Chapter

The Concept of Risk and Natural Hazards

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Abstract

Risks have always shaped the way society has grown and evolved. Consequently, the risk concept has been studied and applied by different disciplines such as natural sciences as well as by economic, engineering, health, and insurance sectors. However, its definition and application are heterogenous and often vary among research communities. This chapter introduces the concept of risk and provides an overview of definitions and interpretations by key policy actors, including associated terms such as hazard, exposure, and vulnerability. Its use and the general importance of "risk" in the Alpine Space are emphasized, especially in the light of the increasing impacts of socioeconomic, environmental, and climatic changes on natural hazard risk by discussing resulting consequences and challenges. Furthermore, we provide an overview of the main policy actors, organizations and networks that address integrated natural hazard risk management in the Alpine Space.

Keywords: risk concept, hazard, exposure, vulnerability, disaster risk reduction, climate change adaptation, mountain areas

1. Introduction

Since the beginning of time, social developments were driven by the need to respond and adapt to different challenges such as natural hazards and the resulting risks [1, 2]. Only recognizing, accepting, and dealing with risks and their consequences has allowed us to grow and evolve to the society we know today by passing through an endless process of trials and errors. Therefore, every achievement or modification of the surrounding environment can be evaluated from a risk perspective [2]. Being part of the past and current developments of our society, the generic concepts of risk, risk assessment and risk management are well established in many disciplines, from technical applications (e.g., in industrial plants and airports), to project management, the finance sector or civil protection [3, 4]. However, their considerations and definitions are not as coherent as one might think [5]. Risk and its associated concepts have been defined heterogeneously, in relation to their specific application in a certain field [2].

The broadest definition of risk is given by the International Organization for Standardization ISO Norm 31000 on risk management, mainly addressing organizations and enterprises. ISO defines risk as the "effect of uncertainty on objectives" [6]. This ISO Norm further specifies that "Risk is usually expressed in terms of risk sources [element which alone or in combination has the potential to give rise to risk], potential events [occurrence or change of a particular set of circumstances], their consequences [outcome of an event affecting objectives] and their likelihood [chance of something happening]" [5, 6].

In the context of natural hazards, the climate change adaptation (CCA) and the disaster risk reduction (DRR) communities have a common objective: addressing the prevention and reduction of risks related to extreme weather- and climate-related events [7], and disasters, which are defined as "Severe alterations in the normal functioning of a community or a society due to hazardous physical events [...]" [8]. However, in the past the two research communities have evolved autonomously, adopting complementary approaches [9, 10]. In general, DRR has a longer history and has mainly focused on the present, addressing existing risks. On the other hand, CCA focusses mainly on the future, addressing uncertainty and new risks, also related to slow changes [10]. Consequently, the two research communities have developed different definitions of the risk concept.

In the context of DRR, the definition of risk is primarily based on the Sendai Framework for Disaster Risk Reduction (2015–2030) [11]. The United Nations Office for Disaster Risk Reduction (UNDRR, formerly known as UNISDR) defines disaster risk as "The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity" [12]. Until 2018, the CCA community has instead mainly focused on the concept of vulnerability; however, efforts have been made recently to coordinate and integrate a common concept understanding among both research communities [13].

The Intergovernmental Panel for Climate Change (IPCC) has been key in proposing solutions for common definitions [10]. In its Fifth Assessment Report, the IPCC has introduced the risk concept with the aim to identify and evaluate the risk of impacts from climate change, which is in line with the DRR practice of understanding and addressing natural hazards (e.g., earthquakes, floods or landslides) [4]: risk is "The potential for consequences where something of value is at stake and where the outcome is uncertain, [..., and] results from the interaction of vulnerability, exposure, and hazard" [8] (**Figure 1**; see **Table 1** for IPCC definitions of vulnerability, exposure, and hazard).

