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Economic assessment of landslide risks in the Swabian Alb, Germany – research framework and first results of homeowners' and experts' surveys

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Abstract. Landslide risks are frequently underestimated by political and economic actors as well as by the local population. The InterRisk Assess research project is working to develop a systematic approach to the analysis and evaluation of economic landslide risks at a local and regional scale. Its major aims are to determine the extent of potential damage and economic losses caused by landslides, to analyze individual and collective patterns of risk assessment and to develop recommendations for pro-active risk management.

The research methodology includes GIS-based risk analyses and interviews with relevant actors in politics, administration and planning, private households and land owners. The research findings will facilitate a better-informed, efficient and sustainable use of natural resources and natural risks. The research project also aims to contribute to methodological progress in risk research.

1 Landslides: An underestimated natural risk

Landslides are gravitational mass movements of earth or rock. In the last few decades landslides have caused considerable damage (Münchener Rückversicherung, 2000/2004). Abbott (1996) estimated that US$ 1.5 billion costs are caused by landslides in the United States annually. One example illustrating the consequences of landslides is the destruction of the Alaskan Way Viaduct (near Seattle; landslide caused by the Nisqually Earthquake in 2001). The repairs cost some 500 million US$, replacement would have cost US$ 1 billion (Highland, 2003). In Japan, annual losses due to landslides total about US$ 2 billion. In European countries, annual losses can be even higher, for example US$ 2.6 billion per annum in Italy (Schuster, 1996).

Landslides may occur as an isolated phenomenon or in conjunction with volcanic eruptions, earthquakes or floods. Landslides are among the most significant natural hazards worldwide. They are integral to numerous geosystems, particularly in alpine regions, but also in many low mountain ranges (Dikau and Glade, 2002).

In German low mountain ranges, landslides occur less frequently and with less dramatic consequences than in the Alps. This results in frequent underestimation of the landslide risk in these regions, although landslides cause damage to buildings (in residential areas in most cases), roads, agricultural and forest areas. Smaller landslides occur frequently in Rheinhessen, in the region around Bonn and in the Swabian Alb, for example. Other reasons for the underestimation of risks are the belief that modern technology obviates catastrophic consequences for the population, while a lack of knowledge of landslide processes prevents people from seeing any danger in these movements. Thus it is important to analyze landslide risk and its perception and evaluation by the population and key actors in these regions. In order to reduce private and public losses it is necessary to develop methods to evaluate landslide risks in a socio-economic context. This requires an integrative approach applying different scientific and methodological perspectives.

2 Objectives of InterRisk Assess

InterRisk Assess is part of "InterRisk – Integrative landslide risk analysis and risk evaluation in the Swabian Alb (Germany)". InterRisk is a group of four projects initiated in 2003. By integrating physical, social, historical and economic perspectives InterRisk is working to develop a comprehensive methodological framework to analyze and evaluate landslide risks and to give recommendations to public and private actors. The research framework is applied to landslide risks in the Swabian Alb in the south-western Germany (federal state of Baden-Württemberg).

Within the InterRisk project group, "InterRisk Assess" (Economic evaluation of natural risks of landslides on the Swabian Alb from a collective and individual point of view) aims to examine economic aspects of landslide risks. The

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Fig. 1. Location of the research area.

project combines economic risk analysis and evaluation. It determines regional damage potential and investigates collective and individual patterns of risk evaluation. "InterRisk Assess" has four main objectives:

1. To develop methods for the systematic analysis of risks on a regional scale: The estimation of potential damage (analysis of elements at risk as well as direct and indirect economic effects) must be linked with the identification of exposure to risk. The economic risk assessment is firstly an assessment of financial risk. It will be integrated in a model of systematic risk evaluation, which includes other factors such as perception, prevention or coping capacity (see Objective 2).

2. To develop methods for the systematic evaluation of natural risks: In order to give recommendations to individual actors and public decision-makers, a widely accepted, standardized methodology has to be developed. Individual and collective risk perception and prevention as well as thresholds of acceptability must be studied. In addition, the costs of prevention measures or alternatives should be specified.

3. Search for means of preventing hazards on an individual scale. Analysis of preconditions for actors who take decisions or give recommendations: Actors directly affected include private households, farmers, forest owners or firms located in landslide-prone areas. An analysis of the behavioral patterns of and decisions made by individuals affected or potentially affected is important for optimal adaptation to natural risks and their successful prevention.

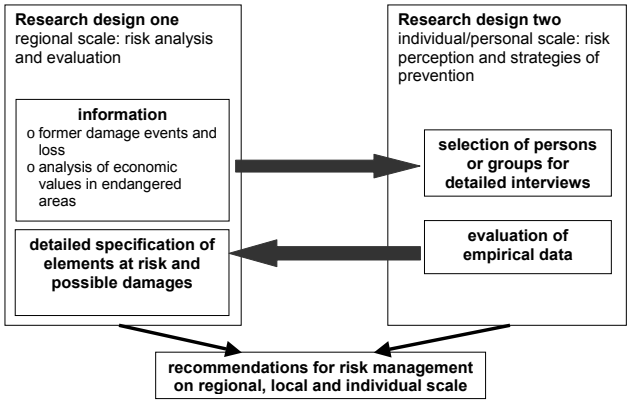


Fig. 2. Basic conception of the working program of InterRisk Assess.

