## Development of options for action to adapt the high Alpine trail network to consequences of climate change

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## Abstract

Landscape alteration resulting from climate change affects many mountain trails and routes. Main problems are for example the impassability of saddles and the risk of rock fall due to glacier retreat and permafrost degradation. A safe and functional trail network is decisive for the appeal of mountain tourism. Thus the high Alpine trail network has to be adapted to landscape alteration resulting from climate change. This contribution presents a work approach to elaborate different scenarios for adaptation. These scenarios will be discussed with stakeholders and strategies to adapt the high Alpine trail network shall be worked out.

Keywords: climate change, landscape alteration, mountain hazards, mountain tourism, trail concept, trail network

### 1 Introduction

The high Alpine trail network is the infrastructural basis for mountain tourism in a mountainous country such as Austria. Due to landscape alteration resulting from climate change, the accessibility of the terrain in high mountain areas is changing leading to considerable risk for mountaineers. Glacier retreat and permafrost degradation seem to be the most important processes in this context (e.g. Schwörer 2002, Behm et al. 2006, Fischer et al. 2006). Moreover, human presence in endangered areas is increasing due to the development of the leisure society, increased tourism development in high Alpine areas, and the readiness to assume higher risk because of better equipment (Schwörer 1999, Lieb 2005).

Alpine clubs work hard to solve problems related to the trail network once they become acute. Lacking funds and voluntary workers in Alpine clubs do not allow activities on a large scale. Moreover the future change of problematic areas cannot be modelled precisely as the processes are very complex, and as accurate data are unavailable for decisive parameters. Existing approaches simplify processes, geomorphologic parameters and climatic development (e.g. Rothenbühler 2006). Therefore individual solutions for problematic sections of the trail network will have to be found in future too. Nevertheless general and strategic considerations could facilitate future planning and development of the high Alpine trail network.

The quality of the trail network is a decisive factor for the safety and appeal of mountain tourism. It has far-reaching consequences for the development of mountain tourism as well as for high Alpine ecosystems and regional economy. To ensure sustainable mountain tourism in future, it is necessary to find options to adapt the high Alpine trail network to the anticipated impacts of climate change. On the one hand these trail concepts have to integrate the expected landscape alteration triggered by climate change and the development of mountain tourism. On the other hand such trail concepts have to consider their impact on high Alpine ecosystems, mountain tourism and regional economy.

## 2 Overview of the approach

This paper presents an approach to identify and discuss different possibilities for adapting the high Alpine trail network to the consequences of climate change. The practical implementation is conducted in the three most heavily glaciated sections of the Austrian Alps: Glocknergruppe, Venedigergruppe, and Ötztaler Alpen.

Figure 1 presents a draft of the approach. The main body of this contribution deals with the first two steps, i.e. data collection and documentation of previous effects of climate change on the trail network reflecting the actual working phase of the project.

In the context of this paper the term "high Alpine trail network" refers to the marked trail network as well as to frequently used routes across and around glaciers. The explanations refer to classical summer mountain tourism in high Alpine areas (mountaineering, high routes, etc.). The effects of climate change on other sectors of mountain tourism such as skiing are not subject of our project.

# 3 Documentation of previous effects of climate change on the trail network

The first objective of the study consists of two parts: A time series analysis of the historical development of the trail network in selected study areas and the development of a catalogue of phenomena affecting the trail network.

#### 3.1 Historical development of the trail network (time series analysis)

For each study area, the trail network as depicted in the respective historical editions of the Austrian Alpine Club hiking maps (1:25,000) is digitised and quantitative changes are analysed using a Geographical Information System (ArcGIS 9.2). This time series analysis shows where and when the trail network has changed in the past.

A descriptive analysis of the changes complements the quantitative analysis. For this purpose additional information is derived from interviews with local experts, e.g. mountain guides, hut-keepers, track maintenance staff. The development is illustrated cartographically and textually for each study area to clarify the processes that led to the changes. Development of options for action to adapt the high Alpine trail network to consequences of climate change 155



Figure 1: Approach to work out different possibilities for the adaptation of the high Alpine trail network.

#### 3.2 Catalogue of phenomena

The catalogue of phenomena contains examples of landforms and processes affected by climate change and that in turn affect the high Alpine trail network. Figures 2, 3, 4 and 6 provide examples of such problematic situations that developed during the last years.