This 2014 IPCC definition of risk introduces a new approach and terminology [5], which is based on the UNDRR and ISO Norm 31000 definitions, allowing for

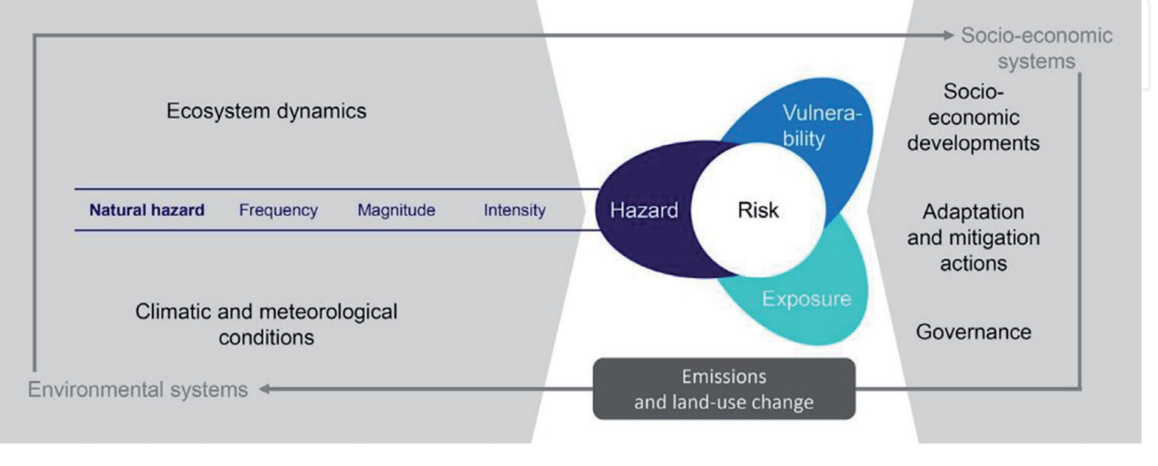

Figure 1.
Conceptual framework of the climatic, ecological, economic, and social impacts on climate-related and natural hazard risks resulting from the interaction of the three (natural) hazard components (frequency: number of times a natural hazard event occurs within a specified time interval, magnitude: energy released by a natural hazard event, and intensity: effects of a natural hazard event at a specific location or area [14]) with exposure and vulnerability of human and natural systems. Adapted from [8].

Hazard	"The potential occurrence of a natural or human-induced physical event that may cause loss of life, injury, or [...] damage and loss to property, infrastructure, livelihoods, service provision and environmental resources."
Exposure	The presence of people; livelihoods; environmental services and resources; infrastructure; or [...] assets in places and settings that could be adversely affected."
Vulnerability	"The propensity or predisposition to be adversely affected."
Risk	The potential for consequences where something of value is at stake and where the outcome is uncertain, [...]."

Table 1.
Defining risk resulting from the interaction of hazard, exposure, and vulnerability [8].

an integration of climate risks into already existing risk management strategies and policies. Some of the terms used in this concept are newly introduced to the CCA community; others are now defined differently [4]. For example, the DRR community interprets vulnerability as the societal, physical, and natural factors which contribute to disaster risk [5], while the CCA community's vulnerability definition focuses on "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change [...]" [15].

Since the late 1990s, the concept of risk has been successfully applied in the field of natural hazard management to evaluate protection measures [16–18]. In this context, risk results from the combination of natural hazards, exposure, and vulnerability (**Figure 1**) [19], similar to the approaches and practices of the DRR community and to the IPCC risk concept [8]. That is, a hazard alone does not constitute a risk, if occurring in an area with no consequences for humans, and not all elements at risk are necessarily impacted given their exposure and vulnerability [8, 20]. Therefore, risk assessment does not only consider the hazard but also the presence and vulnerability of potentially exposed elements (i.e., assets or people). This includes their physical attributes (i.e., building material of houses), their social, economic, and cultural characteristics (i.e., demographics) and their capacity to cope and adapt [4].

2. Coexisting with risk: the example of mountain areas

Understanding natural hazard processes and their potentially harmful consequences constitutes an essential prerequisite for developing and implementing efficient risk management strategies [21], including practices, plans and actions for reducing the natural hazard risk in an area by acting on one or more of the three risk components [22]. Disasters related to natural hazards such as floods, droughts, heat waves, cyclones, volcanic eruptions, earthquakes, rockfall, landslides and/or snow avalanches can vary widely in frequency, magnitude and intensity, mainly due to the environment they originate from [23]. The most severe disasters directly affect local, regional and national socioeconomic developments and livelihood improvements [10]. Their occurrence often reveals how differently vulnerable communities can be, since they are mitigated or amplified by a complex system of interacting factors such as the settlement in exposed areas, poor risk governance, environmental degradation, inadequate risk communication, or a lack of preparedness by public authorities [2, 24]. The trend in increasing numbers of occurring disasters is also linked to the increased exposure of populations, which is caused by socioeconomic factors such as population growth, rapid urbanization and the concentration of populations and economic assets in regions that are regularly affected by hazardous events [25].

