Are alpine regions especially affected by natural hazards? Meso-scale assessment of economic resilience and vulnerability based on the 2005 floods in the Austrian federal states of Tyrol and Vorarlberg

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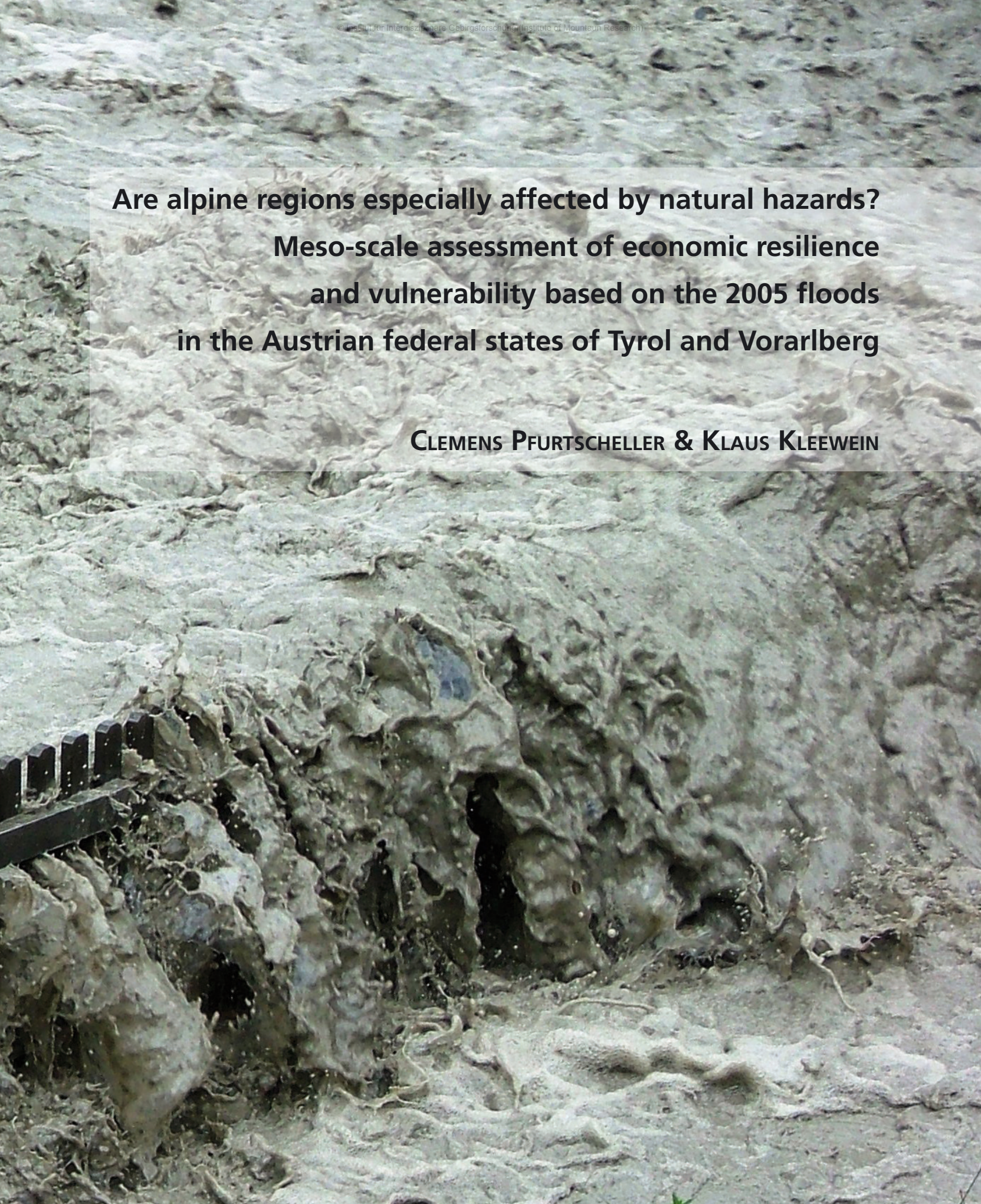

Introduction

The Alps as a mountain region in the heart of Europe are not only a space for recreation and retreat but are also under special threats of natural hazards such as floods, avalanches and storms as well as geological mass movements. The vulnerability of the alpine arc and of mountain areas in general to natural hazards is increasing, not least as a result of recent climate change. A matching increase in damages and an intensification of the natural processes may be expected (Haeberli & Maisch 2007; Allamano et al. 2009).

