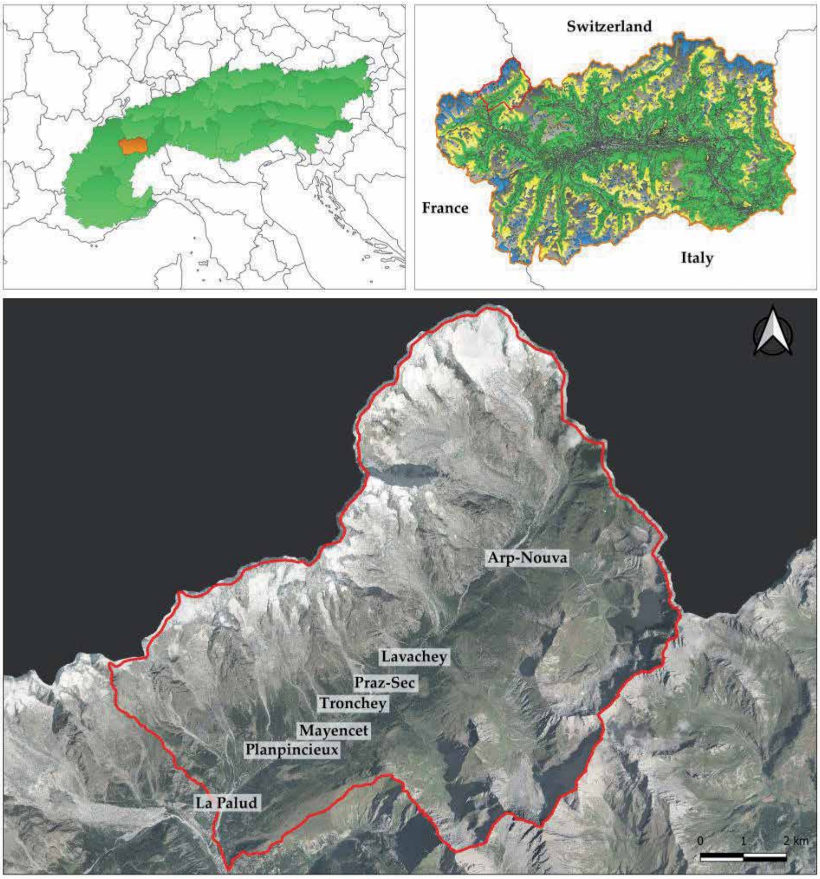


Figure 1.
The Aosta Valley Autonomous Region (northwestern Italy) and Val Ferret PAR in the municipality of Courmayeur.

area for its majestic landscapes. Courmayeur is a typical example of an Alpine location whose population can easily triple due to the presence of tourists. In addition, this area is home to the Mont Blanc Tunnel, which is part of a crucial roadway linking Italy and the rest of Europe, as well as to the new Skyway Monte Bianco cable car, which crosses the Mont Blanc massif and connects Courmayeur to Chamonix.

Over the last two decades, in many alpine areas, the effects of global warming have increased the frequency of numerous types of gravitational slope instabilities (i.e. rockfalls, ice avalanches and debris flows), especially at high elevations, mainly due to glacial and permafrost degradation or extreme rainfall events. The Val Ferret PAR (**Figure 1**) has been affected by all these hazards.

2. PAR description

2.1 General data

The Aosta Valley Autonomous Region is a wide mountain basin consisting of a long main valley (100 km), corresponding to the Dora Baltea hydrographic basin and thirty major tributary valleys.

This area has a temperate oceanic climate, which is transitional to hemi-continental and lacks a dry season. The mean annual temperature varies greatly in the different areas of the valley, mostly because of the considerable altitude differences. For example, the annual average temperature ranges between +10 and +12°C at 500 m, but it is around −7.5°C at 1,200 m [1].

The region has an alpine pluviometric regime, with two rainfall maxima in the middle seasons and two minima during summer and winter. In the central sector of the region, the maximum rainfall occurs in autumn, while the minimum rainfall occurs in summer. The central area of the Aosta Valley is one of the driest sites in the Alps (550 mm/y). The mean annual precipitation is about 950 mm and increases with altitude and towards the watersheds, with the highest contribution on the Great St Bernard Pass (2,476 m) on the northern watershed, which averages 2,000 mm/y (data set since 1817) [1].

The topographic elevation ranges from 400 m, where the valley mouth merges into the Po Plain, to the 4,810 m summit of Mont Blanc, the highest peak in the European Alps. From a geological point of view, the Aosta Valley region belongs to the axial zone of the Western Alps, an imbricated stack of continental and oceanic metamorphic complexes [2].

A very high regional mean altitude of around 2,100 m guarantees the presence of numerous glaciers (precisely, 175), which, according to the Aosta Valley Glacier Inventory (updated in 2019), have an overall extent of approximately 120 km^2, or 3.6% of the basin [3]. Amongst the morphodynamic agents in mountain environments, glaciers play the most important role, by modeling both erosional and depositional landforms as well as indirectly influencing slope dynamics.

Watercourses represent another crucial geomorphic agent, largely affecting the Aosta Valley's landscape through the progressive erosional deepening of valleys. Evident signs of the constant shaping and reshaping of this territory are the widespread alluvial and mixed fans, mainly created by debris-flow phenomena. Finally, yet importantly, gravitational phenomena also contribute to the evolution of the Aosta Valley's geomorphology.

2.2 Val Ferret

Located at the foot of the Mont Blanc massif, the longitudinal profile of the Val Ferret valley progresses in a succession of steps, a distinctive trait of a glacial valley (**Figure 2**), from the village of La Palud to the Col Ferret. Small settlements populate the valley floor, and even if they are not permanently inhabited, they are renowned summer and winter holiday destinations where tourists come to engage in cross-country and backcountry skiing during the winter season and alpinism, mountain biking and trekking in summer. Thus, many economic activities, such as hotels, restaurants and campsites, flourish in this valley.

From a naturalistic point of view, Val Ferret is a Special Protection Area (SPA) [4] that is home to numerous species of nesting birds. Along with Mont Blanc's glacial environments, the Talweg of the Val Ferret valley, an important reservoir for the conservation of hygrophilous plants, is also listed as a Site of Community Importance (SCI) [5].

Larch and pine forests cover both sides of Val Ferret up to an altitude of 1,750 m (on average). The right bank has steep rocky sides that descend from the peaks of the Mont Blanc range to the valley floor at 1,400 m. This incredible drop of approximately 2,600 m is the perfect terrain for avalanches and debris flows. In fact, these natural hazards usually originate well above the timberline and are often associated with rockfalls and extreme precipitation events or, sometimes, to the partial collapses of glacier fronts (i.e. Grandes Jorasses and Planpincieux glaciers). These events flow over existing stream incisions, and their frequency effectively precludes the presence of forests in these areas. The left bank, facing northwest, has more continuous forest cover, up to 2,000 m. On this side of the valley, the forest provides

Figure 2.
Mont Blanc, with Val Veny on the left and Val Ferret on the right (photo: FMS).

better protection from natural hazards, but despite the milder slopes, avalanche phenomena can still occur.

2.3 The main problems relating to natural hazards in the Val Ferret PAR

2.3.1 Winter management

During the winter season, the Val Ferret road is open up to the village of Planpincieux, which is located at the entrance of the valley. From this little town, cross-country ski trails extend to the village of Lavachey, halfway up the valley. The end of Val Ferret is accessible only with ski mountaineering equipment. During the cold season, the valley is a famous tourist destination, even though the high frequency of snow avalanches make access to the valley quite difficult (**Figure 3**).

In mountain areas, local avalanche risk management has always been of crucial importance. In addition to being a complicated task, it requires excellent knowledge of the terrain and avalanche sites, as well as a deep understanding of the seasonal snow cover and the alpine micro-meteorology. For these reasons, the Aosta Valley Autonomous Region has officially established the Local Avalanche Commission (CLV – Commissione Locale Valanghe) [6].

Born to support the decision-making process of avalanche risk management in municipal areas, CLVs have the task of carrying out forecasting activities and assessing the snow and the meteorological conditions and the stability state of the snow masses in the designated areas. It also acts as a body of vigilance, alert and intervention in situations of risk and emergency management, in order to ensure, at the local level, the control of dangerous situations in its area of competence. CLVs also provide a civil protection technical consultative opinion to the mayor.

Regarding the Val Ferret PAR, in the event of avalanche danger, the mayor issues an order for the permanent closure of the municipal road of the Val Ferret valley and, if there is high risk to inhabited areas, the mayor can order the evacuation of the whole valley. The closure is generally preceded by a controlled evacuation plan, according to an intervention regulation as part of the Municipal Civil Protection Plan.

Figure 3.
Aerial view of avalanches between Tête de Bernarde and Mont de La Saxe with the hamlet of Mayencet in the center (photo: FMS).

Avalanche sites	**80**
Total avalanche events	767
Avalanche events causing damage to forest cover	66
Avalanche events involving people	17
Avalanche events involving civil buildings	45
Avalanche events affecting the municipal road system	60
Avalanche events affecting the state road system	17

Table 1.
Avalanche sites and avalanche events in Val Ferret (data: 2020 update) [7].

Snow avalanche data for the Val Ferret PAR are obtained from the Snow Avalanche Inventory of the Aosta Valley Autonomous Region [7]. This database has been updated every winter since the early 1970s and since 2005, it has been fully available online. **Table 1** summarizes some data regarding Val Ferret.

2.3.2 Summer management

In summer Val Ferret is entirely accessible. The municipal road is open up to the hamlet of Arp-Nouva, and side paths are available for mountain bikers and trekkers. On the valley floor there are numerous tourist facilities, such as hotels, restaurants, campsites and a golf course. The valley is crossed by numerous hiking paths, the most famous of which is the Tour du Mont Blanc, a 170 km hiking trail that surrounds the Mont Blanc massif and passes through parts of Italy (Aosta Valley), France (Haute-Savoie and Savoie) and Switzerland (Valais). Every year, this trail becomes the stage of the Ultra-Trail du Mont Blanc, a world-renowned trail running race with up to 10,000 participants.

Given the large number of visitors throughout the whole summer season, risk management is more complex compared to the winter period. Regarding hydrogeological instability, the natural hazards that endanger the valley during summer are more rare and harder to forecast (i.e. debris flows) in comparison to the snow avalanches of the winter season. Alerting abilities are thus less developed, especially because the event precursors are not as evident as those in winter hazards. The Functional Center of the Aosta Valley Autonomous Region manages the meteorological alert system. In Italy, functional centers have been established in compliance with a decree of the President of the Council of Ministers [8] in 1999, following a tragic event in the year before, in an effort to better the civil protection system linked to weather-related hazards.

This legislative act established, for the first time in Italy, an integrated monitoring network, enabling the diffusion of hydro-pluviometric data throughout the whole country, while integrating them in a civil protection system designed to rapidly alert the population in case of a weather-related hazard.

In this context, the different functional centers create a tight net of forecasting, monitoring and surveillance bodies and provide technical support to the competent agencies dealing with risk management and civil protection.

The principal tool used by the functional centers to alert the different agencies and the municipalities is the Bulletin of Critical Issues. This concise report describes, with a progressive color scale, the increasing danger and the expected scenarios according to the forecasted weather and hydrological conditions.

In the Aosta Valley's Bulletin of Critical Issues, the regional territory is subdivided into four areas, for which a risk forecast is presented, in order to activate only the municipalities, authorities and emergency management bodies actually involved in the forecasted event. The municipalities included in the alert areas are required to activate the operational phases defined within the Municipal Civil Protection Plan. The data acquired regarding landslides, rockfalls, floods and debris flows affecting the regional territory are reported in a specific inventory called the "Catasto Dissesti" [9].

During the summer season, the most influential gravitational processes in the Val Ferret PAR are linked to water-related hazards, more precisely to floods and debris flows. These phenomena occasionally reach the valley floor, endangering crowded areas, such as houses, hiking trails and the main road (**Figure 4**).

Streams and river basins that can potentially be affected by these phenomena are very numerous; there are hundreds in the entire regional territory and at least twenty in Val Ferret alone.

In addition, glacier-related hazards have to be considered as well in the risk assessment analysis of the Val Ferret PAR. In fact, the current risk management plan already considers ice avalanches originating from the Mont Blanc massif as a potential threat to the valley floor.

Figure 4.
Debris flow deposit in Val Ferret and clearing operations of timber and debris from the stream bed (photo: FMS).

This subject is addressed in depth in Chapter 3, which is dedicated to the best practices carried out in Val Ferret, such as the open-air laboratory of the Grandes Jorasses glaciers.

2.4 Forest and forestry

2.4.1 Forest management in the Aosta Valley Autonomous Region

About 30% of the total area of the Aosta Valley Autonomous Region is wooded, amounting to approximately 97,970 hectares [10], of which 38,207 hectares (39% of the total forest area) is public property and 59,763 hectares (61% of the total forest area) is private property.

The forestation index might seem low, especially when compared with the average of other Alpine regions. However, the surface morphology and characteristics of the Aosta Valley have to be taken into account. With an average altitude above 2,100 m, an entirely mountainous territory and the considerable presence of glacial and periglacial environments, the area available to forests is limited. In fact, excluding these barren areas would increase the potential surface area of forest to around 195,000 hectares, and would increase the forestation index from 30 to 45%. Therefore, the per capita area of forest in the Aosta Valley is 7,500 m^2, compared to the Italian average of 1,600 m^2. This clearly shows that the current wooded area is quantitatively a significant part of the regional territory. Potentially, this area can still see further expansion, however, and the forest has already regained areas where, in the last three decades, land-use has changed. The constant increase recorded for about a century (**Table 2**) is mainly the result of the decline of agriculture work in mountain areas, lower livestock pressure inside and on the edge of the forest, and reforestation carried out since the first post-war period.

Since the 1960s, the regional administration has implemented regional policies aimed at expanding knowledge about its forest heritage. An important planning instrument is the "Economic Plans of Forestry and Pastoral Assets", which provides a subdivision of property into separate economic classes. The different classes are based on the prevailing functions that wooded areas are required to satisfy: productive, protective, touristic-recreational, and naturalistic. The economic plans define a set of rules that establish the extent of the interventions needed for conservation purposes and the strengthening of the forest.

These regulatory plans for the region, municipalities and consortiums have been constantly updated for 50 years. However, in 2010, due to financial reasons, the review was temporarily interrupted. Today, opportunities to complete the economic plan review, as well as to develop the agricultural and forestry sectors, arise mainly through the EU Rural Development Plan. As a matter of fact, The

Year	Area (hectares)
1962	66,000
1974	75,000
1996	86,550
1999	89,539
2011	97,970

Table 2.
Variation in the forested areas of the Aosta Valley in the past years [11].

Rural Development Program 2014–2020 is currently operational in the Aosta Valley Autonomous Region, carrying out measures to guarantee forest conservation and to increase the potential of the forest-wood supply chain. The forestry plan for the Municipality of Courmayeur and the Val Ferret PAR is currently in place and valid until 2022.

The forest typology of the Aosta Valley Autonomous Region has been analyzed since 1998 in the context of various Interreg projects that have led to the creation of the publication "I tipi forestali della Valle d'Aosta" [12], which identifies 15 forest categories with 49 forest types. As part of the European Alcotra Renerfor Project, in 2011, a new forest map was created [10]. This inventory identified 21 forest categories (14 broad-leaved, 6 conifer and one mixed) and 95 forest types. High forests account for 68% of the wooded area as the prevailing silvicultural system, while coppices are limited to about 15% of the area. Conifers are certainly the most represented species, exceeding 90% in high forests. In particular, in order of occurrence, there are larch, spruce, Scots pine, stone pine and silver fir. Less common are broad-leaved trees, of which less than 10% are in high forest systems. The majority of broad-leaved trees are in coppice populations, generally old growth, and in spontaneous high forest successions. The most represented species are chestnut, downy oak, poplar, ash, cherry, rowan, sycamore maple and beech.

In regard to the Val Ferret PAR, **Table 3** shows the forest types according to the technical report of European Environmental Agency No 9/2006 "European forest types – Categories and types for sustainable forest management reporting and policy" [13].

The subdivision into prevalent functional destinations, with the exclusion of unmanaged forests, is linked to the different conditions of fertility, location and accessibility of each specific forested area. In the Aosta Valley, the main role of forests is protection from natural hazards, even if partially combined with timber production. In fact, it appears that about 80% of the forests of the Aosta Valley perform an irreplaceable protective function against rockfalls, avalanches, debris flows, floods and soil erosion.

2.4.2 Protective forests in the Aosta Valley Autonomous Region

With regard to forests protecting against natural hazards, a recent Italian legislative decree [14] defines "forest of direct protection" as wooded area that, thanks to its peculiar position, performs the function of the direct protection

CODE	Forest type	%
3.1	Subalpine larch-arolla pine and dwarf pine forest	71
3.2	Subalpine and montane spruce and montane mixed spruce-silver fir forest	10
8.4	Portuguese oak and Mirbeck's oak Iberian forest	3
11.2	Alder swamp forest	13
12.1	Riparian forest	< 1
12.2	Fluvial forest	1
13.4	Southern boreal birch forest	2

Table 3.
Val Ferret forest types according to European environmental agency No 9/2006 "European forest types – Categories and types for sustainable forest management reporting and policy" [13].

of people, goods and infrastructure from natural hazards such as avalanches, rockfall, landslides and debris flows, preventing the occurrence of such events or mitigating their effect.

In 2006, a publication containing guidelines for the management of protective forests [11] was published by the Aosta Valley Autonomous Region together with the Piedmont Region. This study, starting from the exchange of experiences between foresters in the Western Alps, provides the necessary silvicultural path needed to enable a specific forest to perform its protective role in a lasting and effective manner. These suggestions were defined considering the main natural hazards characterizing the area. However, the frequency and intensity of natural hazards seem to change, particularly under the effect of climate change. In fact, in response to shifts in temperature and precipitation, many climate models predict an increase in the frequency of extreme weather events (i.e. storms and fires), an impact on the population dynamics of insects, an alteration of ecological niches (species replacement), and an increase in sensitivity to pathogens.

The collaboration between the forest departments of the Piedmont and Aosta Valley regions, has been extended thanks to the Alcotra 2007–2013 Project [15]. This cross-border project between Italy (Aosta Valley and Piedmont regions) and Switzerland (Canton du Valais) resulted in, amongst other things, the publication of cognitive complements on the management of protective forests. The research and experience gained in these five years have been summarized in two publications [16, 17], which expand on the first one [11] through the deepening of the interactions between natural hazards and the stability of protective forest.

In the Aosta Valley, approximately 44,000 hectares of forest plays a "direct object protection" role, equivalent to 45% of the total forest coverage (**Figure 5**). This ratio is even greater in the Val Ferret PAR, despite only 10% of its territory being covered by forests.

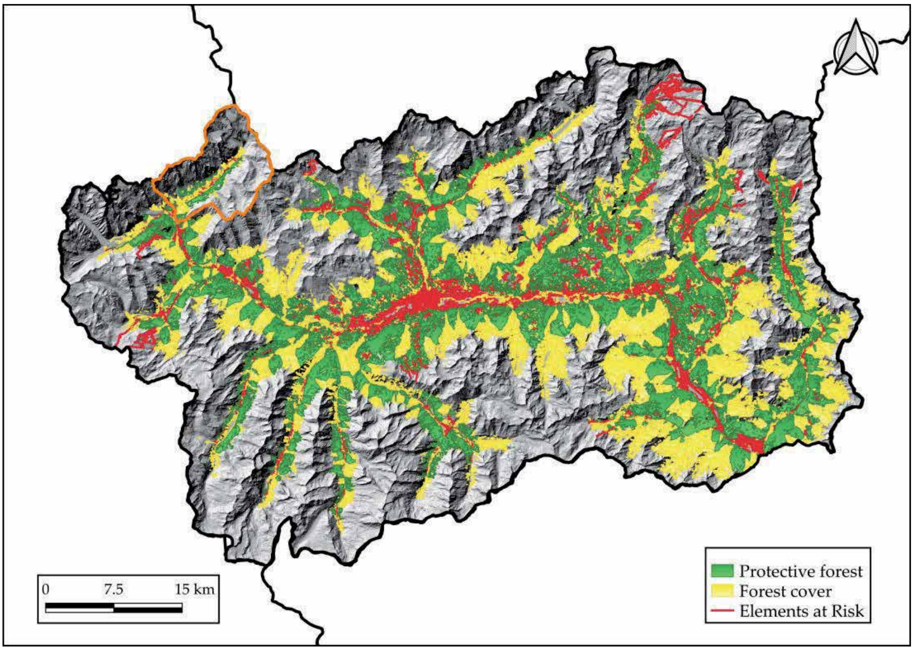


Figure 5.
Map of protective forests in the Aosta Valley Autonomous Region (data from [15]).

3. Grandes Jorasses Glaciers Open-Air Laboratory for the Development of Close-Range Remote Sensing Monitoring Systems: an example of good practice in the Val Ferret PAR

Research on Mont Blanc has always been an interdisciplinary effort, with numerous national and international projects built upon high mountain observation, mass balance measurement and glacial and periglacial environment monitoring. It is of crucial importance to study glaciers and their evolution, especially during this period of rapid change in which global warming is expected to drastically reduce glaciated areas and increase their instability. Moreover, in most mountainous regions of the world and especially in densely populated areas such as the European Alps, glacier-related hazards are a threat to lives and sustainable development. A thorough understanding of glacier dynamics is essential for glacier risk management, enabling the development of mitigation strategies against climate change cryosphere alteration. In order to attain this objective, scientific observation, data acquisition and analysis are fundamental, but the severe mountain environment where most glaciers are located, makes the survey activities very complex. Accessing these impervious areas implies high economic costs as well as potential risks for technicians and scientists. However, the recent development of remote sensing systems allows investigations to be carried out with minimal risks, enabling the measurement of many parameters without even accessing the glaciers, thus representing in many cases the most suitable monitoring solution.

Spaceborne earth observation techniques enable, for example, the extraction of information such as glacier topography, albedo, equilibrium line, mass balance or flow velocity. However, the spatial and temporal resolution of satellite data is not yet effective enough to the measure fast processes (e.g. sub-daily movements - cm/day), and often close-range remote sensing is the best monitoring solution for glacier stability evaluation and risk assessment. The effectiveness of these techniques has been successfully tested and used for several years in the Val Ferret PAR for the polythermal glacial complex of the Grandes Jorasses and Planpincieux glaciers (**Figure 6**). These glaciers, located on the Italian side of the Grandes Jorasses peak, have a southeastern orientation, and their elevation ranges from 2,600 m to 4,200 m. The research and survey activities that have been conducted here since 2009 are arguably amongst the most intensive in the European Alps. Today, this area is an open-air laboratory for close-range remote sensing monitoring systems focused on developing new monitoring solutions and advanced research activities.

3.1 Planpincieux Glacier

Several documented ice avalanches and glacial floods (1929, 1952, 1982, 2005, 2017), which, in some cases, have threatened the village of Planpincieux and damaged the municipal road, have been linked to the Planpincieux Glacier (**Figure 7**) [18].

The Planpincieux Glacier's accumulation area consists of two separate glacial cirques, the largest of which is located at the base of the Grandes Jorasses peak.

The two cirques converge into a singular basin area that feeds the two lower lobes, whose fronts are located at an altitude of about 2,600 m. The ice flow is channeled mainly into the right lobe, which, dynamically, is a very active area, with an average slope of 32° and has a strongly crevassed morphology.