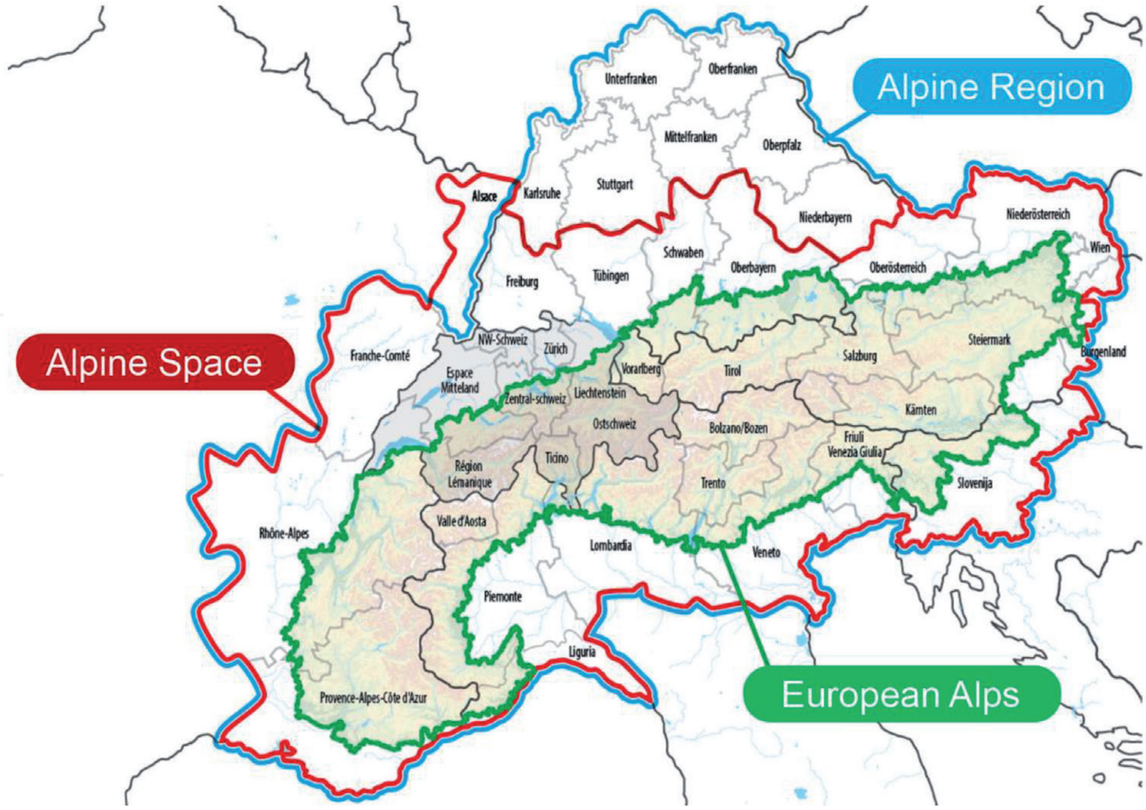

Figure 2.
Extents of the Interreg Alpine Space, the EUSALP Alpine Region and the European Alps (Alpine Convention). Adapted from [30].

One of these vulnerable regions are mountain areas, which occupy 22% of the Earth's surface [26]. Mountain areas vary largely in shape, altitude, vegetation, and climate across the globe [27, 28]. Despite these differences, mountain areas are globally renowned for the biodiversity they host and the ecosystem services they provide, including the provision of freshwater to about half of the world's population [28]. In addition to their acknowledged natural functions, mountain areas are home to more than 915 million people, representing 13 percent of the global population [29]. The inhabitants of mountain areas are particularly exposed and vulnerable to natural hazards as well as climate change [5].

Consistent with the global context, the European Alps (**Figure 2**) have been identified as one of the continent's most vulnerable areas to climate-related hazards [5]. Due to their high population density, the European Alps have always been affected by multiple natural hazard risks since time immemorial. Consequently, the mitigation of natural hazards (i.e., interventions aimed at reducing risks) has always been a major task in the Alpine Region [1, 31, 32]. Following the development of the risk concept and its integration into several international agreements, approaches for DRR in mountain areas have been progressively adopted, i.e., methodologies for identifying and planning mitigation and adaptation measures to reduce risk by reducing vulnerability or, eventually, exposure [33, 34].