The steep relief and the elevation of large parts of the Alps above the height limit of ecumene allows about 17% of the Alps to be settled permanently (Penz 1983; Bätzing 1990; Tappeiner et al. 2008). In Tyrol, at 12%, the proportion of the territory fit for permanent settlement is even lower than the average for the Alps (Tiroler Landesregierung 2009). The approx. 14 million inhabitants of the alpine regions (in 2007; Ständiges Sekretariat der Alpenkonvention 2010: 47) thus have rather limited space at their disposal for settlements and economic activities. This is reflected in the high population density of 400 people per square kilometre of permanent settlement areas. Moreover, the Alpine Space is experiencing conflicting development trends vis-à-vis global change, with some regions on the growing and winning side while others are suffering decline and depopulation (Bätzing 2003). It is the regions with strong growth trends in tourism that make particular demands on the spatial resources (Borsdorf 2006). Processes which in the natural space would represent no danger to humans, become a threat or even a catastrophe only in the expanded areas of overlap with the anthroposphere (Wisner 2007).

These natural processes in mountain regions happen on the basis of relief energy and accompanying morphodynamics, so that avalanches, geologic mass movements, floods, debris flows and related processes trigger existential challenges for alpine regions. Infrastructures are particularly affected, but so are buildings and the entire regional economy due to a possible decline in income. Given the lack of spatial alternatives for the built environment to evade alpine hazards and no available options of substitution for transport and lifelines, an integrated and sustainable management of natural hazards in alpine regions is essential. Following the life cycle of catastrophic events, holistic approaches, including emergency response, reconstruction, long-term coping, prevention, mitigation and adaptation to natural hazards and climate-related risks, have to be implemented in local and regional risk management strategies.

In general, a natural disaster can be seen as a shock to the equilibrium of interrelations between the natural and the social system. The resulting imbalance and the associated magnitude of damages depend on the social system's ability to absorb this external shock. Hence, the aim of disaster mitigation is to increase the tolerance of the social systems vis-à-vis impacts of natural disasters (Kramer 1995). In other words, the management of natural hazards needs both natural science and socio-economic approaches to analyse the social and economic vulnerability (susceptibility) and resilience (resistibility) to extreme events. The following sections introduce the main facts of the floods in 2005 in the federal states of Tyrol and Vorarlberg, Austria, as a basis for the subsequent empirical analyses, present a framework to assess the costs of emergency management and analyse possible indirect economic effects of Alpine natural hazards based on a survey.

The floods of 2005

The catastrophic flood event in August 2005 caused an estimated aggregated total direct loss of € 680 million in both federal states (Vorarlberger Landesregierung 2005; Tiroler Landesregierung 2006). For Tyrol, this equals 2.1% of the gross regional product (basis 2002, total € 19.2 billion, Tiroler Landesregierung 2006).

The main characteristic of flood events in alpine and mountainous regions is the high impact on private structures and the partial or complete destruction of infrastructure such as roads and railways. This leads to

Fig. 1: Process patterns and loss characteristics of low terrains and alpine lateral valleys. Source: Spar Austria, municipality of Pfunds.

the assumption of an alpine damage structure or special vulnerability to natural hazards in mountain regions. The 2005 flood in Western Austria can be separated into two process fields. On the one hand, rock falls, landslides and debris flows in mountain regions and on the other floods, overflowing rivers and rising ground water levels in low terrains formed loss characteristics. It seems typical for mountain regions that it is the combination and mix of processes (multiple hazards) that creates the overall economic losses in flood events.

In August 2005, excessive precipitation with measured high intensities of more than 10 mm per hour and daily precipitation rates of more than 100 mm in the west of Tyrol, single return periods of water gauges of up to 5 000 years, resulted in an estimated 1 300 hectares of inundated land. With 1.511 cubic metres per second at the Innsbruck gauge, the Inn, Tyrol's main river, measured the highest flow rate ever recorded (Tiroler Landesregierung 2005).