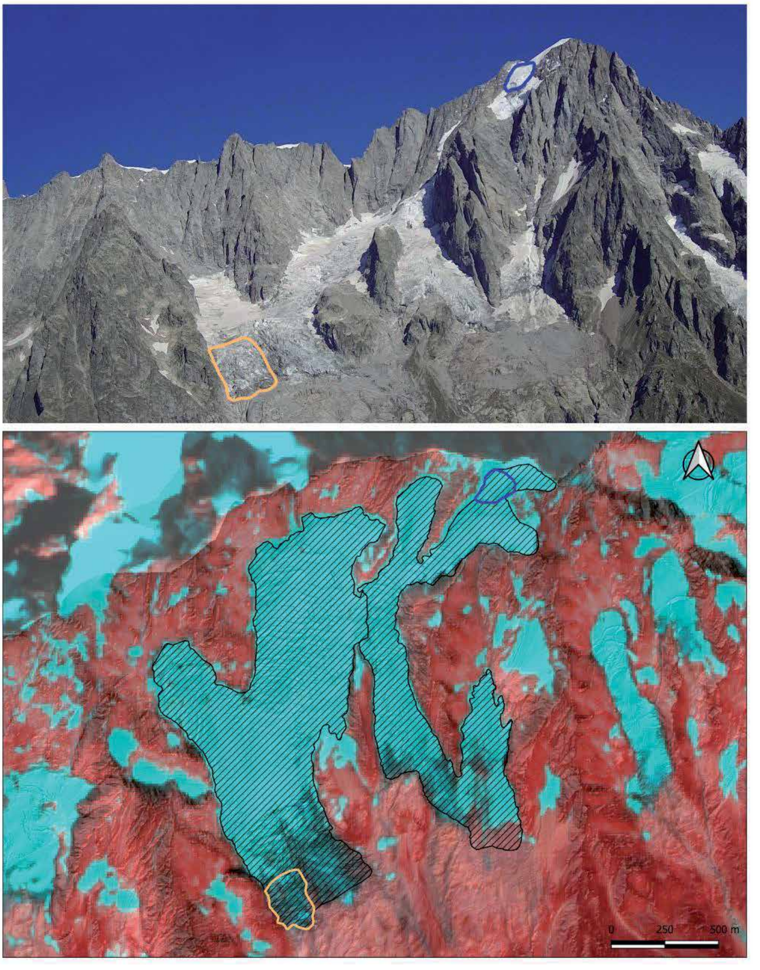


Figure 6.
Overview of the Planpincieux and Grandes Jorasses glaciers. Orange and blue areas indicate the Montitaz lobe and the Whymper Serac, respectively.

Figure 7.
Aerial view of the Planpincieux Glacier and Montitaz stream (photo: FMS).

The right lobe, characterized by a vertical front wall that reaches heights of up to 30 meters, leads into the steep Montitaz stream (**Figure 7**), where numerous ice collapses occur, mainly during the summer season.

Since 2011, when a large crevasse opened in the lower part of the right lobe, the glacier has been closely monitored using different technologies and methodologies. During this 10-year study period, speed increases of the entire right side of the glacier tongue have been recorded (up to 2 m/day at the glacier front), especially during the summer seasons. This fast-flowing motion is mainly induced by the flow of water present between the bedrock and the ice.

In the summer of 2019, a volume of about 300,000 m^3 showed multiple signs of possible collapse. Phases of marked accelerations and decelerations of the ice flow, a subglacial drainage network distributed under most of the tongue, and a state of pervasive fracturation of the ice were all conditions that were present at the Planpincieux front. These unstable conditions could lead to the sudden detachment of the entire portion of the glacier, which, because it is hanging over a steep slope, could generate a large ice avalanche that could potentially reach the valley floor. These same conditions have been recorded in all known cases of temperate glaciers destabilizations: Le Tour – 1949 [19], Allalin – 1965, Fee Glacier – 2009, and Allalin – 2000 [20].

3.1.1 Time-lapse camera applications

The Planpincieux Glacier is monitored by two time-lapse cameras with different focal lengths placed on the opposite side of the Val Ferret valley, 3,800 m from the glacier [21]. The monitoring station is equipped with two solar panels, and an electric cell for power supply and is remotely controlled by a single-board computer connected to a server. A robotic webcam was installed in 2018 to survey the functionality of the station. This monitoring system has been active since 2013 and acquires images at hourly frequency, enabling the accurate identification of the different phenomena affecting the glacier over time. Between 2013 and 2020, this camera system collected more than 40,000 images, contributing to one of the longest continuous series of hourly images in the European Alps.

The surface kinematics of the right lobe of the Planpincieux Glacier has been deeply investigated with image analysis of eight years of time-lapse monitoring [18 21]. The images are processed with a digital image correlation technique to estimate surface ice flow velocities (**Figure 8**).

The ice flow pattern is often composed of distinct kinematic domains, especially during summer. Observation of this phenomenon may indicate the action of high strain rates localized in areas where large crevasses appear.

The behavior of the glacier snout is noteworthy because it reveals the occurrence of a few speed-up periods per year, which can end in significant ice collapses.

3.1.2 Terrestrial radar interferometry applications

The Planpincieux Glacier is likely one of the few glaciers for which terrestrial radar interferometry investigations have been carried out using four different radar models [18], namely: GPRI™ (Gamma Remote Sensing), IBIS-L™ (IDS GeoRadar), FastGBSAR-S™ (MetaSensing) and LiSALab™ GbInSAR (Ellegi).

The surface kinematics of the glaciers was surveyed in five campaigns, in 2013, 2014, 2015, 2016 and 2019. The first two campaigns were conducted using the GPRI™ real-aperture radar (RAR), which surveyed the glacier from both the valley floor and the valley ridge opposite to the glacier. Both campaigns lasted for two days and were able to detect the surface displacement of the glacier tongue. For the following surveys, synthetic aperture radars (GB-SAR) were used.

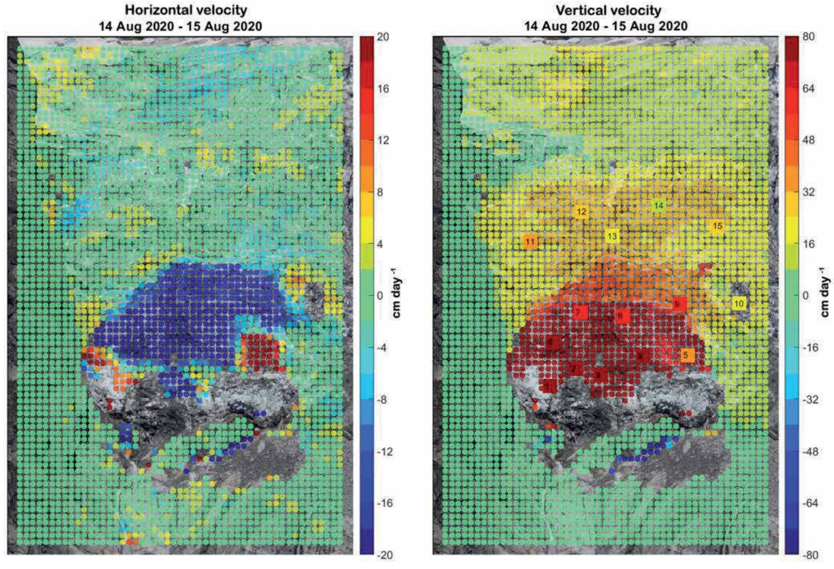


Figure 8.
Digital image correlation of the right anterior lobe of the Planpincieux Glacier. The displacement difference in the frontal area of the glacier, below the large crevasse, is clearly visible.

Thanks to the 2015 campaign, which lasted for a longer period compared to the previous ones, it was possible to distinguish the different kinematic domains of the Montitaz Lobe, although the meteorological conditions were severe, and the radar acquisitions were affected by a strong atmospheric phase screen.

In order to minimize the atmospheric disturbance, FastGBSAR-S™ measurements with an acquisition frequency of 10 seconds, were carried out in 2016. The last

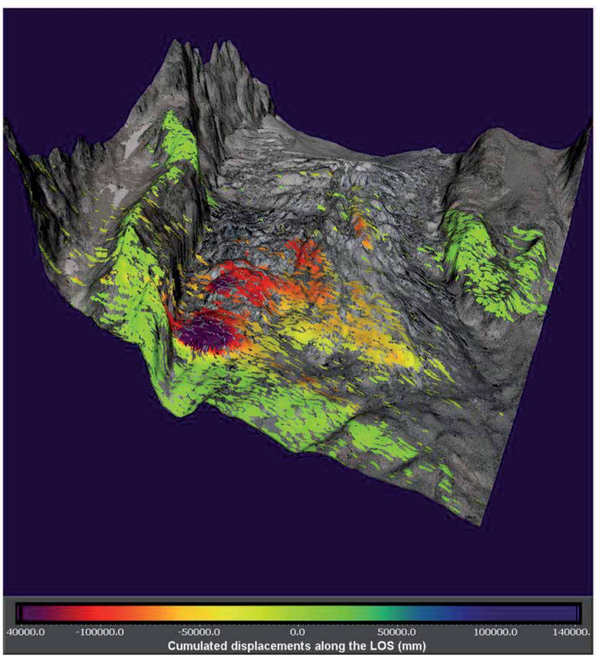


Figure 9.
Cumulated displacement measured by the LiSALab™ GBInSAR from December 2019 to march 2021.

investigation (LiSALab™ GBInSAR) began at the end of September 2019 for civil protection purposes (**Figure 9**). This campaign, which was still active during the writing of this article, is by far the longest, allowing for a dataset of almost two years.

During the Planpincieux Glacier 's most active phases, velocity displacements up to 200 cm/day were recorded on the right lobe, while movements on the left lobe never exceeded 20 cm per day. This separation and difference in surface velocities occurs during the summer season in particular.

3.1.3 Doppler radar applications

In 2020, an AVYX™ Doppler radar (Geopraevent) was installed for real-time detection of ice avalanches from the Planpincieux Glacier (**Figure 10**). After the calibration phase and numerous simulations, the alert system went into operation at the beginning of July 2020. This system includes automatic road closures upon avalanche detection in the defined "closure zone". The road is automatically re-opened if the avalanche does not reach the "danger zone", which is a specific area at the bottom of the slope visible from the radar location.

The avalanche radar system placed in Planpincieux detected 103 avalanche events between July and December 2020. Of these, 75 were detected within, or at the border of, the closure zone, which led to the closure of the road. The radar further detected 28 events outside the closure zone which did not lead to a road closure.

3.1.4 Hydrometer applications

In the summer of 2020, a water measurement system was installed in the Montitaz stream, at the end of the right lobe of the Planpincieux Glacier. This data could be useful for eventually identifying water pockets retained by the glacial body.

This system has been tested throughout the whole summer season but snow and ice deposition into the Montitaz channel, from glacier ice collapses, have made these data somewhat unreliable.

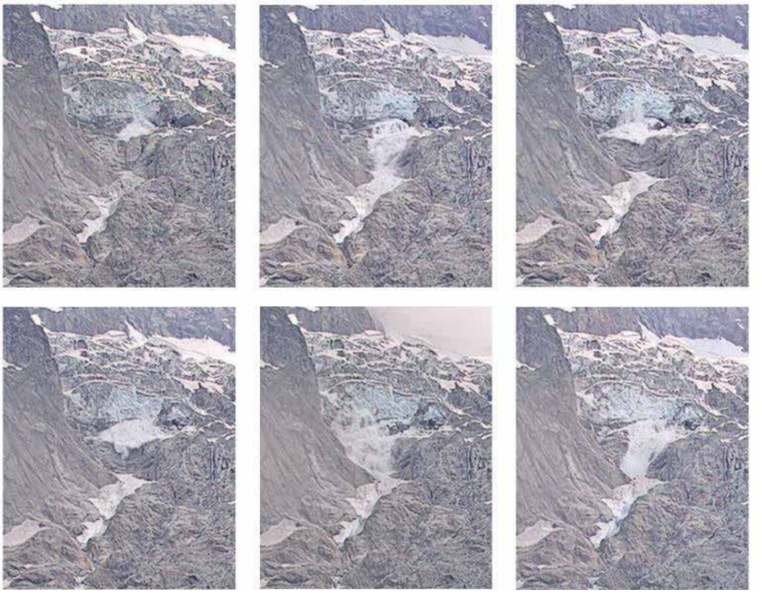


Figure 10.
Consecutive Doppler radar ice collapse detections from the Planpincieux Glacier (photo: Geopraevent AG).

3.2 Whymper Serac of the Grandes Jorasses Glacier

The south face of the Grandes Jorasses peak contains two steep glacial cirques, which form the accumulation zone of the Grandes Jorasses Glacier. The Whymper Serac, whose front is located at 3,800 m, forms the left cirque (**Figure 11**) and is defined as an unbalanced cold hanging glacier.

When hanging glaciers are entirely located above equilibrium-line altitude, ice avalanching becomes the dominant form of glacial ablation. Morphological evidence and historical data indicate, in fact, that the Whymper Serac is progressively increasing in volume, reaching unstable geometries that are subject to recurrent breakoffs. The time between these collapse events ranges from a few years to more than a decade.

Therefore, a collapse can also occur during the cold season, when it might easily trigger a large snow avalanche that could seriously threaten the buildings and the road located on the valley floor. Four collapse events have been well documented so far: August 1993, June 1998 [22] (**Figure 12**), September 2014 [23] and November 2020.

Despite the absence of fresh snow and the limited dimension of the avalanche triggered by the 1993 event, eight mountaineers that were climbing in the area lost their lives.

3.2.1 Time-lapse camera applications

Since 2010, the Whymper Serac has been continuously monitored by a time-lapse camera placed on the Skyway Monte Bianco cable car station platform at Pointe Helbronner. Since 2019, digital image correlation has been applied to the images of the Whymper Serac in order to measure the surface displacement. However, due to the high brightness, low color contrast and smooth texture of the scene, measuring the ice flow is more difficult than for the Planpincieux Glacier. This requires a robust outlier correction method to remove the artifacts present in the displacement maps.

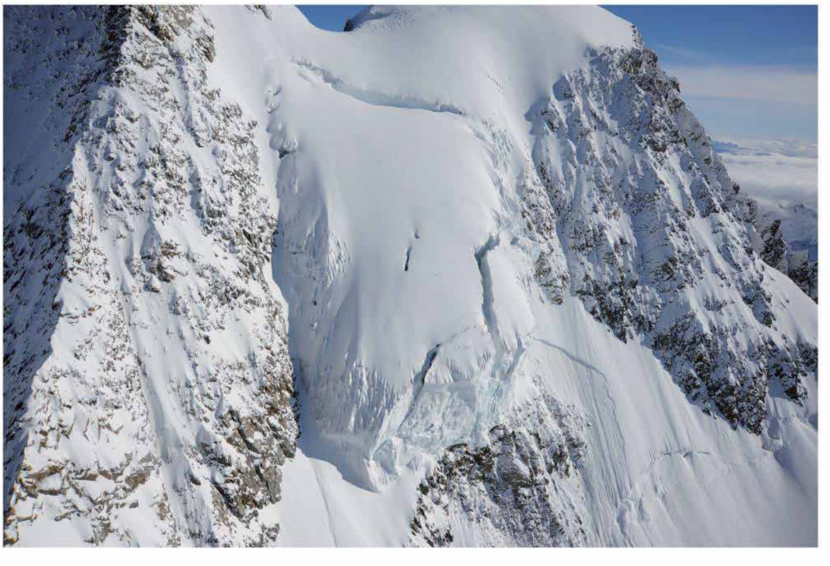


Figure 11.
Aerial view of the Whymper Serac of the Grandes Jorasses Glacier (photo: FMS).

Figure 12.
Aerial view of the deposit of the 1998 collapse. The ice and snow mass stopped a few hundred meters from the municipal road and houses of Val Ferret (photo: Lorenzo Cosson).

3.2.2 Robotic total station applications

Surface velocity measurements of the Whymper Serac from a robotic total station installed in front of the village of Planpincieux 4,800 m from the glacier have been continuously taken since 2010 [22, 23]. The survey is conducted with a Leica TM30 that operates automatically on target recognition mode. The reflector network is composed of several prisms installed on poles inserted into the serac's unstable portions (**Figure 13**), while a few prisms placed in the surrounding bedrock serve as reference points. A complete acquisition of the entire network is conducted every two hours, tracing the position of the prisms and enabling the analysis of surface displacements.

Figure 13.
One of the prisms positioned on the Whymper Serac, pointing towards the robotic total station located in the hamlet of Planpincieux (photo: FMS).

Even if the sensor-to-target distance is beyond the operating limits declared by the producer, the instrument works correctly. However, extreme atmospheric conditions due to the high-mountain elevation, such as heavy snowfall and strong wind, occur frequently, causing the loss of some reflectors, which must be replaced with the help of mountain guides. It is thus clear that measuring the surface velocity of the Whymper Serac with a robotic total station is a difficult task, and a robust data processing method has been developed especially for it. Nonetheless, this data allowed the break-off of the serac in October 2014 to be forecasted ten days in advance [23].

3.2.3 Terrestrial radar interferometry applications

In 2020, an IBIS-FM™ GbInSAR (IDS GeoRadar) was installed to test the capability of radar to monitor the Whymper Serac displacements beyond the instrument's operating limits (approximately 5 km) and in unfavorable environmental conditions. In addition to the correlation between radar data and the existing monitoring system, this new tool was of fundamental importance in identifying the kinematic domains that underwent a progressive acceleration before the ice collapses of 18 October and 11 November 2020.

Starting from the end of October 2020 and during the month of November, a further test was carried out with a LiSALab™ GbInSAR (Ellegi) under the same conditions. This experimentation allowed the acquisition of important data allowing the comparison between the two radar systems, especially regarding the sensitivity to the glacial velocity increase before the collapse of the 11 November 2020 (**Figure 14**).

3.2.4 Other studies: thermal regime investigations

Due to climate change, the high altitude glaciers in the Mont Blanc massif are known to be warming. If the base of these glaciers nears the melting point, they could slide on their beds and become unstable, causing massive ice avalanches.

Observations of internal temperatures of the Whymper Serac were made for the first time in 1997, with thermistors installed in boreholes (**Figure 15**). At that time, the recorded ice temperatures where all below 0°C. These measurements were repeated in October 2020 (**Figure 16**).

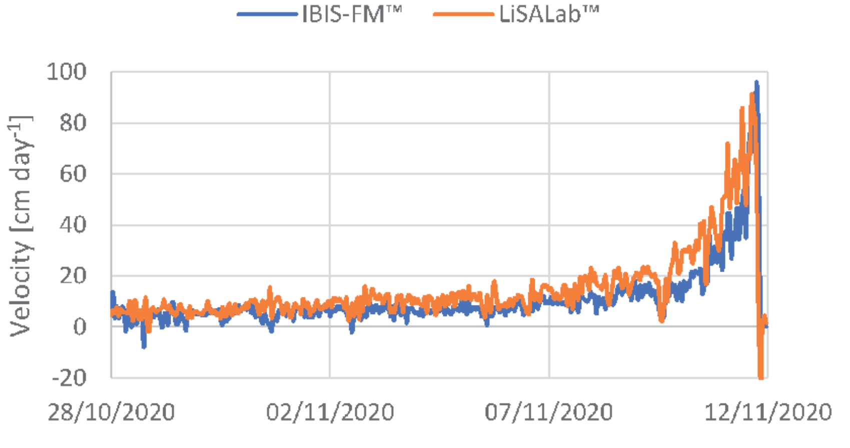


Figure 14.
Comparison of the measurements (surface velocity) made by two different GbInSAR before the failure of 11 November 2020.

Figure 15.
Preparation of boreholes on the Whymper Serac in 1997 (photo: FMS archive).

Figure 16.
Preparation of the working site in 2020 (photo: FMS).

According to the new observations, the upper part of the glacier, near the rimaye, seems temperate (0°C), while the downstream part, near the front, remains at a negative temperature.

In comparison with the observations of 1997, it seems that the ice has warmed significantly, but it has to be considered that the glacier does not have the same geometric configuration (especially after the substantial collapse of 1998) and that the topography of the current glacier is, undoubtedly, very different from that of 1997. It should also be noted that the glacier, which is located on a very steep slope, is strongly fractured and that some of the temperature profiles (in 1997 and in 2020) have been disturbed by the presence of crevasses. Nevertheless, the warming of this glacier ice over the past 23 years is clearly evident. In order to collect more data, a new measurement campaign has been planned for 2021.

3.3 Grandes Jorasses and Planpincieux glacial complex

3.3.1 Ground-penetrating radar applications

A helicopter-borne ground-penetrating radar (GPR) survey was conducted on the Planpincieux - Grandes Jorasses glacial complex in 2013, and 16 GPR traces homogeneously distributed on the glacial surface were acquired.

Due to the difficulties caused by the rough glacier surface and numerous crevasses, which often caused the scattering of electromagnetic waves and obscured the reflections, there was considerable noise in the radar data. However, in the areas of high-profile densities, it was possible to estimate the ice thickness quite reliably.

In the framework of the stability assessment of the lowest part of the Planpincieux Glacier, GPR measurements were repeated in 2020 with a novel dual polarization system. In total, 12 km of profile data were acquired. The data quality allowed the identification of the bedrock for 7 km of profile data. The ice thickness of the Planpincieux - Grandes Jorasses glacial complex ranges between 10 and 100 m, while in the unstable lower part of the Planpincieux Glacier, the thickness varies between 20 and 60 m. By comparing the two measurement campaigns (2013–2020), it can be stated that the two data sets do not provide any evidence of a significant change in the ice thickness during this period. In addition to the glacial thickness data, important information regarding altitude and rough morphology of the bedrock was obtained.

3.3.2 Digital elevation model analysis

Digital Elevation Models (DEMs) obtained during LiDAR and regional terrestrial laser scanning surveys and from specific photogrammetric surveys by drone and helicopter (**Figure 17**) enable the monitoring of the morphological evolution of the glacier surface. Furthermore, consecutive surveys can be analyzed through DEM of Difference (DoD) calculation, allowing the estimation of the surface elevation change between different periods. This can allow, for example, the measurement of the current instable ice volume or the ice mass lost or gained by the glacier.

Since 2019, numerous surveys of the topography have been carried out in order to identify and quantitatively determine the morphological changes of the two glaciers.

3.3.3 Other studies: numerical simulation of ice avalanches

In 2009, a numerical simulation of ice avalanches from the Whymper Serac was carried out using the RAMMS::Avalanche [24] and RAMMS::RKE Rock-Ice models developed by the Institute for Snow and Avalanche Research (SLF).

In 2012 and 2020, these activities were repeated for the Planpincieux Glacier, using new software versions and updated terrain models.

In parallel, Fondazione Montagna sicura, in collaboration with the University of Vienna and University of Graz, carried out the same simulations using the r.randomwalk [25] and r.avaflow [26] models.

The results obtained from the two different methodologies are comparable and confirm the robustness of the analyses (**Figure 18**), which, for the calibration of the parameters, were based on the back calculation of ice avalanches from the Planpincieux Glacier that were mapped between 2017 and 2020.

Figure 17.
Point cloud rendering of the Whymper Serac obtained from a drone survey.

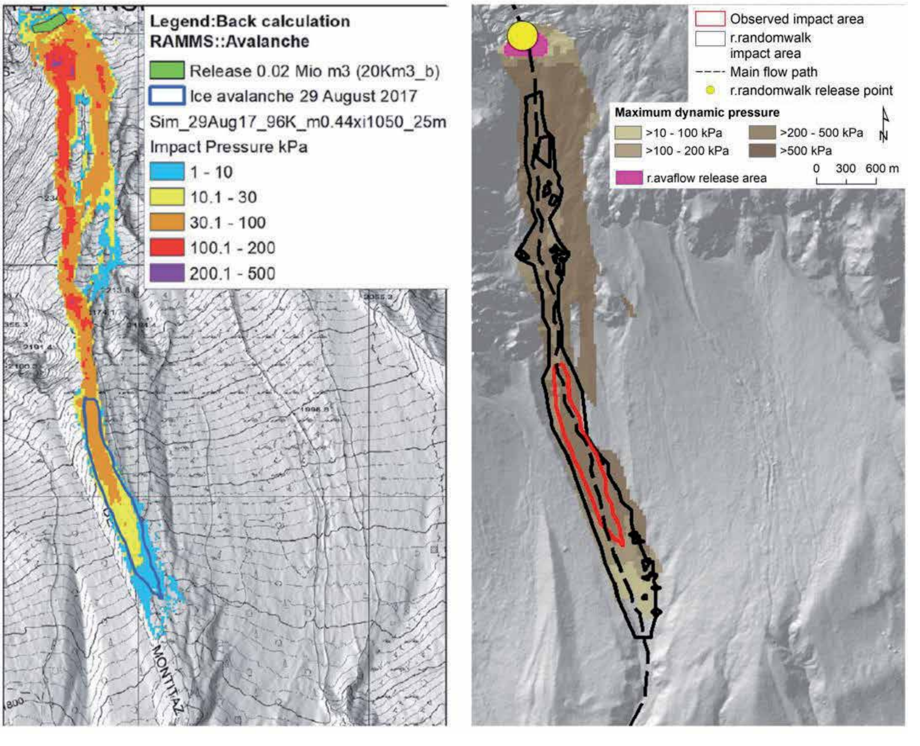


Figure 18.
Back calculation from the RAMMS model (left) and r.avaflow model (right) of an ice collapse mapped in 2017.