However, significant changes in the Alpine landscapes over the last century caused by fast and profound socioeconomic developments, force mountain communities to continue facing new and complex challenges:

- Population expansion has led to high-density settlements located in areas that were previously considered to be unsafe [1, 31];

- Transportation infrastructure crossing the Alps have significantly increased, making this region one of the main thoroughfares in Europe [35]; and

- Alpine tourism has gained popularity, so that many remote mountain areas that were previously avoided are now expected to be permanently accessible [36, 37].

This increase in assets and people driven by urbanization and socioeconomic processes has led to an increase in the number of potentially exposed elements. The resulting damages to assets and infrastructures and losses to the residential, commercial, industrial, agricultural and public sectors are worth billions of Euros [36]. For example, at least 4,750 casualties were caused by snow avalanches alone in the Alps from 1970 to 2015, of which approximately 670 occurred in controlled terrain (settlements and transportation corridors) [38], and 1,370 people were killed by landslides and rockfall in Europe between 1995 and 2014 [39].

Recent disasters caused by floods, storms, avalanches, and other natural hazards have resulted in a shift towards an aware coexistence with such hazards and in a growing need for greater investments in protection measures [40, 41]. Limited space for settlement expansion, changes to frequencies and magnitudes of natural hazard events and natural forest disturbances as well as changes in traditional land