The hydrological situation was exacerbated by a very low soil storage capacity as a result of high precipitation rates during the entire month, snow-free glaciers with a low storage capacity for precipitation, high groundwater levels and a high snowline. Together, these factors

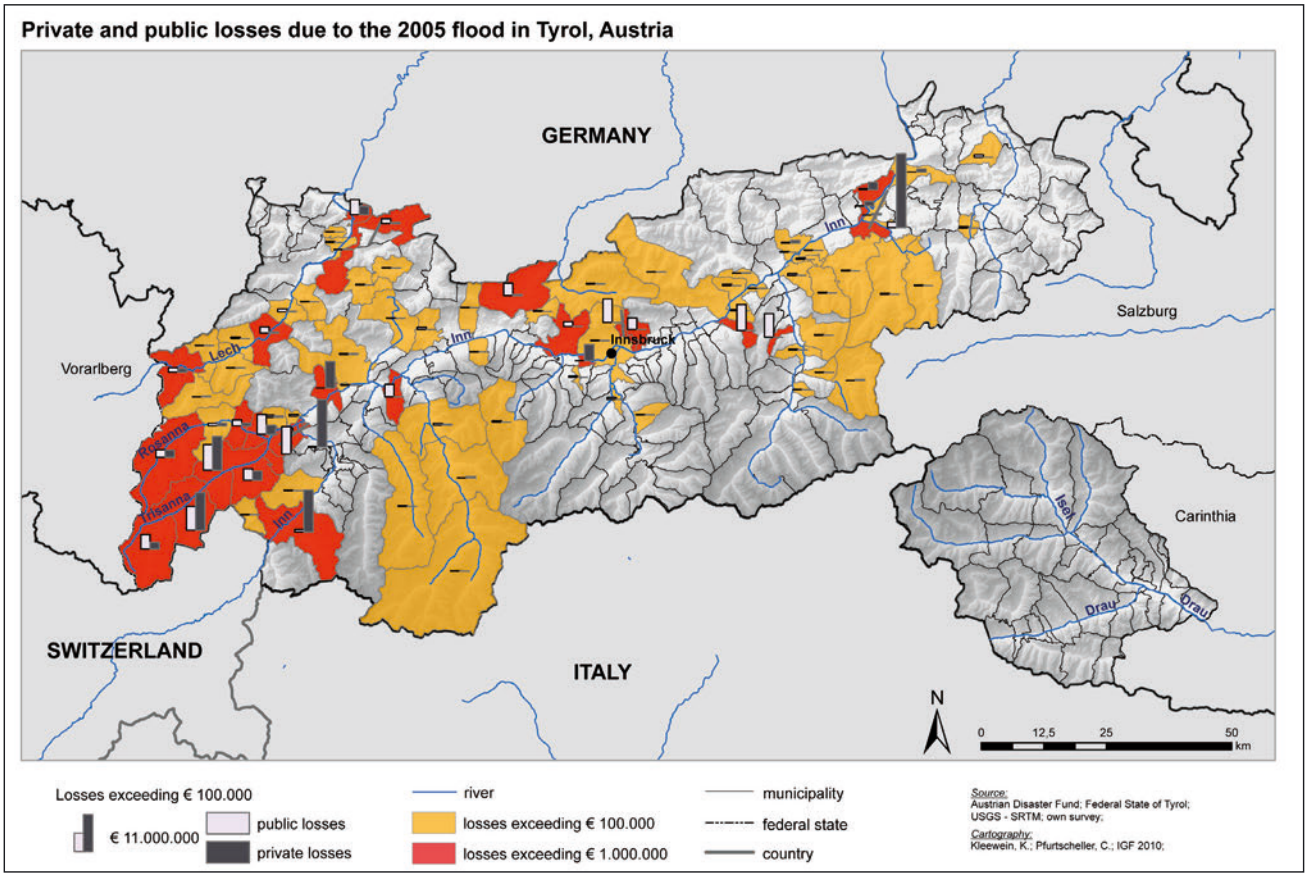

Fig. 2: Private and public economic losses at regional level, 2005 floods, federal state of Tyrol.

Fig. 3: Deployment of heavy machinery to clean up sediments and rubbish after debris flows. Source: municipality of Pfunds.

generated and intensified direct damages to public and private assets. Altogether, this extreme event affected 61 of the 279 municipalities in Tyrol, with 20 municipalities worst hit. In total, 1 200 structures and buildings were partly damaged or totally destroyed.