The results of the simulations were then translated into risk scenarios and safety concepts based on the unstable volumes of the glacier.

4. Conclusion

The Val Ferret valley was included as a PAR of the GreenRisk4Alps project since it is both a famous tourist location at the foot of Mont Blanc and a high-risk area for all types of mass movement processes. Risk management in this area includes, in addition to the construction of structural measures, both site-specific knowledge and forecasting capabilities of the Aosta Valley's CLVs and Functional Center. More than 45% of the PAR's total wood coverage plays a "direct object protection" role, proving to be effective not only in reducing soil erosion but also in preventing avalanche release and mitigating rockfall impact in runout zones. Nonetheless, glacier-related hazards develop well above timberline in high mountain environments and in areas that are difficult to access, making both technical and ecosystem-based measures partially or completely ineffective. Monitoring and early warning systems are therefore essential, and remote sensing methods that are able to measure many parameters without accessing the glaciers often represent the most suitable solution. For these reasons, the Grandes Jorasses and Planpincieux glacial complex is a reference area for natural risk assessment and management, where different close-range remote sensing techniques can be used and tested in an open-air laboratory that improves our knowledge of new technologies while increasing our understanding of the recent evolution of alpine glacial environments.

Acknowledgements

A special thanks to everyone who contributed to the production of the materials used for the drafting of this text.

Author details

Paolo Perret[1*], Jean Pierre Fosson[1], Luca Mondardini[1] and Valerio Segor[2]

1 Fondazione Montagna sicura, Courmayeur, Italy

2 Struttura Assetto idrogeologico dei Bacini Montani della Regione Autonoma Valle d'Aosta, Aosta, Italy

*Address all correspondence to: pperret@fondms.org

References

[1] Mercalli L, Castellano C, Cat Berro D, Di Napoli G, Guindani N, Montuschi S, Mortara G, Ratti M. Atlante climatico della Valle d'Aosta. Società Meteorologica Subalpina, Torino; 2003. 405 p.

[2] Dal Piaz GV. Le Alpi dal M. Bianco al Lago Maggiore. Società Geologica Italiana, Guide Geologiche Regionali. Be-ma (eds), Milano; 1992. 311 p.

[3] Sistema delle Conoscenze Territoriali SCT Catasto Ghiacciai della Regione Autonoma Valle d'Aosta [Internet]. Available from: http://catastoghiacciai.partout.it/ [Accessed: 2021-04-01]

[4] Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds. OJ L 20, 2010-01-26, p 7-25. [Current consolidated version: 2019-06-26]

[5] Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. OJ L 206, 1992-07-22, p. 7-50. [Current consolidated version: 2013-07-01]

[6] Legge regionale 2010/29 – Disposizioni in materia di Commissioni locali valanghe. Regione Autonoma Valle d'Aosta. BU 34, 2010-08-17, p 3988-3995. [Current consolidated version: 2010-08-17]

[7] Sistema delle Conoscenze Territoriali SCT Catasto Valanghe della Regione Autonoma Valle d'Aosta [Internet]. Available from: http://catastovalanghe.partout.it/ [Accessed: 2021-04-01]

[8] Decreto del Presidente del Consiglio dei Ministri del 15 dicembre 1998. Approvazione del programma di potenziamento delle reti di monitoraggio meteo – idropluviometrico. GU Serie Generale 23, 1999-01-29, p 11-29.

[9] Sistema delle Conoscenze Territoriali SCT Catasto Dissesti della Regione Autonoma Valle d'Aosta [Internet]. Available from: http://catastodissesti.partout.it/ [Accessed: 2021-04-01]

[10] Carta forestale della Valle d'Aosta. Italy - France Alcotra Program 2007 – 2013. Renerfor Project. 2011.

[11] Regione Autonoma Valle d'Aosta, Regione Piemonte, editors. Selvicoltura nelle foreste di protezione - Esperienze e indirizzi gestionali in Piemonte e in Valle d'Aosta. Compagnia delle Foreste, Arezzo; 2006. 224 p.

[12] Camerano P, Terzuolo PG, Varese P. I Tipi Forestali della Valle d'Aosta. Compagnia delle Foreste, Arezzo; 2007. 240 p.

[13] European Environment Agency, editors. European forest types - categories and types for sustainable forest management reporting and policy. Technical report No 9/2006. Copenhagen, Denmark; 2006. 114 p.

[14] Decreto Legislativo 2018/34 – Testo unico in materia di foreste e filiere forestali. GU Serie Generale 92, 2018-04-20, p 1-23. [Current consolidated version: 2018-04-20]

[15] Italy - France Alcotra Program 2007 - 2013. Foreste di protezione: tecniche gestionali e innovazione nelle Alpi occidentali.

[16] Regione Autonoma Valle d'Aosta, Regione Piemonte, editors. Foreste di Protezione diretta – Disturbi naturali e stabilità nelle Alpi occidentali. Compagnia delle Foreste, Arezzo; 2012. 144 p.

[17] Regione Autonoma Valle d'Aosta, Regione Piemonte, editors. Foreste di Protezione diretta – Selvicoltura e valutazioni economiche nelle Alpi

occidentali. Compagnia delle Foreste, Arezzo; 2012. 144 p.

[18] Giordan D, Dematteis N, Allasia P, Motta E. Classification and kinematics of the Planpincieux Glacier break-offs using photographic time-lapse analysis. Journal of Glaciology. 2020; 66(256):188-202. DOI: 10.1017/jog.2019.99

[19] Glaister R. The ice slide on the glacier du tour. Journal of Glaciology. 1951; 1(9):508-509. DOI: 10.3189/S0022143000026587

[20] Faillettaz J, Funk M, Vincent C. Avalanching glacier instabilities: Review on processes and early warning perspectives. Reviews of Geophysics. 2015. 203-224. DOI:10.1002/2014RG000466.

[21] Giordan D, Allasia P, Dematteis N, Dell'Anese F, Vagliasindi M, Motta E. A low-cost optical remote sensing application for glacier deformation monitoring in an alpine environment. Sensors. 2016; 16(10):1750. DOI: 10.3390/s16101750

[22] Margreth S, Faillettaz J, Funk M, Vagliasindi M, Diotri F, Broccolato M. Safety concept for hazards caused by ice avalanches from the Whymper hanging glacier in the Mont Blanc massif. Cold Regions Science and Technology. 2011; 69(2-3):194-201. DOI: 10.1016/j.coldregions.2011.03.006

[23] Faillettaz J, Funk M, Vagliasindi M. Time forecast of a break-off event from a hanging glacier. The Cryosphere. 2016; 10(3):1191-1200. DOI: 10.5194/tc-10-1191-2016

[24] Bartelt P, Salm B, Gruber U. Calculating dense-snow avalanche runout using a Voellmy-fluid model with active/passive longitudinal straining. Journal of Glaciology. 1999; 45(150):242-254. DOI: 10.3189/s002214300000174x

[25] Mergili M, Krenn J, Chu HJ. r. Randomwalk v1, a multi-functional conceptual tool for mass movement routing. Geoscientific Model Development. 2015: 8(12), 4027-4043. DOI: 10.5194/gmd-8-4027-2015

[26] Mergili M, Fischer JT, Krenn J, Pudasaini SP. r.avaflow v1, an advanced open-source computational framework for the propagation and interaction of two-phase mass flows. Geoscientific Model Development. 2017: 10(2), 553-569. DOI: 10.5194/gmd-10-553-2017

Chapter 4

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

Christoph Hintner, Stefano Terzi and Stefan Steger

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

- 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

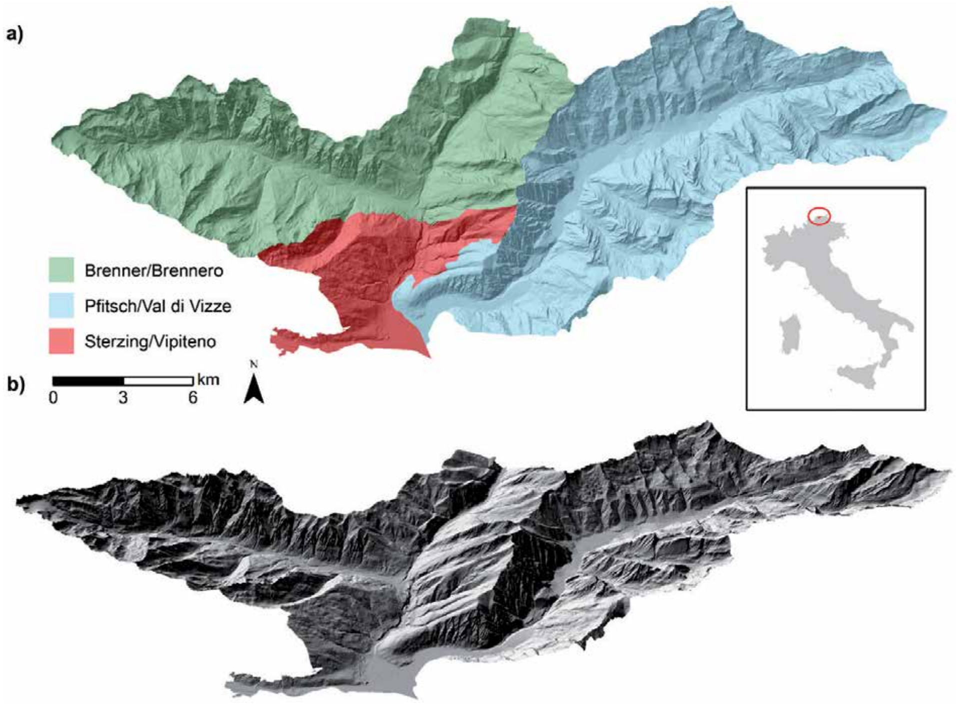


Figure 1.
The location of the Wipptal south PAR within Italy and the areal extent of the three associated municipalities (a). The 3D shaded relief image provides a visual impression of the morphology of the area (b). (data source: GeoKatalog of the province of South Tyrol – http://geokatalog.buergernetz.bz.it/geokatalog/#!).

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].

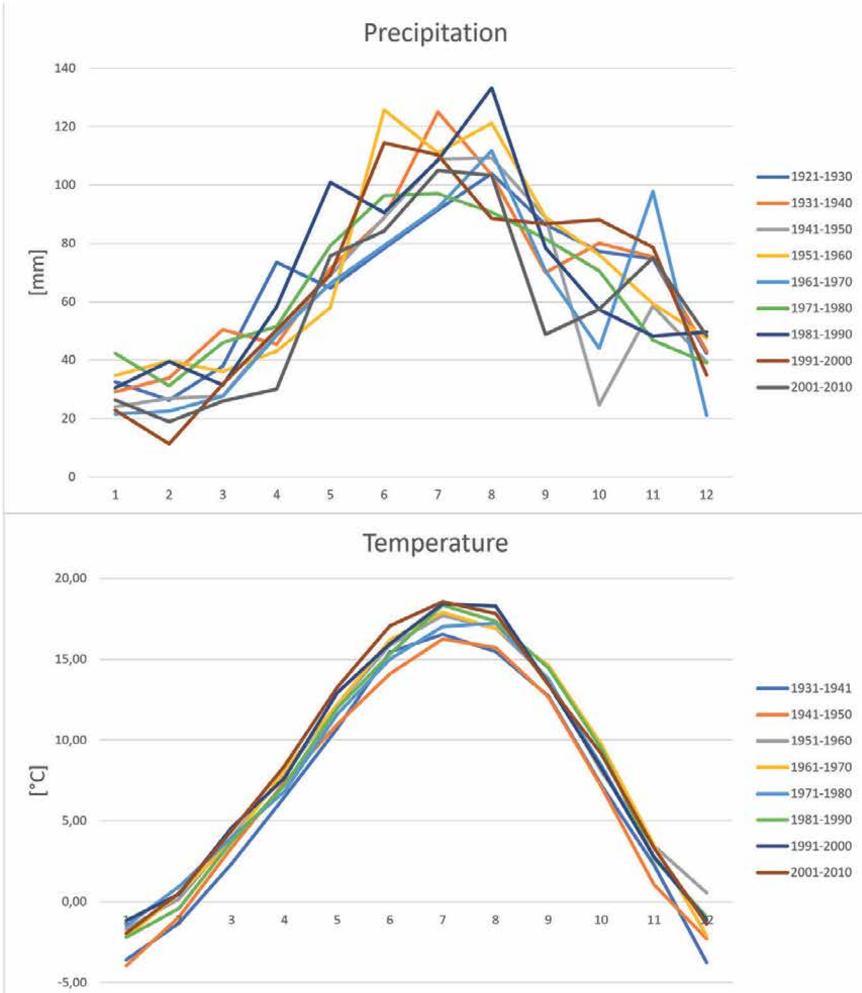


Figure 3.
Ten-year average monthly (x-axis) precipitation and temperature (y-axis) recorded at the weather station in Sterzing/Vipiteno from 1931 to 2010 (data source: http://meteo.provincia.bz.it/download-dati.asp).

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

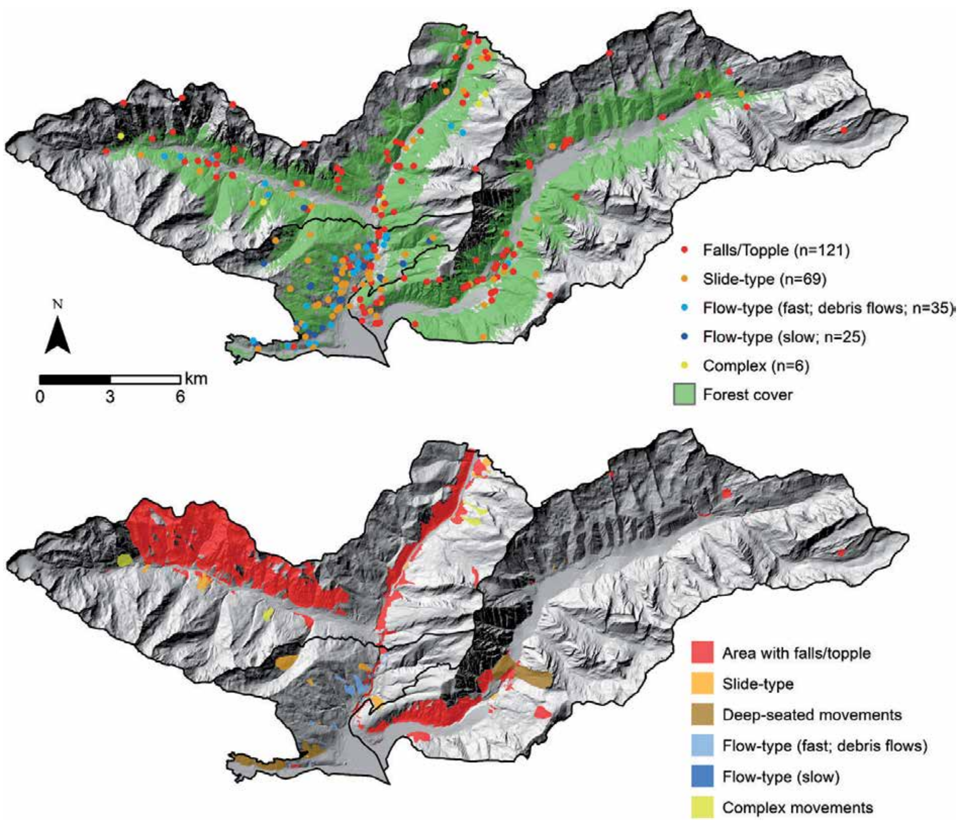


Figure 4.
Point and extension information for different landslides types. (data source: GeoKatalog of the Autonomous Province of South Tyrol – http://geokatalog.buergernetz.bz.it/geokatalog/#!).

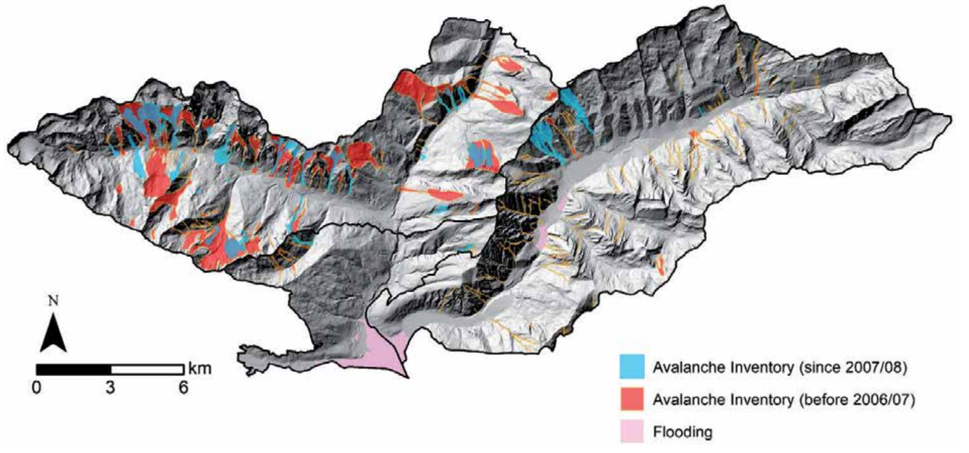


Figure 5.
Snow avalanche inventory of the area (light blue and red) and flooding area (light red). (data source: GeoKatalog of the province of South Tyrol – http://geokatalog.buergernetz.bz.it/geokatalog/#!).

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 sub-alpine 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

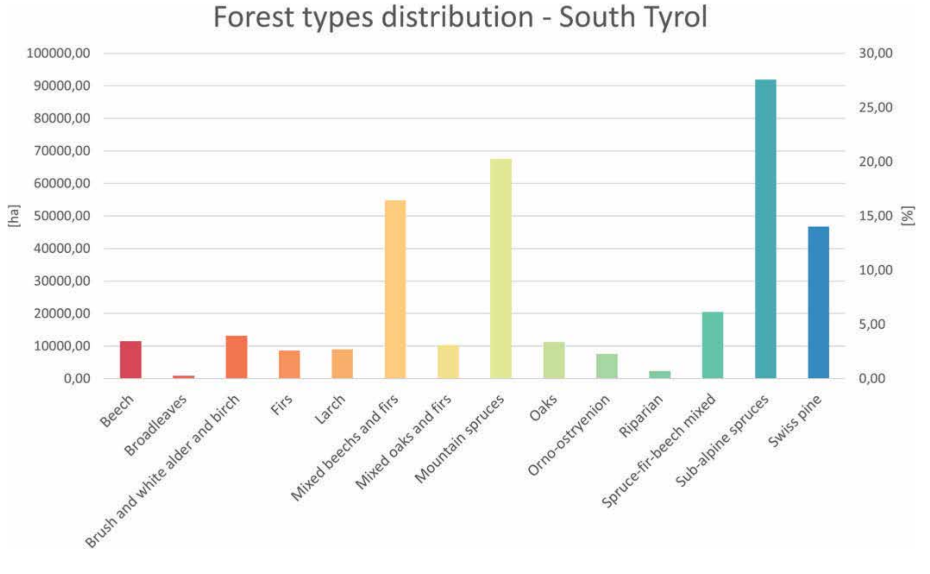


Figure 9.
Areal extent of forest type distributions and percentage of total forested area in South Tyrol (provincial forest type classification, data source: GeoKatalog of the province of South Tyrol – http://geokatalog.buergernetz.bz.it/geokatalog/#!).

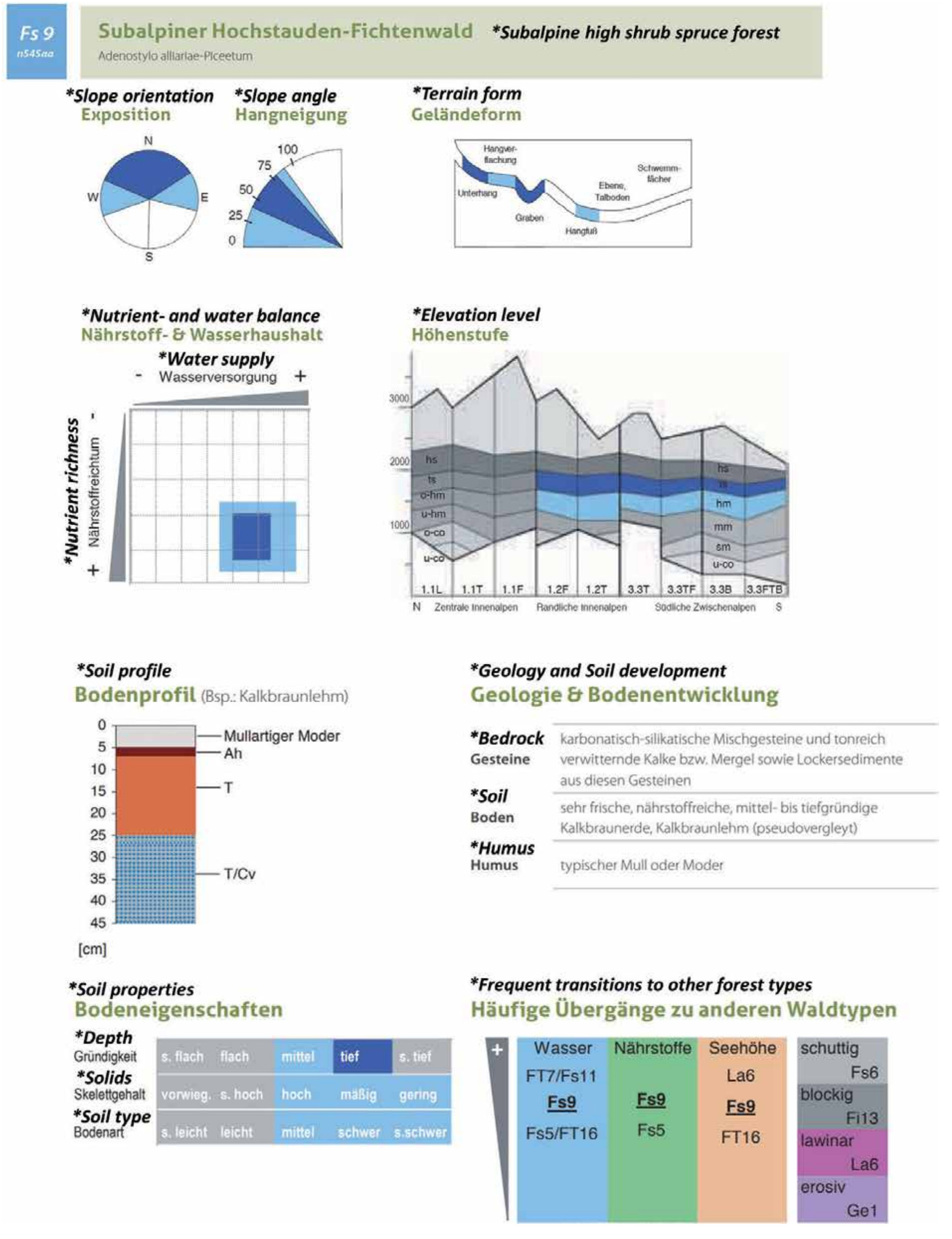


Figure 10.
*Example of the representation of one specific forest type (Adenostylo alliariae-Piceetum) from the original handbook (volume 1). For this figure, the main categories were translated into English (marked with *). For details refer to the text below.*

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.