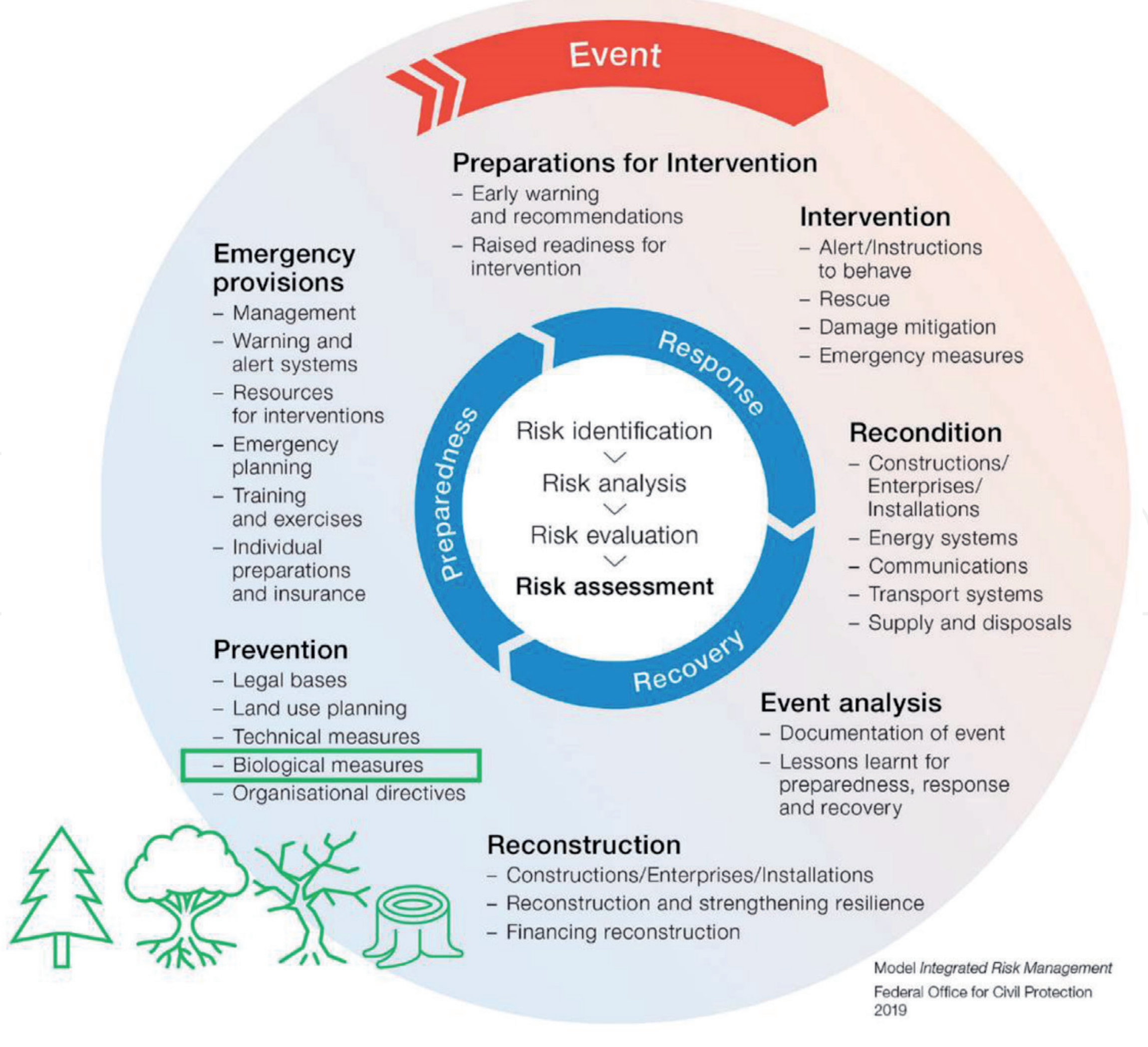

Figure 3.
The integrated risk management cycle. Forests are integrated as biological prevention measures. Adapted from [45].

use practices and land cover, including mountain forests, cumulatively affect natural hazard risks [42]. Thus, the safety of mountain populations needs to be ensured, in accordance with the preservation of precious mountain environments, a fundamental precondition for the sustainable development of the Alpine Space (i.e., the cooperation area of the Alpine Space programme covering the Alps and their surrounding lowlands [43]; **Figure 2**). Such challenges require risk governance concepts, including adaptive and integrated natural hazard risk management [1, 34, 40].

The concept of integrated risk management (IRM) refers to an overall risk management process in conjunction with the ISO Norm 31000 [6], including risk assessment (risk identification, analysis and evaluation), as well as risk treatment (preparedness, response and recovery) [44]. IRM is a systematic approach to cope with all societal-relevant hazards and related risks in an area by considering sophisticated damage indicators as well as ecological, economic and social sustainability criteria, the full spectrum of available measures, and all relevant decision-makers, experts, and those who are affected in a structured way (**Figure 3**).

3. Climate change risk in mountain areas

In the last decades, anthropogenic climate change has become the biggest threat to our society, and especially for the inhabitants of mountain areas [34]. Indeed, it was climate change's recognition and the assessment of its devastating effects which encouraged the latest international advancements in disaster risk management concepts and collaborations among scientists, practitioners, and policy makers. The increasing impacts and awareness of climate change were the motivation for the development of the IPCC's "risk of climate-related impacts" concept [8]. It is widely recognized how the adverse impacts of climate change on humans and nature are limiting the possibility to achieve global conservation and development objectives such as the Aichi Biodiversity Targets and the Sustainable Development Goals [46]. The diverse impacts of climate change, in terms of both subtle trends and abrupt events, are unprecedented over decades to millennia: the increased concentrations of greenhouse gases have led to higher air temperatures, the atmosphere and oceans have warmed, the amounts of snow and ice have diminished, and sea level has risen [8].

The reason for its big influence on developing risk-based evaluation and management approaches is climate change's peculiar nature of influencing all three components of the risk concept. That is, climate-related hazards such as extreme weather events are impacting our communities more frequently and with greater intensity, and changes in the climatic system can exacerbate disaster risk [19], a trend that is projected to continue with global warming [7, 47]. In addition, the currently unsustainable exploitation of ecosystems increases the vulnerability of humans and nature to natural hazards, provoking environmental (degradation, conversion, and other ecological changes), social (loss of adaptive capacities, knowledge, and institutions; loss of livelihood options and resilience), and economic (globalization, trade, markets) impacts [2, 48]. Furthermore, climate change is also driving socioeconomic processes by forcing people to migrate, weakening the economic basis of their livelihood, and/or threatening public health, and therefore enhancing their exposure [5].

The recent achievement by the IPCC of addressing climate change impacts in the framework of the risk concept is the direct outcome of decades of efforts from several research communities and policy makers. While the DRR community focuses on sudden hazardous events of a certain magnitude with immediate and severe consequences, climate change risks also include trends that evolve over long time periods. The adverse consequences of these trends are rather manifested in slowly increasing pressure on the environment and people's livelihoods than in immediate impacts [2]. Therefore, the IPCC framework is particularly suitable for a global perspective on risk, which is needed to manage systemic climate change risk and its cascading effects [41, 49]. In parallel, several global agreements were signed to translate the IPCC findings into political action, such as the 'Sendai Framework for Disaster Risk Reduction 2015–2030' [11], the 'Paris Agreement' [50], the 'Addis Ababa Action Agenda' [51], the 'New Urban Agenda' [52], and ultimately the so far 17 Sustainable Development Goals (SDGs) [53].