Costs of emergency management

Economic losses triggered by flood events may be subdivided into direct (buildings, infrastructure, etc.) and indirect damages, e. g. costs for emergency management and interruption of lifelines (Messner et al. 2006). Local spending on emergency services is often substantial and can reach economically critical levels, especially for low-income municipalities. The cost of emergency services, evacuation, securing infrastructure and clean-up often exceeds public funds.

During the 2005 floods in Tyrol, the local fire brigades carried out about 200 000 unremunerated voluntary service hours. In the main, these costs are economic ones, reflected in gross domestic and regional product, depending on the scale of assessment. In most cases the ex-post economic analysis of natural hazard events is limited to assessing direct economic costs.

In the case of Austria and Germany, there is no statistical basis for estimating costs for emergency, evacuation und clean-up. The main reason for this is the split responsibility of different statutory and voluntary organizations for emergency services such as national civil protection and the army, voluntary local fire brigades, Red Cross, etc. The costs of emergency services are often borne by both statutory and voluntary organizations, such as the civil protection office, the national military, voluntary local fire brigades, the Red Cross, etc.

Costs of emergency services therefore include (Pfurtscheller & Schwarze 2010):

- costs of municipal and national services (army, fire brigade, police, medical service) in searching, rescuing, and evacuating people;
- costs of voluntary organizations for assistance to flood victims (food and shelter, health services);
- costs incurred by municipal and private services for flood control and clean-up (sandbagging, pumping water out of flooded neighbourhoods);
- costs of avoiding water pollution from oil or chemical seepage / leaks;
- costs of protecting and safe-guarding buildings against structural damage and contamination.

For the precise assessment of emergency management costs we have to take into account the marginal costs triggered by the flood event as above-average incurred costs. It would be misleading to analyse the costs of establishing and maintaining resilience infrastructures, because these costs were not triggered by the exogenous shock. The marginal costs could be categorized by number of service hours, loss of material and costs of hiring heavy machinery for clean-up. Based on data from a survey of the voluntary public and corporate fire brigades as main resilience infrastructure in Austria, emergency management costs of the 2005 floods ($n = 325$, $n_{returned} = 51\%$) were computed with a quite simple approach – the sum of the service hours is multiplied by a monetary equivalent to obtain gross incomes of the men of the fire departments (Pfurtscheller & Schwarze 2010).

Other costs of emergency management have to be added of course to arrive at the total costs of emergency management triggered by flood events.

Indirect effects of floods

Indirect (economic) flood losses are those where the damage does not arise from the physical contact of objects with flood water but where it is induced by the direct impacts and transmitted through the economic system. For example, a production facility might experience a shortage of an essential input as a result of a flood event in its suppliers' areas, which renders it unable to operate, thus incurring financial loss. Indirect loss is necessarily attached to some form of interruption of usual business but strictly different from the business interruption caused by the direct physical impacts of flood water on production facilities (Cochrane 2004).

Most companies have no reporting system set up for direct and indirect damages or for interruption of operations. This makes it impossible to put an exact figure on the economic damages resulting from natural hazards. Often it is not possible at the level of a business to attribute negative impacts of natural hazards explicitly to a particular cause. Here we have to rely on estimates.

The assessment of indirect damages is closely related to entrepreneurs' perspective and actions. Based on a random sample survey on the 2005 flood in the federal states of Tyrol and Vorarlberg (Austria), 1 300 companies were polled about risk management, direct and indirect losses, business interruption and adaptation strategies ($n_{returned}$ = 14%). 30% of the interviewed companies had been affected in some form by the 2005 floods or by processes in their wake. 45 companies experienced direct damages and 46 companies indirect damages. One third of all surveyed companies regard their premises as located in flood-prone areas but, surprisingly, assess their exposure as marginal. Apart from flooding and inundation, the companies see debris flows, raising ground water levels, log jams and land slides as the main risks. Roughly half of the interviewed

Fig. 4: Interruption of lifelines – road barrier at the outer Paznaun valley, Tyrol. Photograph by C. Pfurtscheller.

companies have risk management set up, in most cases as insurance against natural hazards. Almost 33% of businesses are insured against direct damages and 30% against interrupted operations. Only 20% are actively securing their premises themselves through construction measures such as mobile flood barriers, raising the company land or building protection walls. A similar number of companies employ a security officer, which is also a legal requirement if the company exceeds a certain size. Despite the catastrophic scale of the 2005 floods in Tyrol and Vorarlberg, only about 3% of the companies operate comprehensive risk management that includes insurance, construction measures, risk and vulnerability analyses and emergency planning. Those companies are either part of a corporation or of sufficient size to carry the additional cost of such risk management.