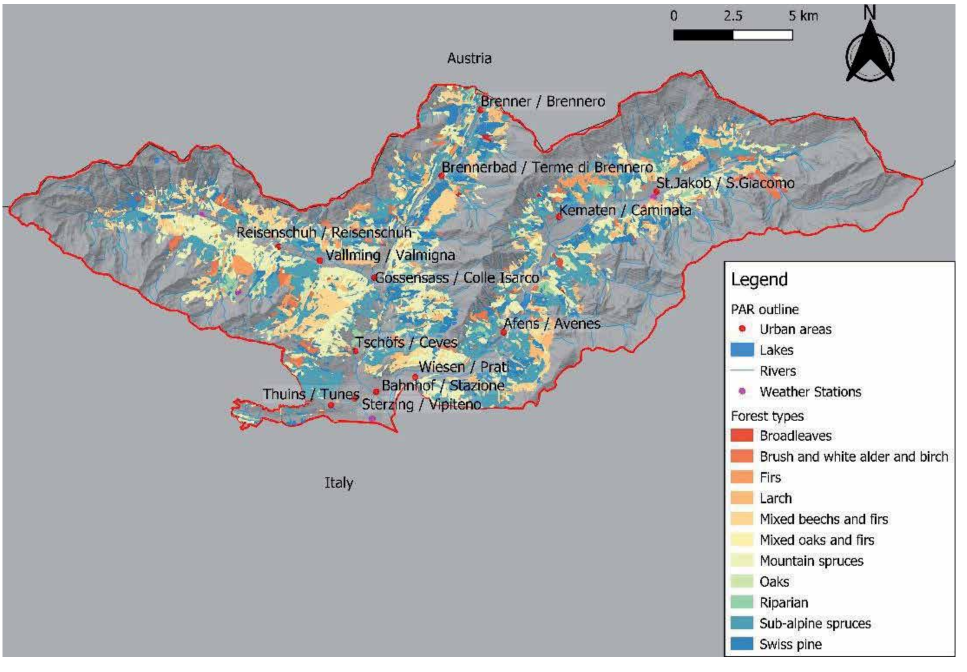


Figure 11.
Wipptal south PAR area and location in South Tyrol with a visualization of the main forest types according to the European environmental agency (EEA) forest categories and types, weather stations, urban areas, lakes and rivers. (data source: GeoKatalog of the province of South Tyrol – http://geokatalog.buergernetz.bz.it/geokatalog/#!).

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**).

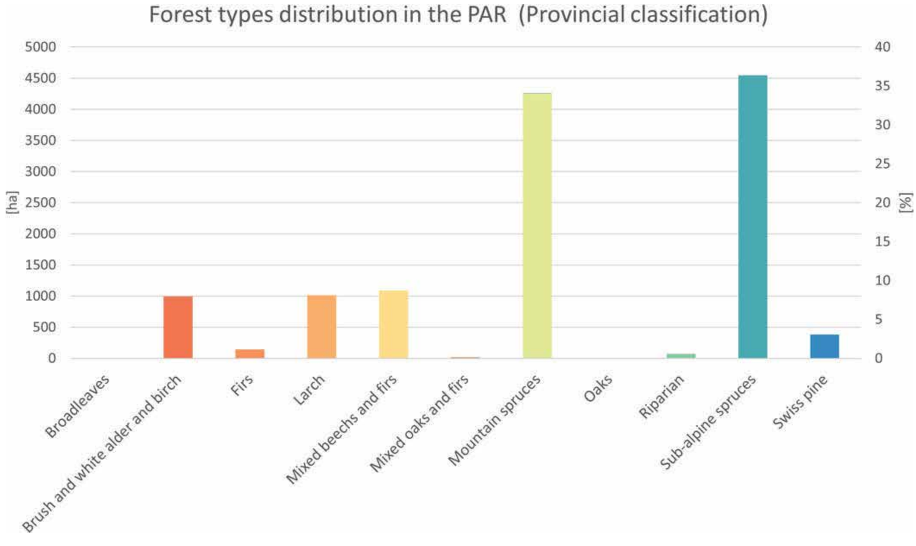


Figure 12.
Areal extent of forest type distributions and percentage of total forested area in the Wipptal south PAR according to the data presented in **Figure 11** *(provincial forest type classification, data source: GeoKatalog of the province of South Tyrol – http://geokatalog.buergernetz.bz.it/geokatalog/#!).*

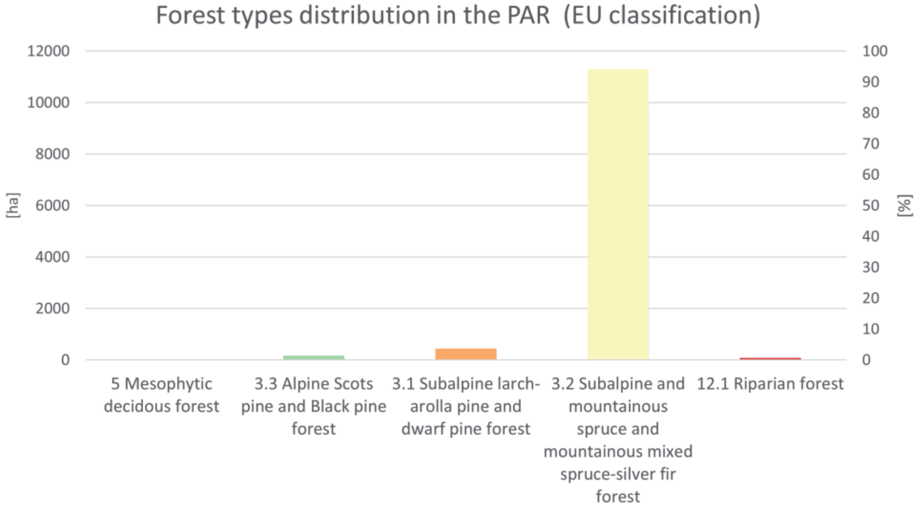


Figure 13.
Areal extent of forest type distribution and percentage of total forested area in the PAR (EU forest type classification, data source: GeoKatalog of the province of South Tyrol – http://geokatalog.buergernetz.bz.it/geokatalog/#!).

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

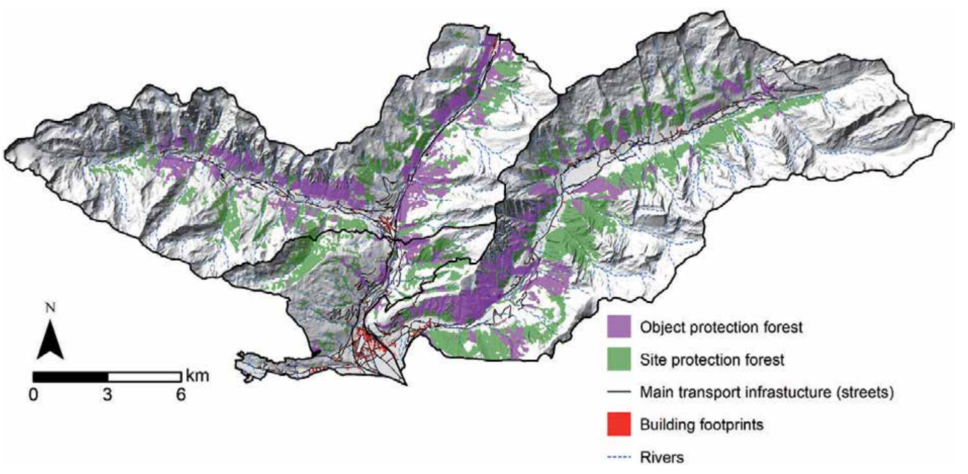


Figure 14.
Protective forest map for the Wipptal south PAR according to the south Tyrolean protective forest indication map (data source: GeoKatalog of the province of South Tyrol – http://geokatalog.buergernetz.bz.it/geokatalog/#!).

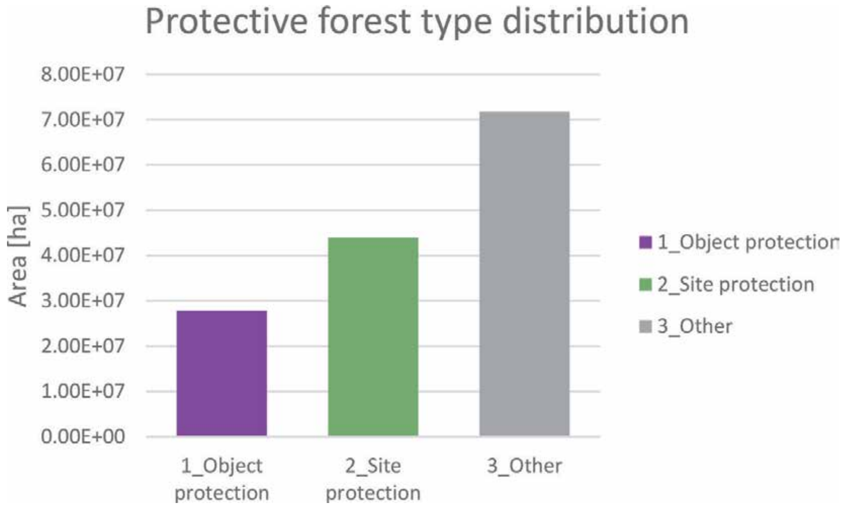


Figure 15.
Protective forest type distribution in Wipptal south according to the south Tyrolean protective forest indication map. Note that the class "other" was derived as the difference between the total forested area and the protective forest types, i.e. object and site (data source: GeoKatalog of 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.

Acknowledgements

We thank the province of South Tyrol for providing data and photographs.

Author details

Christoph Hintner[1], Stefano Terzi[2,3] and Stefan Steger[3]*

1 Forest Inspectorate Sterzing/Vipiteno (Forstinspektorat Sterzing/Ispettorato forestale Vipiteno), Sterzing/Vipiteno, Italy

2 United Nations University Institute for Environment and Human Security (UNU-EHS), Bonn, Germany

3 Institute for Earth Observation, Eurac Research, Bozen/Bolzano, Italy

*Address all correspondence to: stefan.steger@eurac.edu

References

[1] Entwicklungsplan L. LAG Wipptal 2020 Lokaler Entwicklungsplan. 2020;(1305).

[2] IDM Südtirol - Alto Adige. South Tyrol - The Economy. 2013;40.

[3] Steger S, Teich M, Crespi A, Kindermann G, Jandl R, Hormes A, et al. Green Risk 4 Alps - Deliverable WP T1 PRONA. 2020.

[4] Brönnimann S, Rajczak J, Fischer E, Raible C, Rohrer M, Schär C. Changing seasonality of moderate and extreme precipitation events in the Alps. Nat Hazards Earth Syst Sci. 2018;18(7):2047-2056.

[5] IPCC. 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. 2014.

[6] Isotta FA, Frei C, Weilguni V, Perčec Tadić M, Lassègues P, Rudolf B, et al. The climate of daily precipitation in the Alps: Development and analysis of a high-resolution grid dataset from pan-Alpine rain-gauge data. Int J Climatol. 2014;34(5):1657-1675.

[7] Schmidli J, Goodess CM, Frei C, Haylock MR, Hundecha Y, Ribalaygua J, et al. Statistical and dynamical downscaling of precipitation: An evaluation and comparison of scenarios for the European Alps. J Geophys Res Atmos. 2007;112(4):1-20.

[8] Schmidli J, Frei C. Trends of heavy precipitation and wet and dry spells in Switzerland during the 20th century. Int J Climatol. 2005;25(6):753-771.

[9] Nikulin G, Kjellström E, Hansson U, Strandberg G, Ullerstig A. Evaluation and future projections of temperature, precipitation and wind extremes over Europe in an ensemble of regional climate simulations. Tellus, Ser A Dyn Meteorol Oceanogr. 2011;63(1):41-55.

[10] Rajczak J, Schär C. Projections of Future Precipitation Extremes Over Europe: A Multimodel Assessment of Climate Simulations. J Geophys Res Atmos. 2017;122(20):10,773-10,800.

[11] Stingl V, Mair V. Einführung in die Geologie Südtirols:[aus Anlass des 32. Internationalen Geologischen Kongresses im Sommer 2004 in Florenz]. Autonome Provinz Bozen-Südtirol, Amt f. Geologie u. Baustoffprüfung; 2005.

[12] Steger S, Mair V, Kofler C, Pittore M, Zebisch M, Schneiderbauer S. A statistical exploratory analysis of inventoried slide-type movements for South Tyrol (Italy). In: Guzzetti F, Mihalić Arbanas S, Reichenbach P, Sassa K, Bobrowsky PT, Takara K, editors. Understanding and Reducing Landslide Disaster Risk, Volume 2 From Mapping to Hazard and Risk Zonation. Springer Nature Switzerland AG; 2021.

[13] Ostermann M, Sanders D. The Benner pass rock avalanche cluster suggests a close relation between long-term slope deformation (DSGSDs and translational rock slides) and catastrophic failure. Geomorphology. 2017;289:44-59.

[14] Il bosco altoatesino in cifre | Bosco, legno, malghe | Amministrazione provinciale | Provincia autonoma di Bolzano - Alto Adige [Internet]. [cited 2021 Feb 22]. Available from: http://www.provincia.bz.it/agricoltura-foreste/bosco-legno-malghe/bosco-in-alto-adige/il-bosco-altoatesino-in-cifre.asp

[15] Kofler H. Heimatbuch Gossensass und Pflersch mit den Weilern

Giggelberg und Pontigl. Band 1; Häuser- und Höfegeschichte. Hg.: Marktgemeinde Brenner. 2004.

[16] Oberrauch H. Tirols Wald und Waidwerk, ein Beitrag zur Forstund Jagdgeschichte. 1952. 328 p.

[17] Mutschlechner G. Hochwälder, Schwarzwälder, Bannwälder. 1981.

[18] Stern R. Der Waldrückgang im Wipptal. Mitteilungen der Forstlichen Bundesversuchsanstalt in Wien; 70. Heft; Österreichischer Agrarverlag. Wien; 1966.

[19] Trenkwalder A. Beiträge zur Geschichte des Pfitschtales. 1978.

[20] Gemeinde Pfitsch. Gemeindebuch Wiesen Pfitsch. 1998.

[21] Wopfner H. Bergbauernbuch. Von der Arbeit und Leben des Tiroler Bergbauern in Vergangenheit und Gegenwart. Hg.: Nikolaus Grass. Wirtschaftliches Leben. Band 3. Innsbruck: Universitätsverlag Wagner; 1997. 722 p.

[22] Ennemoser G. Gossensass - Beiträge zur Geschichte der Gemeinde Gossensass mit besonderer Berücksichtigung der Zeit von 1850-1914. Universität Innsbruck; 1975.

[23] Wieser J, Trenkwalder A, Staindl L. Wiesen-Pfitsch. Südtiroler Gebietsführer. Bozen: Athesia; 1981.

[24] Fröhlich H. Die Einkommensverhältnisse der Landwirte im Wipptal. Beiträge zur alpenländischen Wirtschafts- und Sozialforschung. Innsbruck; 1968.

[25] Ennemoser G. Gossensass – Brenner –Pflersch. Südtiroler Gebietsführer. 1984. 39 p.

[26] Provincia autonoma di Bolzano Alto Adige. Legge provinciale 21 ottobre 1996 n. 21. 1996.

Chapter 5

Gries am Brenner/Vals Pilot Action Region: The Tyrolean Ski Tour Steering Concept - A Contribution to the Protection of Wildlife and Object Protective Forests

Matthias Plörer and Dieter Stöhr

Abstract

When people engage in recreational activities in sensitive forest habitats, there can be unintended negative impacts on wildlife and forests. These include disturbance and displacement of wild game as well as damage to young plants (tree seedlings and saplings from ski or snowshoe compaction or direct physical damage from ski edges). These are just a few examples that highlight the need to manage the impact of recreationists with different measures in order to minimize the disturbance of game (especially red deer and roe deer) and the impairment of important object protective forests that this in turn causes. In Section 2 of this chapter, we describe the tourism, population, settlement area, economy, forestry and natural hazards in the GreenRisk4Alps Pilot Action Region (PAR) of Gries am Brenner and Vals in Tyrol, Austria. Section 3 provides an overview of the overarching initiative and integration forum, "Tyrolian mountains – experience together", which was initiated by the Amt der Tiroler Landesregierung (Office of the Tyrolean Provincial Government). We then provide a description of the exact workflow, the possible measures and other details on ski tour steering options. Ski tour steering measures in the Gries am Brenner and Vals PAR can be found in Section 3.4, followed by a critical review of the experiences in Section 4.

Keywords: protective forest, red deer, ski touring, natural hazards, recreation

1. Introduction

With the expansion of settlement and industrial areas, and the space-intensive development of infrastructure in the Austrian Alpine region, the importance of forests as an efficient protection measure against natural hazards has increased over the last hundred years [1]. Necessary management strategies to maintain the protective capacity of these forests must include silvicultural adaptation concepts which also address climate change. The challenges in the face of climate and socio-economic change are considerable. In addition to the influence of climate change, wildlife management and tourism are among the factors that make it difficult for forest managers to maintain the protective functions and effects of forests against natural hazards [1].

In this chapter, we focus on one of our six GreenRisk4Alps pilot action regions, which is represented by the two municipalities of Gries am Brenner and Vals in the Tyrolean Wipptal Valley. This area is subject to numerous natural hazards, such as rockfall and snow avalanches, which endanger residents as well as visitors and key infrastructure. Therefore, it is essential that the surrounding protective forests and their protective effects are managed sustainably and as a priority.

The maintenance and improvement of the protective effects of these forests as a necessary integral part of modern risk management can be achieved through a combination of diverse interventions, management methods and strategies. In this best-practice example, we highlight how the steering of winter recreation activities such as ski touring, snow shoeing and off-piste skiing in combination with wildlife management can play a central role in protective forest management. We demonstrate how targeted visitor management with a variety of cost-effective measures can contribute to the preservation of the protective effect of forests against natural hazards.

2. Description of the Gries am Brenner and Vals PAR, Tyrol, Austria

2.1 General

The municipalities of Gries am Brenner and Vals are located in the Wipptal Valley in the southern part of the Austrian Federal Province of Tyrol, adjacent to the Italian border on the main ridge of the Alps (**Figure 1**). The two municipalities span an area of approximately 105 km^2. Only 10 km^2, i.e. 10% of the total area, are permanent settlement areas, and about 35% of the total area is forested. The remaining areas of the municipalities constitute agricultural land, water bodies, future construction areas, gardens and high alpine areas covered with pastures, alpine meadows or scree and rocks (30%) [2, 3].

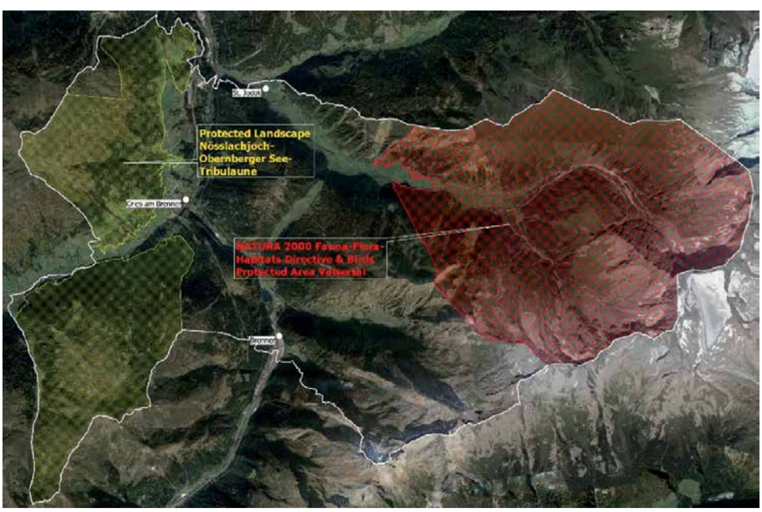


Figure 1.
Protected areas in the PAR. Source shapefiles: Land Tirol – Department Geoinformation. Aerial image: Google satellite.

DOI: http://dx.doi.org/10.5772/intechopen.99011

2.2 Population and settlements

The region of Gries am Brenner and Vals is home to 1,882 inhabitants (as of 2019), and the population growth is relatively slow compared to that of the entire region of Tyrol [4, 5]. In 2020, there were 671 registered buildings [6, 7]. Compared to other regions in the state of Tyrol, this region is not particularly densely populated.

2.3 Economy and tourism

The two municipalities of Gries am Brenner and Vals are quite different. Vals has only 28 businesses (excluding agriculture), while Gries am Brenner has 73 [8, 9]. This is due, among other things, to its location: the Valsertal is a side valley of the Wipptal Valley, while Gries am Brenner is located in its middle at the Brenner Pass, which is an important international transit route. From a tourism perspective, the Valsertal is less important compared to the municipality Gries am Brenner. While 43,789 overnight stays were recorded in Gries am Brenner in 2019, only 12,786 were recorded in the municipality of Vals [10, 11]. Based on these numbers, this destination region represents only a small share in Tyrol's tourism economy.

Winter tourism infrastructure such as ski areas (lifts, lodges, built ski trails), which attract large numbers of tourists to the region of Tyrol, are de facto absent in the PAR. One small ski area formerly located on Sattelberg Mountain is no longer in operation. However, parts of the municipality of Gries am Brenner and the Valsertal have become quite popular for ski touring and snowshoeing, which led to the initiation of the best-practice example described in Section 3.

2.4 Protected areas

Two protected landscapes provide large areas for sensitive plants and animals within the region, "Nösslachjoch-Obernberger See-Tribulaune" in the municipality of Gries am Brenner and a "Natura2000 Fauna-Flora-Habitat" area in the municipality of Vals (**Figure 1**).

2.5 Dealing with natural hazards

Transportation corridors and settlements are partly located at the base of steep rock faces. The region lies in the continental central alpine climate zone, which is characterized by wide temperature ranges and low precipitation with a pronounced summer maximum. A regional feature is the "Föhn" wind, a dry downdraft wind that can reach hurricane-like speeds. The mean annual precipitation for the period 1981–2010 was 817 mm [12]. This corresponds to a significantly below-average value compared to all other stations in Austria (mean maximum annual precipitation = 2,403 mm).

Overall, all notable alpine natural hazards occur in this PAR. Large areas of the municipality of Gries am Brenner are prone to shallow soil slides, and several torrents from various side valleys have the potential to produce flooding and mudflows. In the Valsertal, avalanches and rockfall are highly frequent. The lithological-geotechnical situation (pronounced schistosity and high crack and joint density) leads to a high frequency of rockfall and occasionally to larger rock avalanches (e.g. volume > 110,000 m^3 occurred in 2017). In winter, at least 25 avalanche paths are repeatedly problematic in the Valsertal [13].

As in other parts of the Alps, natural hazard process areas that endanger buildings and infrastructure have been preventively managed here for decades.

Especially on the orographic right side of the Valsertal and in the center of the municipality Gries am Brenner, dams, nets and single block protection measures have been installed to mitigate rockfall hazards [14]. The so-called "Sill-Avalanche" has been controlled with steel snow bridges and tripods. Along the Austrian railroad line (ÖBB), the operator itself provides extensive protection. In the Lueg area, where there is a steep rock face located directly above the railroad tracks, protection against gravitational natural hazards has been provided for decades by technical structures of various ages and functions. To protect against flooding, the streambed in the center of St. Jodok (Vals) was extensively expanded a few years ago. All these technical protection measures are implemented (planning and execution) by the WLV as well as by the transport and infrastructure operators ÖBB (railway) and ASFINAG (highway).

The WLV is (besides the Federal Water Engineering Administration) responsible for the protection of settlement areas. The costs of measures are mostly divided between the federal government (main share), the federal states and the municipality (usually the smallest share). For example, extensive protection measures (monitoring with early warning systems, relocation of a road and construction of dams amounting to several million euros) were implemented in 2018–2020 in response to a major rock avalanche event that occurred in Vals in 2017.

At locations that have not yet been or cannot be protected by technical measures, other strategies must be implemented. For example, an avalanche commission convenes several times each winter – on a statutory basis – to assess and avert avalanche damage. Local fire brigades also play an extremely important and indispensable role in disaster response and recovery. These institutions, which are all comprised of voluntary members, are the first responders in case of emergencies. Flooding, soil slides, avalanches and rockfall are in most cases dealt with by volunteer fire brigades during an event. Before and after an event, the WLV and the Tyrolean Geological Survey (Landesgeologie) play an important role as support organizations.