At the current project phase, examples of the different phenomena have been compiled and described by field mapping, expert interviews and by studying reports of current changes in the trail network from all over the Austrian Alps. The geomorphological attributes of the phenomena such as slope angle, altitude, exposition, geological description, glaciation, etc. are surveyed and collected in a database (realised in MS Access). They are supplemented by a textual description, a photo documentation and if necessary, by a simplified situation sketch.

The classification of the phenomena in the catalogue should reflect how they affect mountaineers and the trail network. For two reasons a classification following the causal processes does not seem adequate: First, many phenomena may be linked to different causal processes. Increased debris fall, for instance, may occur due to glacier retreat, permafrost degradation, alteration of the frost line, or increased weathering. Therefore the specific processes causing the phenomena are sometimes unknown. Yet for the mountaineer it makes little difference. Second, the scenarios that are based on this documentation shall focus on the impacts on mountaineering and on the high Alpine trail network and not on modelling the causal processes.

Reflecting how these phenomena affect mountaineering, one can distinguish two consequences: those influencing the accessibility of the terrain and those affecting the potential of mass movements and the related hazards for mountaineers. Figure 5 presents a proposal for the classification of the phenomena, an overview of main causal processes and the consequences for mountaineering. It was developed during the data collection for the catalogue of phenomena based on field mapping, reports of current changes in the trail network, expert interviews and discussions with mountaineers.

## 4 Next steps

#### 4.1 Creation of framework scenarios

Based upon the documentation of previous effects of climate change on the trail network, decisive factors affecting the trail network will be identified. As a next step, framework scenarios, describing different possibilities of the landscape alteration due to climate change during the next decades, will be generated. They refer to assumptions of the future development of decisive factors and phenomena described in the catalogue and will both integrate scientific expert knowledge (mainly regarding future development of morphodynamic processes) as well as the knowledge of stakeholders (mainly concerning the demands and the development of mountain tourism). Following the ideas of scenario planning, the framework scenarios should Development of options for action to adapt the high Alpine trail network to consequences of climate change 157



Figure 2: Loose morainic material on a steep slope without proper trail left of a vanished glacier. Getschner Scharte, Silvretta (Photo: F. Braun).



Figure 3: Steep debris-covered ice slope – a terrain difficult and dangerous to cross. Lisener Ferner, Stubaier Alpen (Photo: F. Braun).



Figure 4: Retreating glacier uncovering steep rock walls that make fixed ropes in the route necessary. Wiesbadener Grätle, Silvretta (Photo: F.Braun).



Figure 5: Classification of phenomena resulting from climate change reflecting how they affect mountaineers and the high Alpine trail network.

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Figure 6: Debris on a steep bare-ice glacier slope causing debris fall on the route crossing below. Turmferner, Stubaier Alpen (Photo: F. Braun).

represent the spectrum of possible future developments (Gausemeier et al. 1996, Scholz & Tietje 2002).

As mentioned above, the intention of this study is not the accurate modelling of the future landscape alteration, but the development and discussion of different options for action for the adaptation of the high Alpine trail network. For this purpose scenario planning approach seems to be adequate.

#### 4.1.1 Creation of adaptation scenarios

Based on the framework scenarios, different adaptation scenarios will be designed (cf. figure 1). Describing consequences for mountain tourism, regional economy and high Alpine ecosystems the scenarios intend to provide different possibilities for future action as a discussion basis for stakeholders. Some possible adaptation scenarios may be:

- Abandonment of hazardous trails and routes and thinning of the trail network.
- · Building new trails in glacier forefields and ice-free passages.
- Avoidance of glacial passages in the trail network by shifting the trails to ridges where it is possible.

#### 4.1.2 Scenario assessment and development of adaptation strategies

The adaptation scenarios will be evaluated and discussed in stakeholder workshops. Important stakeholders are the Alpine clubs as the main track maintainers, their funding authorities, mountain guide organisations and local tourism organisations and landowners. Strategies for the adaptation of the high Alpine trail network to the consequences of climate change will be worked out collaboratively. This transdisciplinary research approach aims at integrating scientific knowledge and local case actors' experience (Balsiger 2004).

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