The main causes of loss of business earnings are interruptions in the connections to the suppliers or to the customers (economic indirect impacts), direct damage to buildings, production equipment and fleet (business interruption) and staff being unable to reach the business premises as a result of closed roads. After the 2005 floods, the affected businesses reached production levels of 50% on average after 15 days and 100% after 40 days.

Natural hazards like the 2005 floods in the west of Austria can, however, also have positive effects. The construction businesses and related trades in particular as well as the haulage businesses in the affected areas

Fig. 6: A possible micro-scaled migration scenario for the Alps? Large flooded agricultural areas in the upper Salzach valley in the federal state of Salzburg, 2005 floods. Source: city of Mittersill).

achieved increases of 10% on 2004 on average and up to 20% in some cases.

We also asked the companies about adaptation strategies and lessons learned from the 2005 floods. The companies restricted their efforts to the most minimal steps, implementing only what was absolutely necessary. This included in the main construction measures, an extension of insurance cover and plans for cooperation with state institutions, such as the regional departments of hydrography and hydrology and the Austrian office of avalanche and torrent control. We only observed learning effects with businesses immediately affected by the 2005 floods.

The average entrepreneur thus takes a relaxed view of the future, even though awareness of climate change and changing environmental conditions is on the increase. Extreme events like the 2005 floods in Tyrol and Vorarlberg have not triggered any change or adaptation in terms of a sustainable handling of natural hazards on the part of businesses nor at national economic level.

Conclusion

In general, alpine regions are particularly exposed and especially vulnerable to natural hazards as a result of natural processes combined with socio-economic characteristics such as small lateral valleys, marginal permanent settlement areas and the occurrence of multiple hazards.

Hazard events like the 2005 flood offer an opportunity to analyse the triggers and effects of extreme hydrometeorological events in Alpine regions from a spatial economic perspective. Such an approach includes assessment of direct and indirect losses as well as the costs of emergency management. Taken together, these costs can be crippling for a region's wealth and development.

The main causes of direct and indirect losses in the case of alpine flood events are the high morphodynamics, related process intensities and the occurrence of multiple events (Kleewein 2010). In addition, there is often no possibility to substitute lifelines and transportation infrastructure. The high dependence of employees on commuting and the concentration of valuable structures and infrastructure in valleys and thus in endangered areas lead to possibly catastrophic effects for alpine regions. Beyond that, modern production enterprises are subject to globalization and related aspects such as short order and delivery periods, interlinking production processes and just-in-time manufacturing. A breakdown of production caused by indirect effects of natural hazards can lead to substantial financial impacts, unemployment and a possible decline of gross regional product.

But is there a solution for the overlap of alpine hazards with the anthroposphere which triggers the severe economic losses?

From an economic perspective, society has to decide if the possible hazard impacts are acceptable – and if not, needs to consider comprehensive / integral risk management under efficiency and cost-benefit aspects (Kramer 1995; Weck-Hannemann 2006). Above all, it is the Cost Benefit Analysis (CBA) which provides decision support for public sector projects. In the case of natural hazards, it evaluates protection measures and non-technical mitigation projects. This is of great importance to the region's economy, because, as a public good, these measures have to be paid for by the public.

In a CBA, the benefits of protection measures are interpreted as reduced losses. Moreover, CBA serves to identify the most efficient result from a set of alternatives. From an integrated point of view, risk management includes mitigation and prevention measures, systematic land-use planning but also strategies for migrating to less affected areas as already implemented for a small residential area in Vorarlberg, which can also be the most cost-efficient result of a CBA.

Literature

Allamano, P., P. Claps & F. Laio 2009. Global warming increases flood risk in mountainous areas. *Geophysical Research Letters* 36: L24404.