The official hazard zone plans of the WLV are the fundamental basis for spatial planning when dealing with natural hazards (**Figure 2**). For each municipality – including Gries am Brenner and Vals – the spatially explicit hazard zones for avalanches and torrents are shown (**Figure 2**). The process runout lengths and intensities in these plans are based on event documentation, silent witnesses,

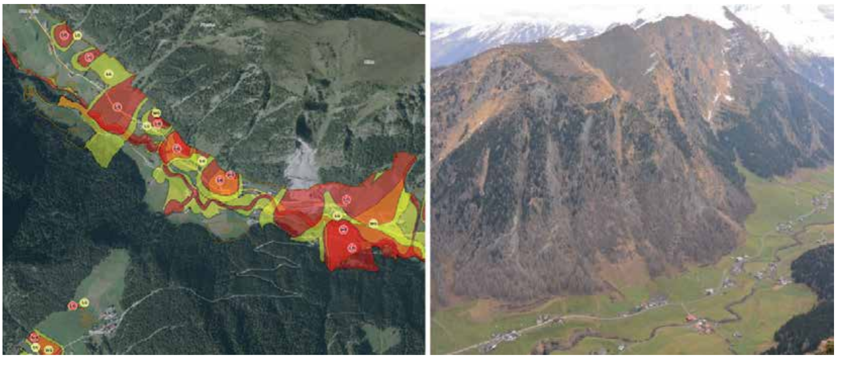


Figure 2.
Left – Excerpt of the hazard zone plan for avalanches and torrents from the Austrian Service for Torrent and Avalanche Control (WLV) in the Valsertal. Source shapefiles: Land Tirol – Department Geoinformation. Aerial image: Google satellite. Right – The southwest-exposed side of the Valsertal. Low building density but pronounced steep slopes of partially unstable rock walls with high susceptibility to rockfall activity. Image source: Matthias Plörer.

eyewitness accounts, numerical simulations and expert input. The hazard zone plan is the basis for the construction zoning plan and indicates building bans or possible technical requirements for protection against natural hazards. Rockfall processes and landslides are only roughly defined in the official hazard zone plans as hazard indication areas in the spatially relevant areas [15].

Finally, forest management plays an important role in the prevention of natural hazards. In addition to forest rangers, who are employed by the municipalities, the nearby Bezirksforstinspektion (District Forestry Inspectorate) in Steinach am Brenner and the various forestry departments of the Landesforstdirektion (State Forestry Directorate) in Innsbruck are responsible for the management of the (protective) forests to prevent natural hazards.

A strategy that goes beyond the official institutions and includes all relevant stakeholders is described in detail and as our "best-practice example" in the following chapters.

2.6 Forests and forestry

2.6.1 Share of forest cover

In total, an area of around 3,718 hectares (35.6% of the overall land area) is covered by forest within the municipalities of Gries am Brenner and Vals (**Figure 3**). Other large areas are uncultivated heathland or high alpine rocky landscapes.

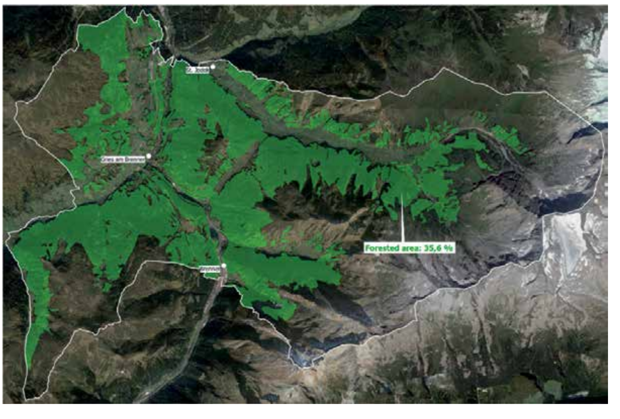


Figure 3.
Recent forest cover in the communes of interest. Source shapefiles: Land Tirol – Department Geoinformation. Aerial image: Google satellite.

2.6.2 Forest categories/forms of operation

The forests in the two municipalities can be divided into (low-yield) protective forest and (high-yield) production forest as well as mixed forms and unstocked forest areas. According to the forest database provided by the Amt der Tiroler Landesregierung (Office of the Tyrolean State Government) – Department of Forest Planning [16], the following forest categories are distinguished (**Figure 4**):

- "WW" production forest
- "WS2" production forest with medium protective function

- "SiE" protective forest in yield
- "SaE" protective forest out of yield (high forest)
- "SaEK" protective forest out of yield (krummholz)
- "NHB" unstocked forest area

As shown in **Figure 4**, 78% of the total forest area in the region is protective forest (protective forest in yield, protective forest out of yield in the form of high forest and protective forest out of yield with krummholz). Production forests, including those with a medium protective function, account for 21% of the total forest area. According to the Tyrolean forest management plans, forests in yield (production forest, production forest with medium protective function, protective forest in yield; 58% of the total forest area) can be managed in a planned and sustainable manner by regular harvesting [17].

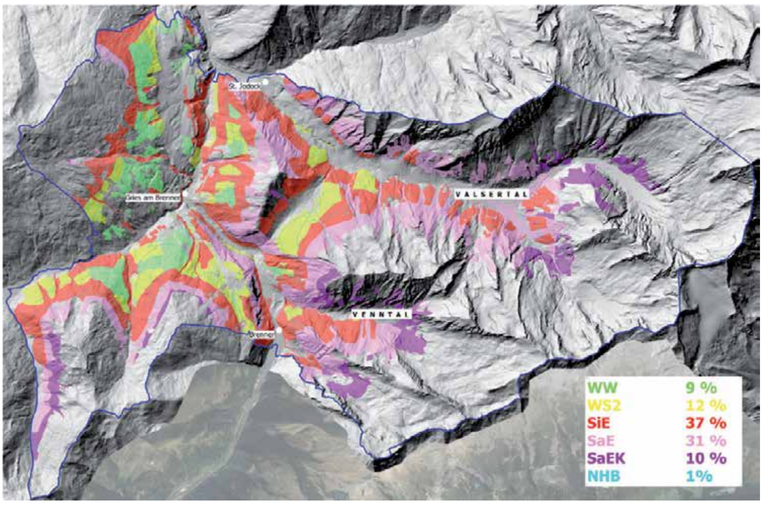


Figure 4.
Forest categories/form of operations. WW: Production forest, WS2: Production forest with medium protective function, SiE: Protective forest in yield, SaE: Protective forest out of yield (high forest), SaEK: Protective forest out of yield (Krummholz), NHB: Unstocked forest area. Source shapefiles: Land Tirol – Department Geoinformation. Aerial image: Google satellite.

2.6.3 Tree species distribution

The description of the tree species distribution in this PAR is based on the Waldtypisierung Tirol (forest typification of Tyrol). For the forest typification, similar forest units – determined by the combination of site characteristics such as location, climate, soil, and potential natural vegetation – were aggregated [18, 19]. This typification is not entirely identical to the actual species distribution, but the potential vegetation is largely consistent with the current one. We categorized forest types based on the forest typification and according to the European forest types (**Figure 5**) [20].

According to the European forest type catalog, type 3.2 (subalpine and montane spruce and montane mixed spruce-silver fir forests) is the most represented with a share of 67% of the total forested area followed by type 3.1 (subalpine larch-arolla pine and dwarf pine forest) with 37% of the total forested area. Types 3.3 and 12.1 occur only in very small proportions.

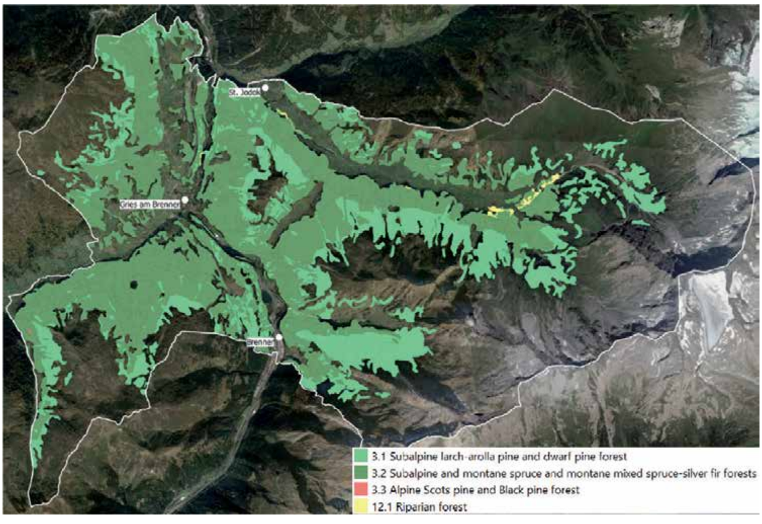


Figure 5.
Tree species distribution according to the European forest type catalog. Source shapefiles: Land Tirol – Department Geoinformation. Modified after the European forest type catalog. Aerial image: Google satellite.

2.6.4 Ownership structure

Forests in Austria can be owned by a wide variety of entities and individuals. In addition, especially in Tyrol, there is the atypical form of the agricultural communities to which municipal property (in the form of forest) was transferred decades ago. These transfers were declared unconstitutional by the Austrian Constitutional Court on 11 June 2008. This municipal property is now owned in an atypical manner by the municipalities as well as the beneficiaries (farmers) and organized as an agricultural community. The municipality is entitled to the intrinsic value of the land. This is the value that remains after agricultural and forestry use by the beneficiaries. The land itself and, for example, the income from gravel extraction is municipal property [21].

In the area of Gries am Brenner and Vals, the following types of property can be distinguished, according to the Tyrolean Forest Database (**Figure 6**) [16]:

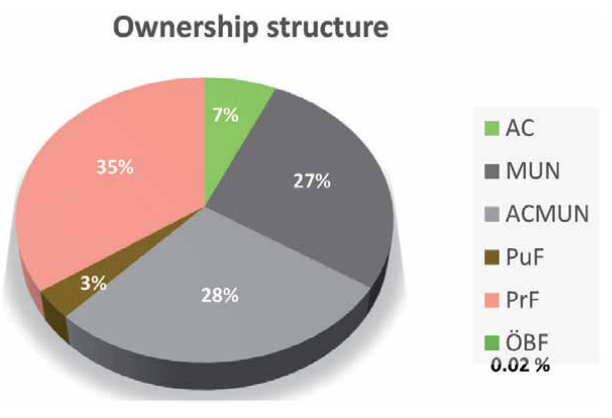


Figure 6.
Ownership structure of forest within the region of Gries am Brenner and Vals. Generated from the Forest database. AC: Agricultural communities, MUN: Municipal property and assets, ACMUN: Agricultural communities from municipal property, PuF: Other public forests, PrF: Private forests, ÖBF: Austrian Federal Forests. Source: Land Tirol – Forest planning department.

- Municipal property and assets "MUN"
- Agricultural communities from municipal property (atypical form) "ACMUN"
- Agricultural communities "AC"
- Private "PrF"
- Austrian Federal Forests "ÖBF"
- Other public forests (e.g. State of Tyrol, highway and train line operators) "PuF"

More than one third (35%) of the forest is owned by private individuals (PrF), which often own very small forest plots. The traditional agricultural communities in Tyrol, which are mostly associations of private farmers, own 7% of the total forest area within the PAR. Classical community forest and atypical community forest (community forest with beneficiaries and management by an agricultural community) together account for a share of 55%. Other forests under public law account for 3%.

2.6.5 Felling quantity/harvested volume

Figure 7 shows data from the forest database of the Provincial Forestry Directorate Tyrol for all forest users (private, public, cooperatives) over the last 20 years [16]. The harvested volume, which includes both pre-use /intermediate cut (thinning, thicket maintenance) and the final use/regeneration cut (including damaged timber removal), varied between 2,000 and nearly 13,000 m^3 over the past two decades.

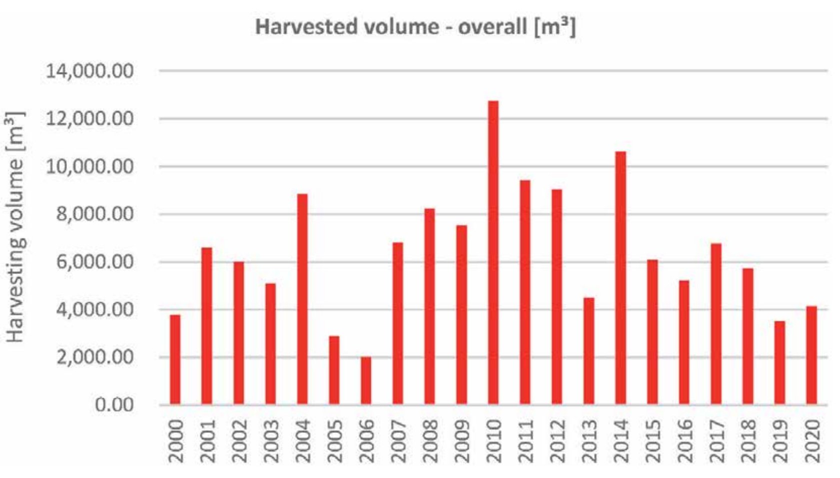


Figure 7.
Harvesting quantity in Gries am Brenner and Vals by private and public use. Generated from the Forest database. Source: Land Tirol – Forest planning department.

2.6.6 Growing stock and increment

The existing forest management plans for the two municipalities record 329 m^3 (agricultural community of Vals), 361 m^3 (municipality of Gries am Brenner) and 377 m^3 (agricultural community of Niedererberg/Fraderwald) growing stock per hectare. The growth increment lies between 6.0 and 6.6 m^3 per hectare per year. Most of the growing stock consists of spruce and larch [17, 22, 23].

These plans were prepared by the Forest Planning Department for periods of 20 years and cover agricultural community forests and community estate forests located in the PAR. Private forest land is not included, so while the data cover large portions of forest land in this region, they do not fully represent it [17, 22, 23].

3. "Tyrolean mountains – experience together": Ski tour steering – An example of best practice in the region of Gries am Brenner and Vals, Austria

3.1 Introduction

More and more people are enjoying nature through various sports such as hiking, biking, snowshoeing, skiing and ski touring. This benefits the tourism industry as well as individual health along with our healthcare system. However, the increase in outdoor recreation also leads to conflicts. Mountain bikers use hiking trails, ski tourers unintentionally scare game away from winter resting areas and sport climbers trample through farmers' meadows on their way to rock climbing routes. It is usually individual users who do not always follow the rules that make conflict-free coexistence in nature difficult [24].

The program *Tyrolean mountains – experience together* (translated from "Bergwelt Tirol – miteinander erleben") was launched by the Tyrolean government in the spring of 2014. This program includes the management and control of recreational activities in summer (mountain biking, rock climbing, hiking, etc.) as well as in winter (ski and snowboard touring, snowshoe hiking) by involving all relevant stakeholders and representatives from tourism, agriculture, forestry, hunting, politics, nature conservation and landowners, especially in regions or locations where conflicts may arise or have already arisen. To achieve a balance between the interests of the various stakeholders, a large number of institutions are involved in the program, including among others the Tyrolian provincial government, the Austrian Alpine Club, the Chambers of Agriculture & Commerce, the Tyrolean Hunters' Association and Tirol Advertising Ltd. [24].

3.2 Ski and snowboard tour steering: an initiative to protect wildlife and protective forests

3.2.1 Basic concept

"Experience the winter mountain world under your own power with climbing skins – skiing started like this – long before our mountains were made accessible by ski lifts. In recent years the sport of ski touring has increased substantially in popularity" [25].

One part of the program "Tyrolean mountains – experience together" is the so-called "Ski tour steering".

According to the head of the mountain sports department of the Austrian Alpine Club, Michael Larcher, the number of people in Austria who practice mountain sports in the form of ski touring is now between 500,000 and 600,000. The Corona pandemic with the consequence of partial ski area closures also seems to be contributing to the fact that, especially in the winter season, more and more people are seeking recreation on touring skis and snowshoes in the forest. Larcher expected a further increase of approximately 20% before the start of the winter season 2020/2021 [26].

The "Ski tour steering" initiative aims to demonstrate that ski touring can be done in an environmentally friendly way despite a massive increase in the number of winter recreationists, if certain rules are followed. In locally implemented ski touring projects throughout the state of Tyrol and together with the project partners and stakeholders, protection zones are defined for the most important protected targets, and measures are developed to not only improve the ski touring experience, but also the coexistence of people, wildlife and nature.

There are areas or specific locations in Tyrol where, due to tourism and recreational activities (ski and snowboard tours), the potential for conflicts with other interests such as hunting, nature conservation or forest management prevail or where conflicts have already occurred. Especially in the context of forestry and hunting, conflicts can arise if tourism activities and recreational sports disturb game or wildlife habitats and, therefore, affect the protective forest.

The 60-page "Tyrolean Ski and Snowboard Touring Concept" [27] (**Figure 8**) was developed by all institutions and experts involved in the program, which contains, among other things, information and guidelines for the following topics:

Figure 8.
Most important topics in the "Tyrolean Ski and Snowboard Touring Concept" [27].

According to the basic concept, several protected targets must be considered when the elaboration of a steering concept starts (**Figure 9**).

Figure 9.
Protected targets that are identified as important for ski touring projects in Tyrol. The red and green highlighted topics are of particular interest in the GreenRisk4Alps project. Icon made by Freepik from www.flaticon.com.

3.2.2 Protected targets: red deer, roe deer and protective forest

In the context of the GreenRisk4Alps project, the protection of red deer and roe deer as well as protective forest is of particular interest (highlighted in red and green in **Figure 9**). Protective forests can be negatively affected either by human influence or by game. Disturbance of game can lead to an impairment of its energy balance and, as a direct consequence, to increased browsing pressure leading to peeling damage on trees (**Figure 10**) [27].

Figure 10.
An example of severe damage to protective forest caused by red deer. Recorded in the Gries am Brenner PAR. Source: Matthias Plörer.

3.2.2.1 Protective forest—direct damage

Direct damage to forest regeneration by ski edges occur on frequently used ski tour routes and lead to the delayed development of the stand and financial loss for the forest owner [27]. This damage must be taken seriously, and steering measures to prevent it must be undertaken. A distinction must be made as to which protective category the affected forest belongs. In case of damage in object protective forests of priority 1, steering measures that are suitable for reducing the damage must be developed by the regional working group in any case. In the assessment of the extent of damage, the district forestry inspectorate participates [28].

3.2.2.2 Red deer, roe deer and the indirect influence on protective forest

Game disturbances in winter are highly relevant because animals are adapted to rest and consume as little energy as possible during this period of food shortage. Animals adapt physiologically to the low food supply and low temperatures. They do this, for example, by lowering their heart rate [27]. However, when disturbed, deer usually respond by increasing their heart rate, which is associated with increased energy consumption [29]. The animals then require more food. Game, in particular, which in the winter season is fed by hunters in Tyrol, has a higher metabolic rate and therefore requires more food to compensate for this when disturbed [27].

Disturbances at dawn and dusk, especially near game feeders, have the most fatal consequences. The game then often avoids the feeding area for a longer period and peeling off bark and eating shoots occur more frequently in protective forest stands. This increases the stress on the forest [30].

Animals can partially get used to disturbances if they are of a similar nature and predictable. Therefore, in wildlife habitats it is important that ski tourers stick to consistent routes and times instead of touring at all hours of the day. Disturbances should therefore be reduced to a minimum if possible, especially in winter [27].

When disturbed by humans, red deer and other game species have the potential to strongly influence and change their habitats through grazing behavior.

In addition, game hunting can be made more difficult when tourists disturb the game. This leads to lower hunting harvest numbers, which then leads to increased peeling and browsing damage in the forest stands caused by a larger number of surviving animals. This can result in a conflict between hunting and forestry.

According to the ski and snowboard touring concept [27], the following key points regarding feeding and disturbance of red deer are important:

- In winter, the habitat of red deer can be delineated by intensive feeding at a suitable, quiet location without hunting pressure.
- Red deer are accustomed to routine touring parties.
- The distance between recreationists and game where there is visual protection (e.g. dense forest) should be 300 m, and at least 500 m without visual protection (e.g. open field).
- Unpredictable skiing through feeding areas is fatal for deer and the forest vegetation, and therefore the protective forest.
- Disturbances have a particularly strong effect at dusk.

3.3 The workflow for local ski tour steering projects

In areas with obvious conflicts or in areas where ski touring is to be particularly promoted and advertised for tourist interest, such as in the municipality of Gries am Brenner, a precautionary elaboration of control measures makes the most sense to avoid advanced conflicts which are more difficult to handle [31].

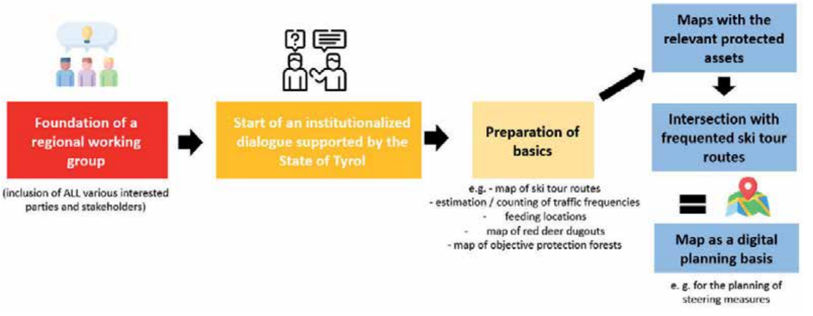


Figure 11.
Scheme of workflow for local ski tour steering projects (after [27]). Icons made by Freepik from www.flaticon.com.

As outlined in **Figure 11**, the existing problem areas and suitable solution strategies are developed together. This results in a map of the protection zones for different protected targets. The definition of the relevant protected targets is the fundamental core of the respective local projects. However, it is not the goal to cover as many as possible or all somehow relevant protected targets, but to define the most relevant targets to be protected and to focus all further steps on the needs of this protection goal and its interested parties [27].

In addition to the experts and institutions that are in principle involved in the initiative, there are numerous other people and representatives of institutions that should participate in local steering projects. The local working groups for the development of ski touring control measures consist of all (representatives of) stakeholders, and the success of the projects shows how important such integration forums are to reach a solution that is acceptable to all stakeholders (**Figure 12**) [32].

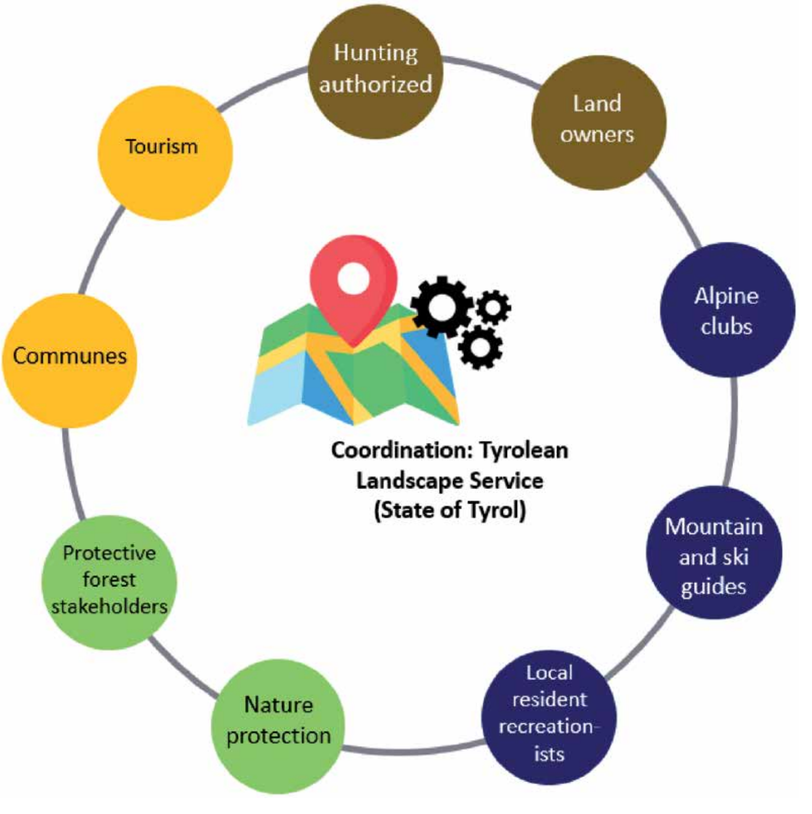


Figure 12.
Example of the composition of a local working group or integration forum, coordinated by the Tyrolean landscape service (after [27]). Icon made by Freepik from www.flaticon.com.