Today, scientists agree that anthropogenic climate change is altering natural hazard patterns in mountain areas [23, 25, 33]. For example, melting of glaciers and permafrost due to rising air temperatures and changes to mountain hydrology amplify the release of rocks and debris, destabilizing slopes and leading to further erosion, resulting in increasing rockfall and landslide activities [54]. In recent years, several global policy initiatives agreed on the risk paradigm and helped mountain communities to face climate change impacts on their livelihoods by adopting risk mitigation strategies and more resilient lifestyles [41, 55]. An overview of the key scientific networks and policy actors involved in natural hazard risk management in the Alpine Space is given in **Table 2**.

Name	Acronym	Scope	URL
International Commission for the Protection of the Alps	CIPRA	Non-governmental and non-profit umbrella organization which promotes the protection and sustainable development of the Alps at the international level. One of its initiatives was the establishment of the Alpine Convention.	[56]
Disaster Risk Management Knowledge Centre of the European Commission	DRMKC	Instrument to support the knowledge transfer from science into EU policies and to provide informed and evidence-based advice for disaster risk management	[57]
European Strategy for the Alpine Region	EUSALP	Alpine macro-regional strategy to improve the cooperation in the Alpine Region by identifying common goals and implementing them through transnational collaborations	[58]
Global Mountain Safeguard Research	GLOMOS	Collaborative program and scientific alliance between the UN University's Institute for Environment and Human Security (UNU-EHS) and Eurac Research for developing resilient mountain communities	[59]
Interreg Alpine Space programme	—	EU-funded transnational program to facilitate the cooperation between economic, social, and environmental key actors as well as between academia, administration, business and innovation sectors, and policy making	[60]
Mountain Partnership	—	Food and Agriculture Organization (FAO) supported UN voluntary alliance to improve lives and livelihoods of mountain people and to protect mountain environments	[61]
Mountain Research Initiative	MRI	Swiss-based international network for research in mountain environments conducted across borders and disciplines	[62]
Platform on Natural Hazards of the Alpine Convention	PLANALP	Alpine Convention platform to develop common strategies designed to prevent natural hazards in the Alps and to exchange on adaptation strategies	[63]

Table 2.
*Key networks and organizations addressing natural hazard risk management in the Alps, the Alpine Space, and the Alpine Region (**Figure 2**).*

All these initiatives are contributing to transform mountain areas into living laboratories of risk mitigation and management. However, the unique topographic, geomorphologic, and climatic diversity of the European Alps necessitates that policies are implemented by acknowledging regional and local differences [33, 34]. Only then climate-proof and efficient risk management strategies can be provided to local decision makers and practitioners to foster tangible improvements in the safety and livability of the Alpine Space [20, 54].

4. Conclusions

In the light of fast and profound socioeconomic, environmental, and climatic changes, the Interreg Alpine Space project GreenRisk4ALPs (GR4A; [64]) aimed at supporting natural hazard risk governance by developing decision support tools for practitioners and policy makers to include Ecosystem-based solutions for Disaster Risk Reduction (Eco-DRR) into affordable and long term-oriented integrated risk management. Moreover, GR4A supported overcoming conflicts and resistances by addressing all relevant actors involved in natural hazard risk management, providing science-based communication support, and developing harmonized transalpine recommendations – for municipalities as well as governance institutions. To establish efficient and proactive risk reduction measures, it is key to consider potential implications of current and future developments that determine the natural hazard risk [1, 23, 65]. Besides changes associated with elements potentially at risk, an improved understanding of past, current and future climatic trends is vital to achieve an efficient risk reduction, also due to 1) the known influence of climatic and meteorological dynamics on the occurrence of natural hazards, 2) the dependency of mountain ecosystems on climatic conditions, and 3) their interactions with (gravitational) natural hazards [54], such as landslides [66, 67], rockfall [68, 69], and snow avalanches [70, 71].

Supporting an ecosystem-based integrated risk management and the acknowledgment of the key role forests have for risk reduction in mountain areas, the findings of GR4A help identifying mitigation strategies and subsequently efficient risk reduction measures through an improved and participative risk governance system. How forests can act as a solution for Eco-DRR is the subject of the following three chapters of this book [72–74]. Moreover, the methodologies and decision support tools related to the risk concept that were developed and applied within GR4A are presented in [75, 76], the book chapters [77–79], and are explained in detail in the GR4A project reports [20, 65, 80, 81].

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Conflict of interest

The authors declare no conflict of interest.

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