Bätzing, W. 1990. Die aktuelle Siedlungsentwicklung an der Höhengrenze der Ökumene im Alpenraum auf dem Hintergrund des Übergangs von der Agrar- zur Freizeitgesellschaft. In: Aerni, K. (ed.), Siedlungsprozesse an der Höhengrenze der Ökomene am Beispiel der Alpen. *Siedlungsforschung* 8: 165–192.

Bätzing, W. 2003. *Die Alpen. Geschichte und Zukunft einer europäischen Kulturlandschaft.* 2nd ed. München.

Borsdorf, A. 2006. Land-Stadt Entwicklung in den Alpen: Dorf oder Metropolis? In: Psenner, R. & R. Lackner (eds.), Die Alpen im Jahr 2020. *Alpine space – man and environment* 1. Innsbruck: 83–92.

Cochrane, H. 2004. Economic loss: myth and measurement. *Disaster Prevention and Management* 13 (4): 290–296.

Haeberli, W. & M. Maisch 2007. Klimawandel im Hochgebirge. In: Endlicher, W. & F.-W. Gerstengarbe (eds.), *Der Klimawandel – Einblicke, Rückblicke und Ausblicke*. Potsdam: 89–107.

Kleewein, K. 2010. *Economic vulnerability in alpine regions*. Diploma thesis, Innsbruck.

Kramer, R.A. 1995. Advantages and Limitations of Benefit-Cost Analysis for Evaluating Investments in Natural Disaster Mitigation. In: Munasinghe, M. & C.L. Clarke (eds.), *Disaster prevention for sustainable development: Economic and policy issues, a report from the Yokohama World Conference on Natural Disaster Reduction, May 23–27, 1994*. Washington, DC: 61–76.

Messner, F. et al. 2007. Evaluating flood damages: guidance and recommendations on principles and methods. FLOODsite project deliverable D9.1. Available at: http://www.floodsite.net/html/partner_area/project_docs/T09_06_01_Flood_damage_guidelines_D9_1_v2_2_p44.pdf (accessed: 11/08/2010).

Penz, H. 1983. Sozio-ökonomische Wandlungen an der Ökumene in den Alpen – das Beispiel Trentino (Welschtirol). In: Hagedorn, H. et al. (eds.), Tagungsbericht und wissenschaftliche Abhandlungen. *43. Deutscher Geographentag Mannheim, 5.–10.10.1981*. Wiesbaden: 299–301.

Pfurtscheller, C. & R. Schwarze 2010. Kosten für den Katastrophenschutz. In: Thieken, A., I. Seifert & B. Merz (eds.), *Hochwasserschäden – Erfassung, Abschätzung und Vermeidung.* München: 253–262.

Ständiges Sekretariat der Alpenkonvention 2010. Alpenkonvention, Nachschlagewerk. 2nd ed. *Alpensignale* 1. Innsbruck.

Tappeiner, U., A. Borsdorf & E. Tasser (eds.) 2008. *Alpenatlas – Atlas des Alpes – Atlante delle Alpie – Atlas Alp – Mapping the Alps. Society – Economy – Environment.* Heidelberg.

Tiroler Landesregierung 2005. *Hydrologische Übersicht August 2005*. Innsbruck. Available at: http://www.tirol.gv.at/uploads/media/hueb0805.pdf (accessed: 11/08/2010).

Tiroler Landesregierung 2006. *Rechnungsabschluss 2005 des Landes Tirol*. Innsbruck.

Tiroler Landesregierung 2009. *Statistisches Handbuch Bundesland Tirol 2009*. Innsbruck.

Vorarlberger Landesregierung 2005. *Das Starkregen- und Hochwasserereignis des August 2005 in Vorarlberg.* Feldkirch.

Weck-Hannemann, H. 2006. Efficiency of protection measures. In: Ammann, W., S. Dannenmann & L. Vulliet (eds.), *Risk 21 – Coping with Risks Due to Natural Hazards in the 21st Century: Proceedings of the Risk 21 Workshop, Monte Verita, Ascona, Switzerland, 28 Nov.–3 Dec. 2004*. London: 147–154.

Wisner, B. 2007. Regions at Risk or People at Risk? Wie natürlich sind „Naturkatastrophen"? *Geographische Rundschau* 59 (10): 12–18.