3.3.1 Preparatory expert inputs

The protective forest areas of interest are based on the current mapping of the Abteilung Forstplanung (Forest Planning Department of the Office of the State of Tyrol). Protective forest categories are differentiated, whereby object protective forests with the priority “3” are of particular interest due to their protective effect for settlements, traffic routes and transportation corridors. Whether steering measures are necessary due to direct damage to the regeneration from skiers, and thus the maintenance of the protective effect is particularly important, is assessed within the working group by the representative of the Bezirksforstinspektion (District Forest Inspectorate). Whether there is a disturbance of game, especially where there is a high game density in a small area, is decided by a representative appointed by the Tiroler Jägerverband (Tyrolean Hunters’ Association). Sensitive deer resting areas and feeding locations are made available to the regional working group by those authorized to hunt or by the Abteilung Waldschutz (Forest Health Department of the Office of the State of Tyrol). Maps with all relevant ski tours will eventually be provided by the Tiroler Landschaftsdienst (Tyrolean Landscape Service). The data for this come from the maps of the Austrian Alpine Club, ski touring portals or local experts [27].

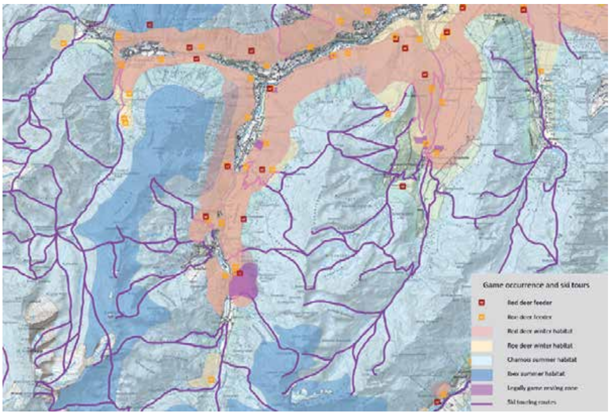


Figure 13.
Map of feeding locations (red and orange dots), spatial occurrence of red and roe deer (red and yellow areas), chamois and ibex as well as official ski touring routes (purple lines). Source: Land Tirol, Forest organization department [27].

Based on elaborated maps as shown in **Figure 13**, different kinds of steering measures can by implemented. In the following subchapter, the most effective measures of the Tyrolean ski and snowboard touring concept [27] are listed.

3.3.2 Which measures and courses of action can be implemented?

The Tyrolean working group for ski tour steering has developed a catalog of measures which basically recommends three different types of measures, and combinations of each (**Figure 14**):

Figure 14.
Possible types of measures and actions for ski tour steering (according to [27]). Icons made by Freepik, Prosymbols & surang from www.flaticon.com.

3.3.2.1 Infrastructure

- Parking lots and parking prohibitions:

  By creating sufficient parking spaces at specifically selected locations, tourers can be redirected to low-conflict routes. Information boards can also be used to provide comprehensive information about game rest areas, ski touring routes, etc. already in place at the parking areas. Parking bans are part of the solution where mass crowds lead to negative impacts.

- Forest paths/routes for ski touring:

  In order to protect adjacent forest regeneration areas or to steer tourers away from game resting places and feeding areas, artificially created forest trails can be an effective measure of steering ski tourers, especially since forest areas and stands have been increasing in Tyrol for decades [33]. However, this approach involves submitting an application in order to be granted permission from the responsible Bezirksforstinspektion (district forestry inspectorate).

- Information boards with ski tours and protection zones & signposts:

  Information boards can be set up, e.g. at starting points for ski tours (parking lots) (**Figure 15**). These can contain low-conflict ski tours, protection zones as well as information on the protected targets and rules of conduct to be observed here. A uniform layout is important for recognition and has been developed by the landscape service (Land Tirol). In addition, guidance can be extended with signposts at strategically important points along the ski tour route.

- Relocation of feeding sites:

  According to §46 of the Tyrolean Hunting Law (TJG), the locations of game feeding sites are to be adapted to local conditions and, if possible, positioned far away from frequented routes of various recreational sports. However, this solution of relocation is usually only considered when other measures have little effect.

Figure 15.
Top right: Structure of a typical information board with ski tour routes, protected targets and protected zones. Top left: Artificial forest aisle with signpost. Bottom: Signpost types for ski tour steering in corporate design [34].

3.3.2.2 Analogue maps and brochures

To be able to communicate the results and requirements of the locally developed ski tour steering measures to ski tourers at low cost, maps and brochures, for example, which are displayed in restaurants or at frequently visited parking lots, are helpful. The distribution and communication by local alpine clubs can also promote this knowledge transfer. Ideally, the protected areas defined in the working groups could also be printed directly on alpine club maps in the future.

To increase the positive perception of ski tourers and promote a uniform image throughout the state of Tyrol, the following steps are important:

- Explanation of the local protected targets with uniform symbols
- Uniform representation of the protected area and/or restricted areas
- Use of the project logo "Bergwelt Tirol – miteinander erleben" ("Tyrolean mountains – experience together")
- Listing of uniform rules of conduct

3.3.2.3 Visitor guidance and steering with new media

As evaluations have shown, the decision on where to go on a tour is made at home the day before or in the tourist's accommodation. If winter tourists have already decided on their route, it is very difficult to influence them afterwards. It is therefore important that the relevant information on ski tour steering (protected areas, restricted areas, protected targets, etc.) is readily available in advance in the most important online portals. This transfer to new media is carried out by the Landscape Service Department (State of the Tyrol), which saves work for the local working group and increases the likelihood that the developed concepts will be circulated.

The official homepage of this initiative (https://www.bergwelt-miteinander.at/winter.html), which contains all the important contents of the project and presents them in a user-friendly way, also serves as a basic tool and means of communication for ski tour steering. Among other things, all regional ski tour steering projects are explained, and the "Tyrolean Ski and Snowboard Touring Concept" is available as a PDF for download.

3.4 Ski tour steering in the Gries am Brenner region

3.4.1 Initial situation

The Obernberg Valley, which is partly represented by the municipality of Gries am Brenner, is a popular destination for ski tourers and snowshoe hikers in winter. Visitors particularly appreciate its natural character, the well-kept rural cultural landscape, the impressive scenic backdrop, easy accessibility and the great variety of ski and snowshoe tours. However, this area is also home to wintering areas for red deer, capercaillie and black grouse. To protect these species, snowshoe and ski touring routes should be designated and should steer clear of their habitats. Therefore, a ski tour steering project was designed and implemented in cooperation with all relevant stakeholders [35].

As outlined in the overall concept, a working group was initiated here to work out the current state, the necessary measures and to answer these basic questions:

- Is there wildlife worth protecting?
- Are forest sites already damaged?
- Are there possibilities to steer ski tourers away?

The local working group is composed of municipality officials, landowners, Austrian Alpine Club representatives, local tourers, tourism association members, hunters, the local forestry authority, nature conservation organizations (e.g. Stubai Alps protected area), a mountain hut owner and the State of Tyrol. All these stakeholders and experts have equal rights and therefore can present their respective concerns [36].

Aside from the committee discussing plans for the region, all ski touring routes were surveyed, visitor counts were carried out at parking spaces and bus stops, the parking behavior of tourers as well as the wildlife habitats were investigated, and the resulting conflict areas were identified (**Figures 16** and **17**) [35].

According to the principles of the "Tyrolean Ski and Snowboard Touring Concept" [27], the project partners agreed on four protected targets after appropriate professional evaluation (**Figure 18**) [36]:

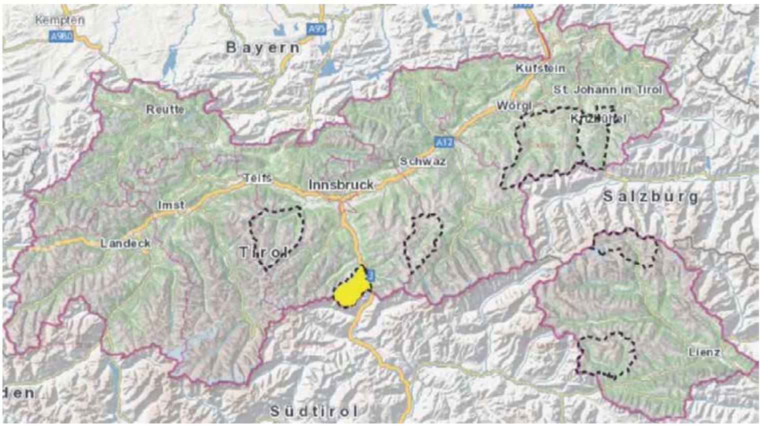


Figure 16.
Projected regions for the ski tour steering program (in black). In yellow: The area of interest near Gries am Brenner. Map source: [37].

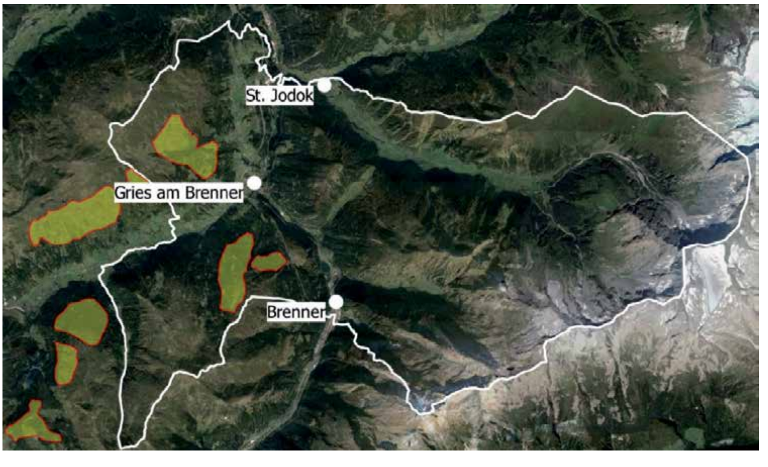


Figure 17.
GreenRisk4Alps PAR (white border) and projected ski tour steering areas (yellow/red). Source shapefiles: Land Tirol – Department Geoinformation. Aerial image: Google satellite.

- Red deer & Roe deer
- Object protective forest
- Chamois & Ibex
- Capercaillie & Black Grouse

Figure 18.
Signs related to the chosen protected targets in the objective region of interest [36].

On this basis, nature-friendly routes, a parking guideline and demarcations for voluntary game protection areas were defined.

3.4.2 What measures have been implemented?

3.4.2.1 New ascent route with signposts

One of the old ski tour ascent routes passed through the middle of a grouse habitat and a nearby red deer feeding location (red sign in the center of **Figure 19**). Due to the high frequency of visitors, there was increased disturbance of game and subsequently also forests at this site. Therefore, a new ascent route was defined and signposted at a sufficient distance from the red deer feeding location and grouse habitat [36].

Figure 19.
Top: Overview of the (new) protection zones and (steered) ski tour routes on Sattelberg Mountain. Source: Department forestry organization. Bottom left: Example of signage for the ascent route. Bottom right: Experts installing signage [36].

3.4.2.2 Panorama boards

Easily recognizable panorama boards providing information about the location of the defined forest and wildlife protection zones have been set up at important trail heads in the region. These boards display the most nature-friendly touring routes and adapted rules of conduct, as well as QR codes that provide further information (**Figure 20**) [36].

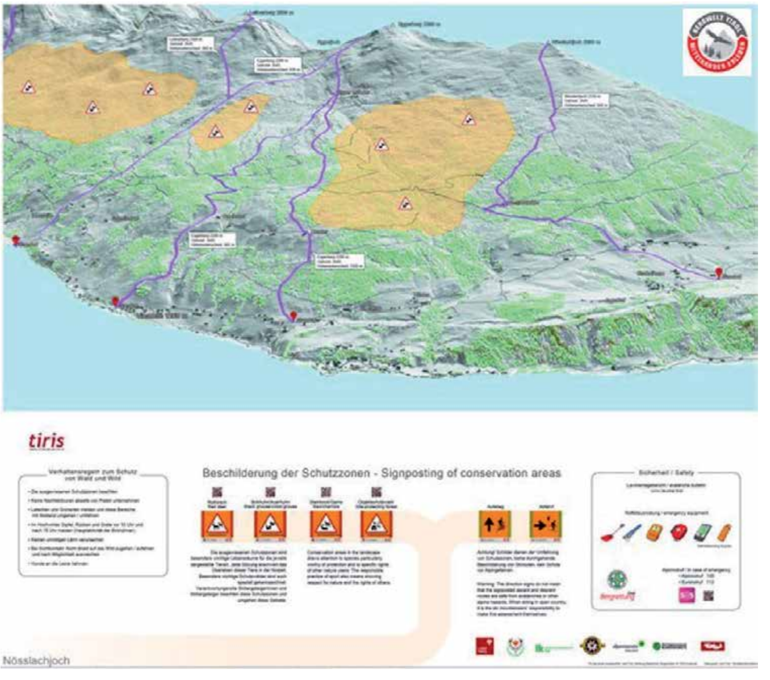


Figure 20.
Panorama board in the objective region with original signposts, suggested nature friendly ski tour routes and safety tips [36].

3.4.2.3 Avalanche transceiver checkpoint

A total of three checkpoints for avalanche transceivers have been set up in the Obernberg Valley (one of them on Sattelberg Mountain). These serve not only as a personal safety check for everyone, but can also record visitor frequency [36], which is particularly helpful for the overall conception of the measures. However, recreationists without avalanche transceivers are not recorded in the survey.

4. Effectiveness of measures/lessons learned

It has been proven that in the projects implemented so far, the targeted surveys and measures have led to a reduction of disturbance factors towards sensitive game and also to a reduction of the negative impacts on the surrounding object protective forests [38].

A webinar held on 20 January 2021 showed that the project described here is not fully completed but is still an important topic of interest and is continually being discussed. The project managers of the Amt der Tiroler Landesregierung (Office of the Tyrolean Government - Department of Landscape Service) invited more than 40 relevant stakeholders and experts from various fields and institutions. Among others, important representatives from the Austrian Alpine Association, the Tyrolean Hunters' Association, the Forestry Directorate of Tyrol with its sub-units, the Tourism Association, Austrian Federal Forests, Tyrol Advertisement Ltd., the Tyrolean Chamber of Agriculture, as well as professional hunters were involved in this meeting. At the beginning, the project initiator presented a status-quo report and practical examples by means of video contributions, which was followed by a lively discussion. According to the meeting minutes of the webinar [38], the following issues were discussed:

- Recent analyses show that the density of tracks (skier lines) in some sensitive areas is still too high despite steering measures. It was noted that ascending skiers are easier to steer than descending skiers, who look for un-skied/tracked areas, e.g. in fresh powder snow. In wide open terrain, the installation of analogue guidance systems is difficult to carry out without considerable effort. Another cause of overuse in sensitive areas arises from ascent routes that have been established for decades, and it is therefore often difficult to persuade locally experienced tourers to use new routes. In already projected regions, the evaluation of visitor frequency (tracks in the snow) will be continued. Continuous optimization of the measures is sought.

- In printed literature such as guidebooks with ski tour descriptions, the desired current state of possibilities (ascent routes, avoidance areas, etc.) is often not yet available. Publishers are sometimes slow to include this information, which needs to be improved.

- In addition to the already established steering measures, the targeted creation of a first track after fresh snowfall would be interesting. Local ski tourers (e.g. on behalf of the Austrian Alpine Association) could create the first correctly running track in order to successfully guide following recreational skiers.

- Even if the intention is only to steer ski tours with particularly strong conflict potential, there is a desire – especially on the part of the hunting association – to speed up the project planning to other areas. Negative hotspots that have been eliminated so far are showing positive effects, but there are still regions where, e.g. due to disturbance of game, shooting plans cannot be achieved. It should be kept in mind that the basic idea behind these projects requires the involvement of all relevant stakeholders, which requires a considerable amount of time and commitment.

- Since ski touring is growing at a fast rate, the topic at hand is becoming increasingly widespread in terms of time and space. In the future, it will be important to raise more awareness within the ski touring community and to make it known that designated protection zones are off-limits for everyone. To be able to identify the location of such protection zones in the terrain, touring platforms need to integrate them into their online services and apps. In addition, social media campaigns of several stakeholders and project partners should be promoted (e.g. avalanche.report, bergfex.at, almenrausch.at, etc.)

- In general, it is important to increase acceptance and awareness of the problem among the public. It will be important to raise concern about the needs of the game and the condition and importance of the protective forest.

Finally, it was noted in this webinar that an overview of related or similar projects as "the best of" from all Alpine regions would be interesting. In principle, the steering concept could be raised to an international level [38], which has already been implemented with the description in this "Best Practice Book" and can thus be promoted and implemented beyond the region of Tyrol!

5. Conclusion

The Tyrolean Ski Tour Steering Concept has been successfully implemented in Tyrol since 2014 and continues to be improved with new ideas involving all relevant stakeholders. So far there have been concrete elaborations of these steering concepts in six Tyrolean regions (**Figure 16**). The successful implementation of local ski tour steering projects contributes significantly to the protection of wildlife and subsequently also to the protection of protective forests. Through targeted surveys of visitor frequencies in sensitive areas, game resting areas, feeding sites and important object protective forests, spatially-specific hotspots can be identified, and measures can be adapted to and implemented in the respective area. The ski touring steering concept clearly demonstrates the importance of integrating all stakeholders in the planning of such governance mechanisms, especially in the case of conflicts, in order to find a satisfactory solution for all parties involved [32].

Acknowledgements

We would like to thank those responsible at the Land Tirol/Forest Group/Department Forest Organization, which launched the initiative "Bergwelt Tirol – miteinander erleben" and continue to develop and move this project forward. Also, all the relevant stakeholders have made significant contributions that have allowed the steering projects to be implemented and this "best practice example" to be written as a result.

Special thanks go to the general project leader and co-author Dieter Stöhr and his team, who not only made the information available to the public but also answered specific questions for online interviews within the framework of this book.

Matthias Plörer was also able to take part in an online workshop, which dealt with the current state and future of the ski tour steering concept. This online workshop with over 40 stakeholders from various disciplines was a clear indication that this concept is not confined to a small user group but will also be of great and broad interest for years to come.

Author details

Matthias Plörer[1]* and Dieter Stöhr[2]

1 Austrian Research Centre for Forests, Department for Natural Hazards, Innsbruck, Austria

2 Amt der Tiroler Landesregierung—Abteilung Forstorganisation, Innsbruck, Austria

*Address all correspondence to: matthias.ploerer@bfw.gv.at

References

[1] Kleemayr, K., Cech, T., Fürst, W., Hoch, G., Ledermann, T., Markart, G., Perzl, F., Schüler, S., Teich, M., Wiltsche, P. (2020): Schutzwald und Extremereignisse. In: T. Glade, M. Mergili, K. Sattler (Hrsg.), ExtremA 2019. Aktueller Wissensstand zu Extremereignissen alpiner Naturgefahren in Österreich. Vienna University Press, S. 623-665.

[2] https://www.statistik.at/blickgem/G0101/g70313.pdf [Accessed: 2021-03-02]

[3] https://www.statistik.at/blickgem/G0101/g70362.pdf [Accessed: 2021-03-02]

[4] https://www.statistik.at/blickgem/G0201/g70313.pdf [Accessed: 2021-03-02]

[5] https://www.statistik.at/blickgem/G0201/g70362.pdf [Accessed: 2021-03-02]

[6] https://www.statistik.at/blickgem/G0404/g70362.pdf [Accessed: 2021-03-02]

[7] https://www.statistik.at/blickgem/G0404/g70313.pdf [Accessed: 2021-03-02]

[8] https://www.statistik.at/blickgem/G0601/g70313.pdf [Accessed: 2021-03-02]

[9] https://www.statistik.at/blickgem/G0601/g70362.pdf [Accessed: 2021-03-02]

[10] https://www.statistik.at/blickgem/G0803/g70362.pdf [Accessed: 2021-03-02]

[11] https://www.statistik.at/blickgem/G0803/g70313.pdf [Accessed: 2021-03-02]

[12] https://www.zamg.ac.at/cms/de/klima/informationsportal-klimawandel/daten-download/klimamittel [Accessed: 2021-03-02]

[13] Hazard Zone Plan: https://maps.tirol.gv.at/synserver?user=guest&project=tmap_master [Accessed: 2021-03-02]

[14] https://www.alpine-space.eu/projects/greenrisk4alps/deliverables/a.t2-actina/d.t2.2.2_report-on-actors-and-networks-for-ecosystembased-risk-management-review-ah.pdf [Accessed: 2021-03-02]

[15] Sausgruber, T. (2019). Risiko Governance bei gravitativen Naturgefahren - ein Abriss zu Österreichs Status Quo. Zeitschrift für Wildbach-, Lawinen-, Erosions- und Steinschlagschutz, 184, 136-149.

[16] Amt der Tiroler Landesregierung, Abteilung Forstplanung (2021): Walddatenbank. Excerpts in the form of Excel tables (ownership structure & harvesting volume) provided by the Province of Tyrol / Forest Planning Department – handed over by Florian Riccabona

[17] Amt der Tiroler Landesregierung, Abteilung Forstplanung (2001): Waldwirtschaftsplan – Gemeindegutswald Gries am Brenner für die Jahre 2001-2020

[18] Amt der Tiroler Landesregierung, Abteilung Forstplanung (2019): Waldtypisierung Tirol – Allgemein

[19] Amt der Tiroler Landesregierung, Abteilung Forstplanung (2019): Waldtypisierung Tirol – Begriffe & Definitionen

[20] European Environmental Agency (2006): EEA Technical report no. 9/2006 "European Forest

Types - Categories and types for sustainable forest management reporting and policy", 113 p.

[21] https://www.tirol.gv.at/landwirtschaft-forstwirtschaft/agrar/agrarrecht/gemeindegutsagrargemeinschaften/ [Accessed: 2021-03-03]

[22] Amt der Tiroler Landesregierung, Abteilung Forstplanung (2001): Waldwirtschaftsplan – Agrargemeinschaft Niedererberg und Fraderwald für die Jahre 2001-2020

[23] Amt der Tiroler Landesregierung, Abteilung Forstplanung (2001): Waldwirtschaftsplan – Agrargemeinschaft Vals für die Jahre 2005-2024

[24] https://www.bergwelt-miteinander.at/ziele-des-programms.html [Accessed: 2021-03-03]

[25] https://www.bergwelt-miteinander.at/winter/ski-snowboardtouren.html [Accessed: 2021-03-03]

[26] https://www.alpenverein.at/portal/news/aktuelle_news/2020/2020_10_20_wissen-skitourensaison-2020.php [Accessed: 2021-03-03]

[27] Amt der Tiroler Landesregierung, Gruppe Forest (2015): Tiroler Ski- und Snowboardtourenkonzept; Bergwelt Tirol – miteinander erleben; 60 p

[28] Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft (2012): Waldentwicklungsplan – Richtlinie über Inhalt und Ausgestaltung; Fassung 2012; Sektion IV (Forstwesen)

[29] Ingold, P. (2005). Freizeitaktivitäten im Lebensraum der Alpentiere. Basel: Haupt Verlag

[30] Reimoser, S. (2013). Störung von Rot- und Rehwild. Weidwerk, 16 – 17

[31] https://www.bergwelt-miteinander.at/winter/ski-snowboardtouren/lokale-projekte [Accessed: 2021-03-03]

[32] Kirchner, M., Krott, M., (2020): Acceptance raising for ecosystem-based risk control. Deliverable D.T4.2.1 report on 'improved RIU model'; Interreg alpine space project "GreenRisk4ALPs".

[33] BFW - Österreichische Waldinventur (2021): http://bfw.ac.at/rz/wi.home [Accessed: 2021-05-05]

[34] https://www.bergwelt-miteinander.at/winter/ski-snowboardtouren/massnahmen.html [Accessed: 2021-03-09]

[35] https://www.alpenverein.at/portal/natur-umwelt/av-naturschutz/besucherlenkung/skitourenlenkung.php [Accessed: 2021-03-16]

[36] https://www.bergwelt-miteinander.at/winter/ski-snowboardtouren/lokale-projekte/obernbergtal.html [Accessed: 2021-03-09]

[37] https://maps.tirol.gv.at/synserver;jsessionid=518ADFAAE5767A493BD20DE0DFCAE1D1?user=guest&project=tmap_master [Accessed: 2021-03-09]

[38] Pietersteiner, K. (2021): Meeting minutes "Webinar Skitourenlenkung – Protokoll zur Videokonferenz am 20.01.2021 von 15:30 bis 17:30 Uhr"

Chapter 6

Kranjska Gora Pilot Action Region: Environmentally-Friendly Construction of the Planica Nordic Centre

Jurij Beguš, Janez Mertelj and Samo Škrjanec

Abstract

The Municipality of Kranjska Gora was chosen as a Pilot Action Region (PAR) due to its location in the Slovenian Alpine area, its extensive forest cover and its important role in tourism and sport activities. As an example of best practice in the implementation of ecosystem-based risk management, the environmentally-friendly construction of the new Nordic center in the Planica Valley is presented, with an emphasis on the role of various stakeholders in the fields of forestry, environmental protection and natural hazard management. The article also presents the forest and forestry in Slovenia and in the PAR, as well as the role of protective forests and other forest functions.

Keywords: protective forest, protective function, forestry, sport centre, cooperation, environmentally-friendly construction

1. Introduction

Several factors contributed to the selection of the Municipality of Kranjska Gora as a PAR area within the GreenRisk4Alps project. The municipality lies in the central area of the Slovenian Alpine region with distinct valleys and steep slopes. The majority of the area is covered with forests, many of which are protective forests that protect buildings and goods against various natural hazards. As one of the main activities in the municipality, tourism is closely connected to forests and their functions. As the host of world-class events, the municipality is also strongly represented in various sport activities, particularly Alpine skiing and Nordic sports.

As an example of good practice related to forest, the environment, tourism, sport and natural hazard management, the world-famous Planica Valley with its newly built Nordic centre was chosen. The centre represents the logical continuation of almost a century of sport and tourism activities in this environmentally sensitive area, where forest, particularly protective forest, plays an important role. Several decision-makers were involved in the siting of the new centre, each of whom contributed to the successful completion of the task from their respective field of expertise.

2. Description of the Kranjska Gora PAR

2.1 General data

The Municipality of Kranjska Gora lies in the northwest of Slovenia, in the three-border area of Austria, Slovenia and Italy, at the foot of the Julian Alps and the Karavanke range, in the narrower area of Triglav National Park, and almost entirely covers the so-called Upper Sava Valley area. It was established as an administrative unit in 1995. It covers 256 km^2 and has about 5,200 inhabitants. The central settlement in the municipality is the village of Kranjska Gora, which dates back to the 14th century; it is the municipal centre and the largest settlement of the Upper Sava Valley (**Figure 1**).

Kranjska Gora is a world-famous winter sport centre [1]. Every year, it hosts the Alpine Ski World Cup on the ski course in Podkoren, and in Planica, it hosts the Nordic Skiing World Cup (ski flying, cross-country skiing) and several other sporting events. In addition, due to its favourable location and rich tourist offer, it is a popular destination for hikers, cyclists, adrenaline enthusiasts, nature lovers and other visitors.

Besides tourism and related activities, other important economic activities include agriculture (livestock breeding, pastoralism and the production of milk and milk-based products), forestry, the timber industry and craft activities (service activities, construction, etc.) [2].

The area of the Municipality of Kranjska Gora is characterised by varied relief with steep slopes, which means that there is a high risk of rapid and intensive natural processes of displacement of materials that could cause material damage to infrastructure, residential and commercial facilities. Many such facilities are situated in the municipality, i.e. roads, cycling trails, mountain trails, ski courses, ski jumps, settlements and hotels, to name just the most important. Due to tourism, these natural risks further endanger human lives, and therefore the municipality is constantly looking for innovative approaches to mitigate these dangers.

Climatologically, the municipality lies in the alpine climate zone. This climate is characterised by long and snowy winters and short, relatively cool summers [2].

The beginnings of tourism date back to 1904. Summer tourism, such as hiking and mountaineering, developed first, followed by winter tourism during the period

Figure 1.
Ski resort in Kranjska Gora (photo: Jurij Beguš).

Figure 2.
The Jasna recreation area near Kranjska Gora is a popular recreational and vantage point (photo by Jurij Beguš).

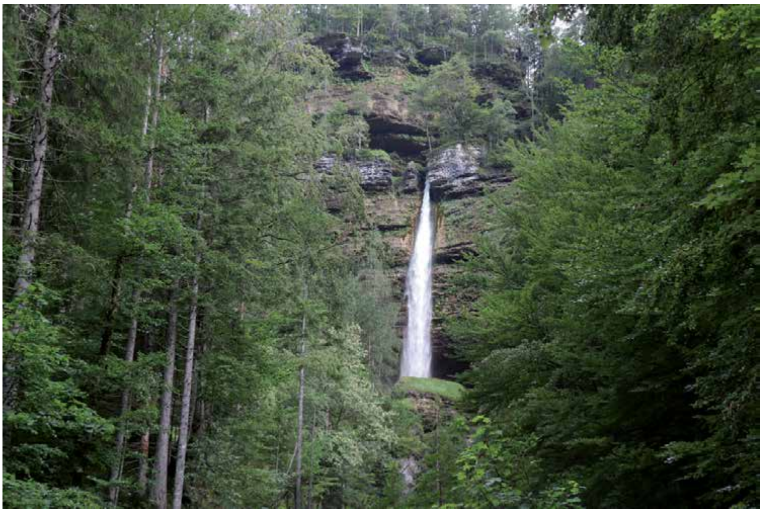


Figure 3.
The Peričnik waterfall (photo: Jurij Beguš).

between the two world wars. This included sledding, skiing and ski jumping in Planica. Besides the already mentioned Planica Valley, the main tourist attractions are the road over the Vršič Mountain Pass with the Russian Chapel, Zelenci (the source of the Sava Dolinka River), the Peričnik Waterfall in the Vrata Valley, the Martuljek Waterfalls, Lake Jasna, the Ajdovska Deklica (Pagan Girl) (a natural feature), the Slovenian Mountain Museum in the village of Mojstrana, and the summit of Tromeja (three-boarder point) on the border with Austria and Italy (**Figures 2** and **3**).

2.2 The main issues and activities in dealing with natural hazards

The area of Kranjska Gora is highly diverse due to various ecological and geomorphological factors. It is a distinctly mountainous area with the Karavanke Mountains in the north (dolomite rock base) and the Julian Alps in the south

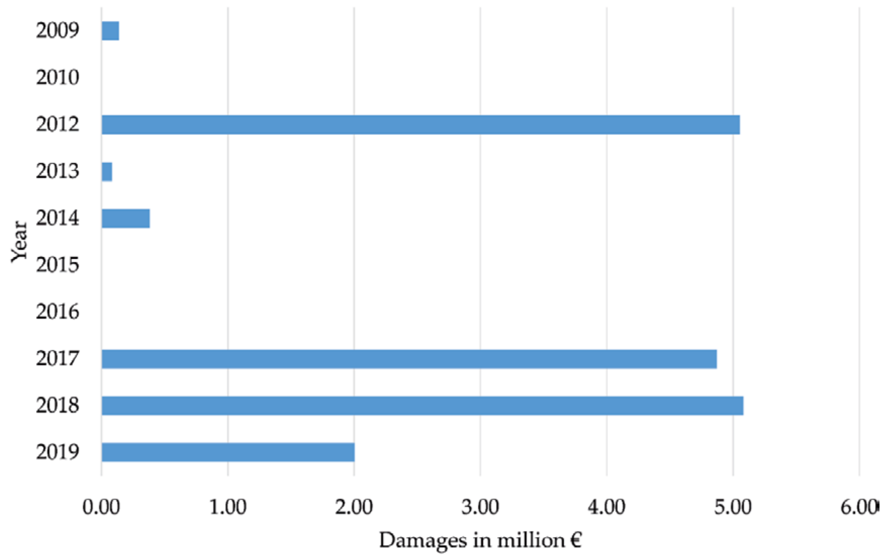


Figure 4.
Damage (in euros) to infrastructure in the PAR caused in the last decade, mainly by storms and wind [3].

(limestone rock base), separated by the flat land of the Sava Dolinka River valley. Due to the steep slopes and high precipitation (1628 mm/year, 2007–2016), the most common natural hazards are torrential riverbeds. Problematic areas can be found throughout the area of the Karavanke Mountains and the Julian Alps. Here, due to material slippage and heavy rainfall, material, which often derives from erosion hotspots, moves along the riverbed and threatens lower settlements and infrastructure. The frequency and economic impact of extreme weather events have been increasing in the past decade (**Figure 4**). Windthrow events, often followed by bark beetle outbreaks (including at higher altitudes), and floods are becoming more frequent. Landslides and rock-falls are particularly dangerous and threaten public and forest roads. In the winter, they are accompanied by avalanches due to the large amount of snow and the long-lasting snow cover.

In addition to technical measures (concrete walls, flood barriers, avalanche galleries, snow protection devices, snow bridges), biotechnical measures in protective forests (preservation of high tree stumps, preservation of fallen trees at a certain angle to the slope, afforestation) have proven to be effective (**Figure 5**).

In the case of extreme events, the Municipality of Kranjska Gora has the authority to activate the Civil Protection Headquarters, which leads the intervention. The Civil Protection Headquarters activates the local fire brigades and subcontractors operating in the field of forestry and infrastructure. Operating within the Municipality of Kranjska Gora is the Kranjska Gora Public Utility Services, which has pre-prepared intervention means and materials for taking quick action (sand, anti-flood bags, rocks, boards, square cross-section timber), and subcontractors are determined in advance (contracts). The intervention system is set up and functions very well. The action follows the already established scheme "prevention – preparedness – response – intervention – restoration".

2.3 Forest and forestry

In order to obtain a clear picture of forests and forestry in the Kranjska Gora PAR, it is necessary to present some basic facts about forests and forestry for the country as a whole (**Figure 6**).

Figure 5.
System of torrent barriers on the Suhelj torrent (photo: Jurij Beguš).

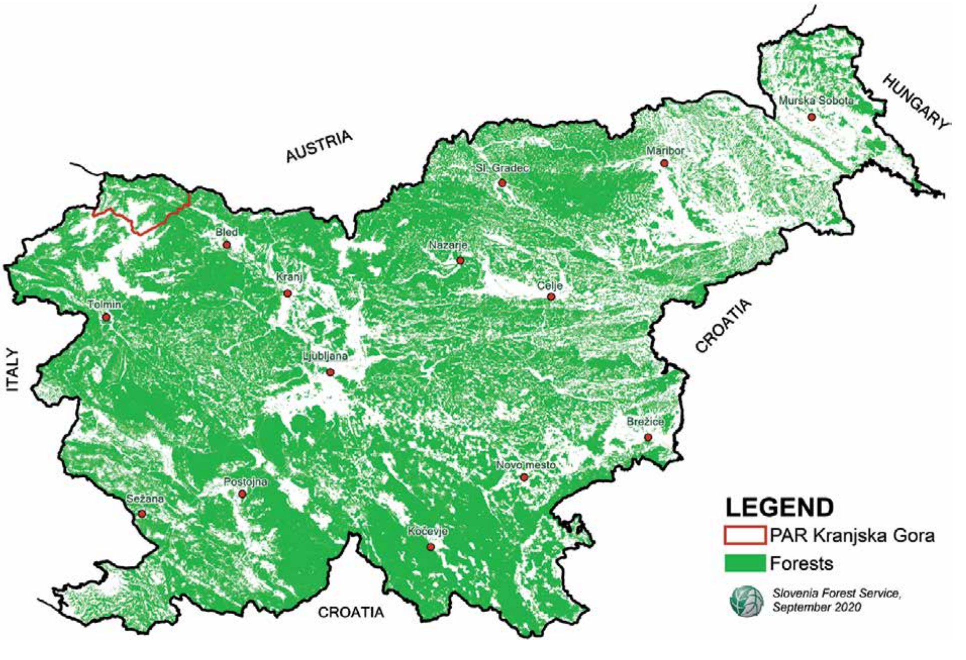


Figure 6.
Slovenian forests and the location of the Kranjska Gora PAR [4].

2.3.1 Forests and forestry in Slovenia

Slovenia is one of the most forested countries in Europe. More than 1.1 million hectares of forests cover more than half (58%) of its territory [4]. There exist more than 70 different forest types in the county, but most forests lie within beech, fir-beech and beech-oak forest sites (70%), which have a relatively high production capacity [5].

Forest management in Slovenia is regulated by the Forest Act [6] and the Slovenian National Forest Programme (SFNP) [7], a fundamental strategic document. The protection function of forests is part of all the main legislation. The Slovenian SNFP contains, among other things, the main strategies for maintaining and strengthening the role of protective forests. Forest management in all forests, irrespective of ownership, is committed to respecting three main principles: sustainability, the close-to-nature concept, and multi-objective forest management. The main tool for the implementation of these principles is the forest management planning system, using a participatory process to address the relevant public (forest owners, municipalities, different organisations, the public). Increasing demands for a vast array of ecosystem services have emphasised the importance of multi-objective forest management. As a solution, the integration model of multi-objective forest management has been practiced, and represents an important management tool to implement the concept of forest functions [5].

According to data on forests collected by the Slovenia Forest Service [4], the growing stock of Slovenian forests amounts to 357 million m^3 or 303 m^3 per hectare. Coniferous trees account for 45% and deciduous trees for 55% of the growing stock. The annual increment is 8.8 million m^3 of wood per year or 7.5 m^3 per hectare. In recent years the annual cut in Slovenian forests has totaled between 5.0 and 6.3 million m^3 of trees.

In Slovenia, 76% of forests are privately owned, 21% are owned by the state and 3% are owned by local communities. Private forest estates are small, with an average area of only 3 ha. They are typically fragmented into several separate plots and are becoming even more fragmented as the number of forest owners is increasing. According to the latest data, there are already 413,000 forest owners in Slovenia [4].

In addition to damage caused by weather (wind, ice, snow), Slovenian forests have recently been threatened by insects (mainly bark beetles), which are the most common reason for sanitary cutting. On average, sanitary cutting ranges from more than 50% to as much as 70% of the entire annual cut.

2.3.2 Forests and forestry in the Kranjska Gora PAR

Forests represent the most extensive and important landscape category in the PAR (**Table 1**), as forest cover more than half of the area. Due to the alpine conditions, protective forests account for 45% of the entire forest cover in the PAR, which is relatively high compared to typical Slovenian conditions.

According to ecological and vegetation conditions, beech forest types predominate. **Table 2** presents the share (as a percentage of the total forest area) of the most important forest types, based on European forest types [10], among managed and protective forests.

	Surface area (ha)	Share of the surface area of the municipality (%)
Area of the municipality	25,631	
Commercial forest	7,926	31
All forests (forest and other forest areas)	14,578	57
Protective forests	6,652	26

Table 1.
Share of forests in the Kranjska Gora PAR area [8, 9].

Forest type	%
Managed forests	
3.1 Subalpine larch-arolla pine and dwarf pine forest	4
3.2 Subalpine and montane spruce and montane mixed spruce-silver fir forest	6
3.3 Alpine Scots pine and black pine forest	3
5.8 Ravine and slope forest	1
6.4 Central European submontane beech forest	10
6.4 Central European submontane beech forest	2
7.4 Illyrian montane beech forest	74
12.1 Riparian forest	1
Protective forests	
3.1 Subalpine larch-arolla pine and dwarf pine forest	25
3.2 Subalpine and montane spruce and montane mixed spruce-silver fir forest	1
3.3 Alpine Scots pine and black pine forest	9
6.4 Central European submontane beech forest	3
6.4 Central European submontane beech forest	1
7.4 Illyrian montane beech forest	61
8.8 Other thermophilous deciduous forests	1

Table 2.
The share (as a percentage of the total forest area) of the most important European forest types – managed and protective forests [9–11].

Although beech forest types predominate, and consequently beech is expected to be the predominant tree species, the leading tree species is still spruce, which is more or less due to a historically conditioned approach to forest management. Spruce accounts for more than half of the growing stock, followed by beech and larch (**Figure 7**).

Most forests are privately owned. The average estate totals 15.8 hectares, which is far above the Slovenian average. In turn, this means that guidance and forest management is easier to implement and more economical here. Forest owners are responsible for forest management (**Table 3**).

Wood production takes place mainly as manual felling and tractor harvesting, while in steeper areas, cable logging is performed (**Figure 8**). Forestry infrastructure, forest roads and skid trails are adapted to these methods.

The average growing stock in the PAR forests totals 373 m^3/ha, and the average increment totals 7.4 m^3/ha. The majority of the growing stock consists of conifers (69%) (**Table 4**).

Forest management guidance is prescribed by forest management plans for all types of properties (private, state-owned, municipalities), which is the task of the Slovenia Forest Service. Forest management planning is also an important tool which enables the transfer of scientific knowledge into everyday use. Thus, models and maps developed in the framework of scientific research are included in forest management plans. For example, models for determining protected forest areas prepared within the GreeRisk4Alps project and management strategies for protected forests are included in forest management plans. Furthermore, the results

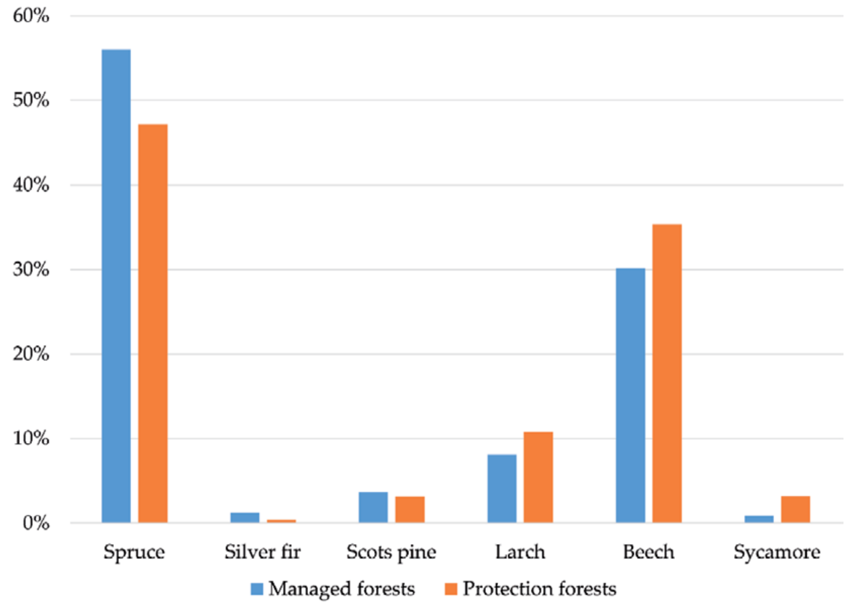


Figure 7.
Shares of the main tree species (%) in the total growing-stock – Managed and protective forests [9].

	Ownership			
	Private	**State**	**Local community**	**Total**
Forest area (ha)	13,300	1,193	85	14,578
Share (%)	91	8	1	100

Table 3.
Forest area in the Kranjska Gora PAR by form of ownership [8].

of research and guiding principles from forest management plans are transferred to the operational level to reach all interested parties.

2.3.3 Natural hazards and forest protection in the light of climate change: Kranjska Gora PAR

Records on the annual cut (regular cut, sanitary cut, ...) for the period 1995–2019 show that until 2003, the share of the regular cut was between 90% and 70%. In 2003, the sanitary cut due to windthrow amounted to more than 40% of the annual cut. Later, in the period 2008–2011, the sanitary cut increased due to a bark beetle outbreak in the aftermath of a windthrow (**Figure 9**).

Major disturbances in the forests continued in the Kranjska Gora PAR with a massive amount of trees felled and damaged by an ice storm in 2014, which was followed by bark-beetle infestations and windthrows. This increased the sanitary cut up to almost 80%. The effects of climate change are clearly visible after 2014, and this has greatly affected forest management in the PAR (**Figure 10**).

2.3.4 Forest functions/ecosystem services in the Kranjska Gora PAR

In Slovenia, multi objective forest management following an integrative approach is applied, and forest functions are used as a main tool. The Slovenian

Figure 8.
Cable logging (photo: Jurij Beguš).

Forest category	Area (ha)	Growing stock (m^3)			Increment (m^3/year)		
		Conifers	**Broadleaves**	**Total**	**Conifers**	**Broadleaves**	**Total**
Managed forests	7,926	2,055,547	973,750	3,029,297	34,670	16,068	50,737
Per hectare		259	123	382	4.4	2.0	6.4
Forests with special purposes[1]	567	53,954	32,760	86,714	710	470	1,180
Per hectare		95	58	153	1.3	0.8	2.1
Protective forests	6,085	706,850	455,147	1,161,997	9,460	8,269	17,730
Per hectare		116	75	191	1.6	1.4	2.9
All forests	14,578	2,816,351	1,461,657	4,278,008	44,840	24,807	69,647
Per hectare		193	100	293	3.1	1.7	4.8
%		66	34	100			

Definition from the Slovenian Forest Act (Section 44):
Forest in which there is a special emphasis on the research function, hygiene-health function or the function of the protection of natural and cultural heritage;
Forest in which there is a special emphasis on the protection, recreation, tourist, educational, defence or aesthetic functions;
Forests in areas that have been declared natural features of interest according to the regulations on the protection of natural heritage.

Table 4.
Basic forestry data for the Kranjska Gora PAR [8, 9].

Forest Act defines 17 forest functions classified into social, ecological and productive functions. The importance of each function is ranked according to three levels: in the first level, the function determines the management regime; in the second level, the function influences the management regime; and in the third level, the function has no significant influence on the management regime. Two forest functions are closely connected to the protective role of forests: 1)

Figure 9.
Bark beetle attack close to the village of Mojstrana (photo by J. Beguš).

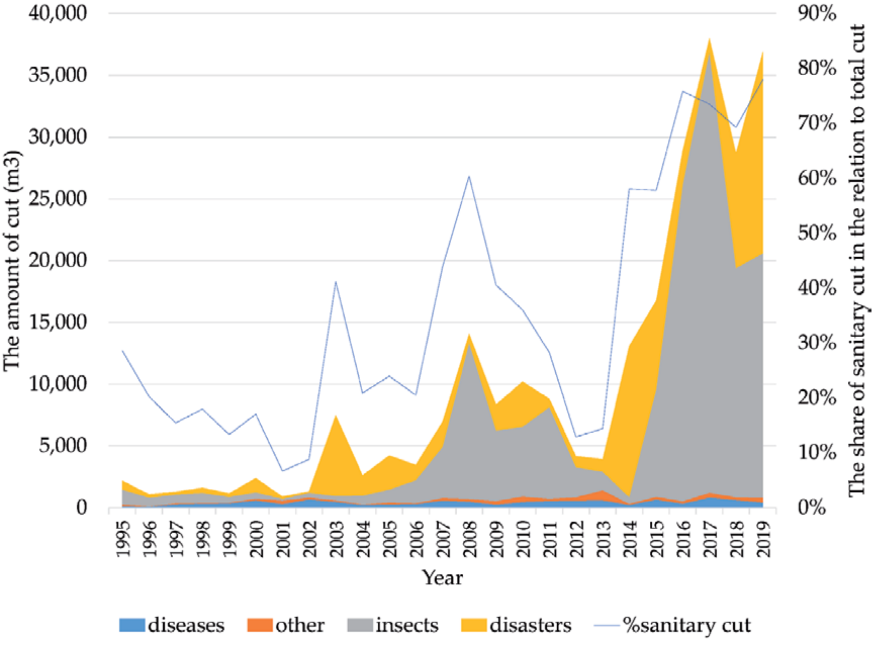


Figure 10.
The amount of sanitary cut in the Kranjska Gora PAR by year [4].

protecting forest soil and stands, hereafter the "indirect protective function", and 2) protecting people, assets and properties, hereafter the "direct protective function". Additionally, forests that during extreme ecological conditions protect themselves, the surrounding site and the land below them, as well as forests with a significant role in any other ecological function (e.g. biodiversity conservation function), are declared by the Forest Decree as a special category of "protective forests". The majority of forests with indirect or direct protective functions are included in this category [8].

In the Kranjska Gora PAR area, many of the functions and interests that need to be considered in forest management are intertwined. In terms of area covered, ecological functions are the most extensive, followed by production and social functions. Among the ecological functions with the first level of importance, the largest area is covered by the function of the protection of forest lands and forest stands, which is set at almost 70% of the forest area, and the function of biodiversity conservation, which is set at 17% of the forest area. The hydrological function has the first level of importance at 12% of the forest area. Among the social functions with the first level of importance, the function of the protection of natural values predominates with 47% of the forest area. This is followed by the recreational function and the research function [7].

2.4 Promotional and extension activities dealing with protective forests

Through promotion and extension activities, relevant stakeholders in forestry are addressed to make sure they are well and properly informed about the importance of the protection functions of forests. To achieve this, different ways of extension (direct contact or at a distance, individually or in groups), different methods (counselling, workshops, training, etc.) and all possible information and education channels (media, internet, training, lectures, etc.) are used. Thus, two main goals are achieved: 1) the content of the statutory regulations and policies in the forest management plans has to be transferred to the stakeholders and 2) scientific results are transferred to users.

A good example is the workshop on "Forestry Operations in Protective Forests with an Emphasis on Rockfall Areas", which was developed under the RockTheAlps project (November 2016 – October 2019) and is also part of dissemination activities under the GreenRisk4Alps project in Slovenia. The main goal of this workshop is to transfer scientific results and legal policy to those who need such knowledge in their everyday activities – knowledge about rockfall problems, the importance of the protective role of forests in Alpine space, and knowledge about the management of such forests, with an emphasis on performing forestry operations. The workshop consisted of a theoretical and a practical part (in the field) and is a part of the extension activities of the Slovenia Forest Service.

3. The new Planica Nordic Centre – An example of good practice in the Kranjska Gora PAR

The valley of ski jumps, as Planica could be called, lies near the settlement of Kranjska Gora in the extreme west of the PAR area and has been the scene of Nordic sport activities at the highest international level for almost a century. At the end of the last century, sport facilities in Planica became somewhat outdated and dilapidated, and it was not easy to follow the requirements of modern sport. In the year 2000, the decision was made to reconstruct and upgrade the existing facilities with the new Planica Nordic Centre (hereafter "Nordic Centre") and to modernise the implementation of existing activities and supplement them with new ones. Today, the offer not only includes ski jumping, but also cross-country skiing, and both activities can be carried out throughout the year (**Figure 11**) [12].

The reason that the construction of the Nordic Centre was chosen as an example of good practice in the Kranjska Gora PAR lies in the fact that the construction in all its phases was carried out in an environmentally-friendly way. The Nordic Centre investors were well aware that without proper cooperation with various stakeholders and institutions, they would not be able to carry out this task successfully. In doing so, it was necessary to respect Slovenian legislation, which is very strict with

Figure 11.
The location of the Planica Valley [13].

respect to nature interventions. Such an intervention as the construction of the Nordic Centre has an impact on the forest, on other natural values, on the water regime with an emphasis on the regulation of torrents, and on the aesthetic image of the natural environment. With the right approach to the planning and construction of the Nordic Centre, the above have not been affected, the impacts of natural hazards have not increased, forest functions have been preserved, and that the Nordic Centre is very well positioned in the landscape.

3.1 General information

The Planica Valley is a typical glacial valley in the northwestern part of the Julian Alps. It is approximately seven kilometres long and stretches from the settlement of Rateče to the "Dom v Tamarju" mountain hut. Except for the village of Rateče, the valley is surrounded by mountains. The varied valley bottom of the Planica Valley is covered by glacial moraines and screes that are swept away by torrents. In the lower part of the valley, the forest is intertwined with hayfields. The upper part of Planica is dominated by forests.

At the beginning of the central part of Planica Valley, at the foot of the Ponce mountain group, a series of Planica ski jumps are the most important facilities of the Nordic Centre. The border of Triglav National Park, the only national park in Slovenia, runs just above these jumps. In the winter, the lower part of the valley is interspersed with regulated runs for cross-country skiing and walking.

3.2 History

Already in 1926, cross-country skiing competitions were organised in Planica. The valley was becoming a popular destination for tourists and nature lovers, and the ideal conditions for winter sports activities attracted an increasing number of athletes, which gave birth to the idea of a modern ski jumping and cross-country skiing centre. This was made possible by favourable winter conditions and the proximity of the railway line, which led to the inauguration of a modern and year-round supplied guesthouse in 1931.

Based on Stanko Bloudek's[1] plans, the Bloudek Giant ski jumping hill in Planica was built in 1934. Even then, the first of many world records was set on the hill.

[1] Stanko Bloudek (11 February 1890–26 November 1959) was a Slovenian aeroplane and automobile designer, sportsman and sport inventor, designer, builder and educator.

Figure 12.
The forests are also important for wind protection (photo: Jurij Beguš).

In 1936, the ski jump was enlarged, and the first man jumped beyond the magical 100 m mark. Thus, Planica became the cradle of ski flying. In 1969, a new, larger ski jump was built based on the plans of the Gorišek brothers[2], and in 1994 the 200 m mark was eclipsed. Despite the centre's worldwide fame, the dilapidation of some of the facilities led to the persons responsible considering a thorough renovation and establishment of a modern Nordic sports centre in Planica.

3.3 Forests and natural hazards in the Planica Valley

The forests in the area of the Nordic Centre and in the entire Planica Valley have, in addition to their production role, other functions that are very important for the operation of the Nordic Centre. One of the most important is the protective role of the forest, which is significant around the Nordic Centre due to the protection of buildings and structures against rockslides and falling rocks, avalanches, torrents and water erosion. These are also the most important natural hazards in the vicinity of the Nordic Centre.

The forests in the vicinity of the Nordic Centre are also important for wind protection, which is crucial for the implementation of competitions and for carrying out training on the ski jumps, especially the giant Planica ski jump. The forest creates an extremely important microclimate with favourable wind and thermal conditions (**Figure 12**).

The aesthetic function of the forest is also very important, as the forest irreplaceably complements the beautiful backdrop of the structures themselves and the entire valley.

Therefore, it is even more important that this landscape component was taken into account as much as possible in the construction of the Nordic Centre and that the forest was encroached upon with filigree precision (**Figure 13**).

[2] Janez Gorišek (born September 13, 1933) and Vlado Gorišek (4 January 1925–2014 June 1997) were Slovenian civil engineers, builders and architects. Their work consisted mainly of the design and construction of ski jumping and ski flying hills worldwide.

Figure 13.
The view of the forests towards mount Jalovec above the Planica Valley (photo by J. Beguš).

3.4 The construction process of the Planica Nordic Centre

The central idea in the construction of the new Planica Nordic Centre was to modernise the sports centre to bring it in line with international standards, which would benefit sports, the state and the municipality, as well as the local population. The idea was to establish a one-stop-shop centre for Nordic disciplines, i.e. ski jumps, cross-country skiing tracks and a covered training centre which would allow the use of the facilities throughout the year, as well as the possibility of recreation and entertainment for other visitors.

The necessary steps were (1) to develop a conceptual plan and apply for European funds; (2) to purchase the land; (3) to adapt the relevant legislation; (4) to establish fair cooperation between the municipality and the local population; (5) to invite all stakeholders – formal and informal – to cooperate; (6) to establish a construction committee; (7) to hold an architectural competition and select the appropriate solution; (8) to obtain all necessary consents and guiding principles from the relevant stakeholders – nature conservation, water protection, forestry, municipality, Triglav National Park, etc.; (9) to carry out construction; and (10) to put the Nordic Centre into operation.

The first activities related to the construction of the Nordic Centre began in 2007, namely with the purchase of land by the Government of the Republic of Slovenia. The Municipality of Kranjska Gora played an important role in this, transferring its land to the state free of charge, thus giving the signal to other landowners that it supported the idea and the project, and thus enabling the purchase of land to take place fairly smoothly. The municipality has actively participated in other ways and is still an important partner of the Nordic Centre. When the Planica Nordic Centre Act was adopted, the foundations were laid for the Planica Institute (established within the framework of the said Act) to prepare all the relevant documentation and apply for funding from the EU Regional Development Fund.

As a coordination body for the construction of the Nordic Centre, a special committee was established, consisting of experts from various fields from the Ministry of Education, Science and Sport; the Planica Institute of Sports of the Republic of Slovenia; and the Ski Association of Slovenia. The committee made a significant contribution to improving the programme and the implementation solutions developed through the architectural competition. A representative of the ministry took care of the financing from the European Regional Development Fund, while the management of the investment and later the management of the new infrastructure were entrusted to the representatives of the Planica Institute of Sports of the Republic of Slovenia.

3.4.1 Legal framework and institutional involvement in the planning and construction process

For the purposes of the construction and management of the Nordic Centre, the Government of the Republic of Slovenia adopted a special Planica Nordic Centre Act (in 2010), which further determines the area and management of the Nordic Centre and the implementation of the spatial interventions necessary for its construction. In 2000, the Municipality of Kranjska Gora adopted the ordinance of the management plan for Planica and in 2012, the ordinance on amendments and supplements to this plan. The management plan is a spatial implementation act, which determines in more detail the criteria and conditions in terms of function, design, infrastructure and protection for regulating and equipping the area in question, and which is the basis for issuing a building permit. Individual articles stipulate the regulation of torrents in the forests alongside the ski jumps, the protection of areas against erosion, the protection of natural heritage and environmental protection.

Based on Slovenian legislation, the following institutions were involved (as approving bodies responsible for forestry, water and nature protection) in the process of constructing the Nordic Centre:

- The Institute of the Republic of Slovenia for Nature Protection (ZRSVN), whose mission is to preserve the natural environment of Slovenia. It strives for the lasting harmonious coexistence of nature and people and the rational use of renewable and non-renewable natural resources. The area in question falls under the responsibility of the Kranj Regional Unit.

- The Slovenian Water Agency, which performs professional, administrative and development tasks in the field of water management in accordance with the regulations governing waters at the national level. The Upper Sava sector is responsible for the area in question; they were mainly responsible in the regulation of the Nadiža watercourse and the Ciprnik alluvial cone.

- The Triglav National Park Public Institution (hereinafter referred to as (TNP) manages the only Slovenian national park, which was established in 1981. The basic goal and purpose of Triglav National Park is to preserve exceptional natural and cultural values and to protect autochthonous flora and fauna, ecosystems and characteristics of the inanimate world.

- The Slovenia Forest Service is the central Slovenian institution in directing the development of forests in Slovenia. It is divided into 14 regional units, and the Bled Regional Unit (hereinafter SFS) is responsible for the forests in the Municipality of Kranjska Gora.

3.4.2 Architectural solution and construction

The public tender for the selection of the most professionally suitable solution for the comprehensive design of the Nordic Center and architectural and landscape architectural solutions was completed in autumn 2009. The special investors'

Figure 14.
The position of ski-jumps at the bottom of Ponce ridge (photo: Jurij Beguš).

commission assessed the proposals on the basis of the attitude towards the entire environment of Planica, including the placement of facilities in the landscape. The selected solution was prepared by Studio AKKA (**Figure 14**).

The Nordic Centre is located in the landscape such that the lines of the ski jumps and slopes meet at one point, and the centre also does not interfere with the view of the mountain landscape. Construction took place from 2011 to 2015. During this time, the following facilities were reconstructed or built: Bloudek's Giant ski jump, three children's ski jumps, two youth jumps, the Gorišek Brothers' ski-flying hill, the Čaplja service facility, a central cross-country skiing facility with a viewing platform, a preparation facility at the top of the ski-flying hill, and cross-country ski trails with a total length of 40 km.

The Čaplja service facility is intended for controlling the operation of the ski jumps, changing rooms, ski servicing, storage of equipment and socialising among the athletes. The facility also has a pumping station for an artificial snow system, ski jump irrigation and central control system.

The central cross-country skiing facility with a viewing platform has two functions. During competitions, it offers all the infrastructure for the implementation of competitions at the highest level, and in the remaining time it serves as the central facility, housing all the programmes intended for visitors to Planica outside the events.

The construction was placed such that all the vegetation was preserved or was supplemented with new plantings. The facilities are multi-functional, and their use takes into account the latest standards of environmentally-friendly energy use. In addition, some temporary access routes and the Macesnovec-Drnice forest road were built to provide access to construction sites.

3.5 The role of individual approving bodies and major stakeholders

3.5.1 The municipality of Kranjska Gora

The Municipality of Kranjska Gora was actively involved in the construction of the Nordic Centre from the very beginning. In order to ensure that construction would run smoothly, and above all, in order to be able to obtain all the necessary permits, it was necessary to adopt certain municipal acts and to ensure that specific legislation was adopted. In 2000, the municipality adopted a management plan for the Planica area. It also participated intensively in the adoption of the Planica Nordic Centre Act, which finally removed all administrative obstacles to the construction of the Nordic Centre itself.

The municipality played a very important role in convincing landowners to sell their land to the state. Setting an example to all, the municipality transferred its land to the state free of charge, thus giving a clear signal to landowners that it supported the construction of the Nordic Centre, and that the construction of the Nordic Centre was a good investment. For this purpose, the municipality organised meetings with landowners, where it also supported the planned project and actively participated in all steps of planning and construction of the centre.

The municipality was clearly aware that such a centre is not only a sport and tourist attraction, but also a great opportunity to promote the place itself, especially in terms of a tourist destination, providing new jobs and earnings for the locals. In addition to tourism and visits to the ski flying competitions, a large part of the earnings is represented by the training of athletes throughout the year. The centre also offers cross-country skiing training in the summer in the covered part of the central building. Thus, according to the centre, 200,000 training units are performed annually, of which 11,000 represent foreigners from 23 countries, which not only means earnings for the Nordic Centre itself, but also earnings for providers of hotel and other tourist services.

3.5.2 Institute of the Republic of Slovenia for nature protection (ZRSVN)

The role of the ZRSVN in the siting of the Nordic Centre was mainly in the formal inclusion of the project in obtaining environmental and nature protection consents with an expert opinion, which were the basis for issuing a building permit.

The ZRSVN prepared several expert opinions and proposed several mitigation measures and recommendations to reduce the negative impacts of the construction on the environment, which were mostly summarised in its decisions by the Slovenian Environment Agency (ARSO). With the investors, the ZRSVN coordinated at meetings and field trips investors' wishes with actual opportunities in nature. During the construction, the investors respected all key mitigation measures and recommendations prepared by the ZRSVN. Since the completion of the construction of the Nordic Centre, this cooperation has been less intense, though it still exists. It focuses on individual questions by the Nordic Centre operator about individual specific measures that must be implemented during operation.

3.5.3 Slovenian water agency

During the preparation, planning and construction of the Nordic Centre, the Water Management Office was still operated within the Slovenian Environment Agency (ARSO). The Slovenian Water Agency (DRSV), and thereby the administrative, professional and development tasks in the field of water management, began its work in early 2016. The entire field of work thus passed from ARSO to the DRSV.

With the decision of the Government of the Republic of Slovenia, all land in the area of the Nordic Centre is owned by the Republic of Slovenia, regardless of the type of use, and managed by the Planica Institute of Sports of the Republic of Slovenia, including lands with water and lands with watercourses on them. In the spatial planning procedures, the field of water management was involved in obtaining guidelines and opinions in the field of spatial legislation. Specifically, water consents were issued for individual phases of the intervention as prescribed by law.

Figure 15.
Regulation of the Nadiža torrent at the foot of the Planica ski-flying hill (photo: Jurij Beguš).

Water permits were also issued for special water uses, such as snowmaking and heat recovery.

The building designers and the Nordic Centre had to pay special attention to the water flow of the Nadiža (Beli potok), which was already regulated by the Nordic Centre, and it was necessary to ensure that flood and erosion conditions would not worsen (**Figure 15**). In doing so, the DRSV participated as an administrative body, also giving advice and recommendations for the implementation of measures that were still acceptable. Upstream of the giant ski jump, the existing flood barrier was raised, restricting the transport of sediments across the regulated section through the Nordic Centre. The Nordic Centre also implemented stabilisation and protection measures on top of the alluvial cone below Ciprnik, which could directly threaten part of the Nordic Centre area during storms, i.e. the central building, the giant ski jump's landing strip, part of the parking lots and the cross-country ski tracks.

The provider of the obligatory state commercial public water management service in the Upper Sava area, as well as for the entire area, also monitors the condition of the watercourses, torrents, lands with water and lands near banks and water facilities, as well as water infrastructure in the area of the Nordic Centre.

3.5.4 Triglav National Park Public Institution

The Triglav National Park Public Institution (TNP) was involved in the process of obtaining nature protection consent for the said intervention as part of the siting of the Nordic Centre. Although the entire intervention was planned and carried out outside the area of the national park, the Public Procurement Agency was included in the procedure by the Slovenian Environment Agency, which conducted the procedure for issuing nature protection consent due to the area of intervention.

Namely, the Nordic Centre was planned directly on the border of the park; therefore, it was estimated that the existing and planned facilities and infrastructure arrangements would lead to a significant increase in the number of people visiting the protected area throughout the year.

Pursuant to the Triglav National Park Act, the TNP participates in the procedures for obtaining consents in the field of the construction of facilities and interventions in space with a mandatory expert opinion. In its expert opinions, the TNP directed the investor to strictly observe the protection regimes of the national park and thus to withdraw interventions from the immediate vicinity of the national park border.

3.5.5 Slovenia Forest Service

The Slovenia Forest Service (SFS) participated in the Nordic Centre project from the very beginning, first as an approving body and subsequently by making a number of proposals and solutions, especially in terms of forest management in the narrower but also in the wider centre area and in connection with the preservation and strengthening of the forest functions in this area.

As some forests on the construction site of the Nordic Centre were proclaimed protection forests by law, the investor had to obtain the positive opinion of the Ministry of Agriculture, Forestry and Food.

An important role of the SFS in the construction of the Nordic Centre was to assist in constructing (mostly forest) infrastructure that provided access to construction sites. In this area, the Macesnovec-Drnice forest road was built. The forest road is important for forest management and for the construction, operation and maintenance of facilities in the Nordic Centre (**Figure 16**). The conceptual route and course of the zero line of the planned forest road was prepared by the SFS in 2009, taking into account the optimal relationship between the needs of forest owners inside and outside the Nordic Centre area and the requirements for access to facilities (**Figure 17**).

In the same year, the chairlift connecting the bottom of the ski jumps with the top of the ski-flying hill was completed, and from the intermediate station, there is access to the Bloudek ski jump inrun. In order to implement the chairlift route, the SFS selected trees for felling in the width envisaged by the project, but it was

Figure 16.
The Macesnovec-Drnice forest road enabled access to the construction site (photo: Jurij Beguš).

Figure 17.
The position of the Macesnovec-Drnice forest road [4].

necessary to pay attention to the stability of the edge trees so that these trees would not later endanger the facility itself.

Wherever necessary, the SFS participated in the selection of trees that needed to be removed due to the construction of the facilities, as well as in the tracing and siting of smaller or temporary transport roads. After the completion of works, most of these paths were reconstructed and the terrain was levelled, grassed over and in some places replanted.

In the final phase of construction, the cross-country ski tracks were built and the final arrangement of the Nordic Centre was carried out. In the first part, the SFS together with other professional services (ARSO, TNP, ZRSVN), managed to provide an optimal solution for the forest and forest area, as well as for the planners of the cross-country ski trails, especially in terms of complexity and the sports and technical parameters of the tracks. In the final arrangement of the Centre, the SFS prepared guidelines and technical requirements for planting (the selection of tree and shrub species and herbs with an emphasis on indigenous and habitat-appropriate plant species) on the basis of the forest management plan of the Kranjska Gora forest management unit and associated silvicultural plans. The time, manner and spatial distribution of planting were also determined.

Due to the construction technology and the gradual construction, and despite the absence of a special integrated logistics plan, practically all of the functions of the forest stands have been preserved. This was facilitated by the exemplary and proactive cooperation of all stakeholders, both the SFS and forest owners, but above all those responsible for project management, in which the stakeholders always had a correct and interested interlocutor.

4. Conclusion

An important focus at the conclusion is that a disregard for legal, professional and aesthetic frameworks in the construction of the Nordic Centre could have irreparably encroached on sensitive natural ecosystems and the picturesque Alpine landscape. The founders of the Nordic Centre were well aware that without proper cooperation with various stakeholders (especially forest owners and the Municipality of Kranjska Gora) and institutions, they would not have been able to perform this task well – in fact, they would not have been able to perform it at all, because Slovenian legislation is very strict in the field of nature intervention. Such an intervention has, of course, an impact on the forest, on other natural values, on the water regime with an emphasis on the regulation of torrents, and on the aesthetic image of the natural environment.

The correctly managed construction of the Nordic Centre is a success story regarding environmental protection and placement of facilities in the landscape. This was the main reason why the Planica Nordic Centre was chosen as good practice in the Kranjska Gora PAR.

Acknowledgements

Finally, we would like to thank everyone who contributed to the creation of the text. We would especially like to highlight the employees of various institutions that participated as co-approvers in the process of building the Planica Nordic Center. The field of nature protection was covered by Mrs. Sonja Rozman; cooperation with the Water Directorate of the Republic of Slovenia was described by Mr. Urban Ilc; information on the participation of Triglav National Park was prepared by Mr. Aleš Zdešar; and Mr. Jure Žerjav helped with topics related to the importance of the Nordic Center and the chronology of its construction. We would also like to thank the employees of the Municipality of Kranjska Gora.

Author details

Jurij Beguš[1]*, Janez Mertelj[2] and Samo Škrjanec[1]

1 Zavod za gozdove Slovenije (Slovenia Forest Service), Ljubljana, Slovenia

2 Zavod za gozdove Slovenije (Slovenia Forest Service), Jesenice, Slovenia

*Address all correspondence to: jurij.begus@zgs.si

References

[1] www.obcina.kranjska-gora.si [Accessed: 2020-06-30]

[2] https://sl.wikipedia.org/wiki/Ob%C4%8Dina_Kranjska_Gora [Accessed: 2020-07-10]

[3] Municipality Kranjska Gora, 2020

[4] Forest data, Zavod za gozdove Slovenije, Slovenia forest Service, Ljubljana 2020

[5] Caring for forest to benefit nature and people, Slovenia Forest Service, Ljubljana 2002, http://www.zgs.si/fileadmin/zgs/main/img/PDF/PDF_BROSURE/Brosura_ANGL.pdf [Accessed: 2020-07-11]

[6] Forest Act, Zakon o gozdovih, 1993, Uradni list RS (Official Gazette of Slovenia) no. 30 and other editions

[7] Resolution on the National Forest Program, Resolucija o nacionalnem gozdnem programu, 2007, Uradni list RS (Official Gazette of Slovenia) no. 111

[8] Forest management plan for regional unit Bled 2011 – 2020, Slovenia forest service, Ljubljana 2012, https://prostor.zgs.gov.si/pregledovalnik/ [Accessed: 2020-09-06]

[9] Forest management plan for forest management unit Kranjska Gora 2017 – 2026, Slovenia forest service, Regional unit Bled, Bled 2017, https://prostor.zgs.gov.si/pregledovalnik/ [Accessed: 2020-09-12]

[10] European forest types, Categories and types for sustainable forest management reporting and policy, European Environment Agency EEA Technical report No 9/2006

[11] Kutnar L, Veselič Ž, Dakskobler I, Robič D: Tipologija gozdnih rastišč Slovenije na podlagi ekoloških in vegetacijskih razmer za potrebe usmerjanja razvoja gozdov, Typology of Slovenian forest sites according to ecological and vegetation conditions for the purposes of forest management, Gozadsrki vestnik 70. 2012, 195:214

[12] https://en.wikipedia.org/wiki/Planica_Nordic_Centre [Accessed: 2020-09-20]

[13] https://earth.google.com/web/@46.48391243,13.72759359,888.94006945a,10210.25911304d,35y,-154.96458047h,59.94556289t,0r [Accessed:2021-07-26]

Edited by Jurij Beguš,
Frédéric Berger and Karl Kleemayr

One of the best ways to improve collective knowledge and practice is through sharing experiences and knowledge between different stakeholders. The idea for the current monograph followed such an approach. The monograph presents six best practice examples from six of the project's Pilot Action Regions (PAR). It is one of the deliverables of the GreenRisk4ALPs project funded by the EU Interreg Alpine Space program. The project aims to develop decision support tools supporting risk-based protective forest management in the Alpine Space. All main outputs of the project have been tested, improved and operationally applied in the PARs. The monograph is primarily intended for forestry experts, decision-makers at all levels of decision-making and other professionals.

Published in London, UK

IntechOpen

ISBN 978-1-83969-330-4
9 781839 693304