4. Recommendations for sustainable risk management at regional, local and individual levels: Landslide risk management is underdeveloped in the Swabian Alb. Therefore it is necessary to develop and apply tools for integrative risk management. Such tools can consist of maps identifying dangers and risks, to be used by planners or administrative authorities. In order to cope with risks one must be familiar with the scale of possible landslide hazards. This task can only be accomplished out in cooperation with the other sub-projects of InterRisk.

3 Research area

InterRisk focuses on the northern edge of the Swabian Alb (Fig. 1). There are three reasons for choosing this area:

Firstly, the Swabian Alb is a landslide-prone area with a high incidence of landslides, some of them as extensive as the well-documented landslide at Mössingen (Hirschkopf) in 1983 (Bibus, 1986). There has already been remarkable damage to buildings at several locations (e.g. in Lichtenstein, Mössingen, Pfullingen, Reutlingen). Early findings of the InterRisk project indicate that much of this damage has been caused by recent mobilization of fossil landslides (see also Bibus, 1986).

Secondly, the highly urbanized areas of Reutlingen (110 000 inhabitants) and Tübingen (85 000 inhabitants) are adjacent to the Swabian Alb and this urbanization puts pressure on the valleys and slopes. In the last four decades, many new housing estates have been built on steep slopes and fossil landslides.

Thirdly, the region has been studied extensively by geomorphologists and geologists. Thus a fairly comprehensive data base on landslide risks, the location of historical landslide events etc. is available (see Bibus, 1998; Terhorst, 1997; Thein, 2000).

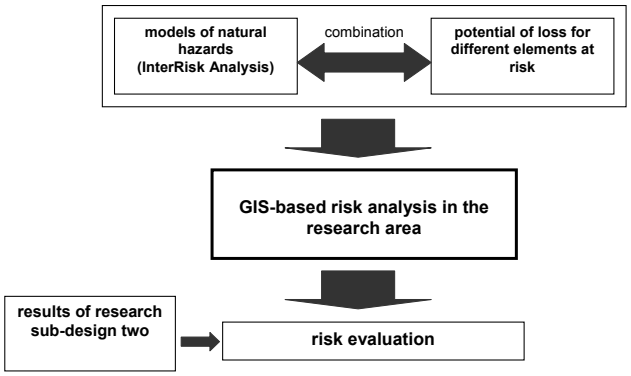


Fig. 3. Research sub-design one.

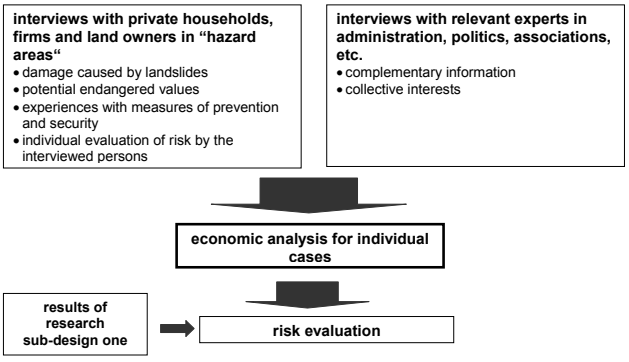


Fig. 4. Research sub-design two.

4 Research design

Two research sub-designs form the general structure of InterRisk Assess (see Fig. 2): "Research design one" analyses and evaluates risks at a regional level. "Research design two" investigates risk perception and the vulnerability of elements at risk, and analyses preventive strategies at an individual level. These two research sub-designs are closely related and complementary. The investigation of probable damage is only one step of risk analysis. The analysis of potential hazard, which is the other essential step of every risk analysis, is carried out by the InterRisk Analysis project (T. Glade, University of Bonn), which makes its findings available to InterRisk Assess. In research design one we will gather information about previous hazardous events in the region and their consequences for people, organizations, firms or infrastructures. This data will be collected by analyzing documents and available statistics. In addition, possible economic damage will be shown on a map of monetary valuations for endangered areas (see Sect. 5). On the basis of this information, persons and organizations will be selected for detailed interviews in research design two, using standardized interview surveys in different residential areas in the Swabian Alb. The results will be used for a detailed analysis of elements at risk and possible damage.

The findings of both research designs will be used to develop recommendations for authorities and individual actors in the region. These must be developed in cooperation with the other projects of InterRisk and local and regional experts. Such recommendations can include the utilization of hazard or risk maps for planning or administration to avoid housing development in endangered areas. The advice for private house and land owners on "best practices" of prevention, which are identified in research design two, could decrease possible damage to buildings and its cost.

4.1 Research design one: Regional risk analysis and evaluation (Fig. 3)

A GIS-based risk analysis will be developed in co-operation with other InterRisk projects. InterRisk Assess contributes a differentiated estimation of financial losses which can be related to natural risk models. A more detailed description will be presented in the following section.

The risk evaluation is based on the economic risk analysis. The evaluation integrates the results of research design two.

4.2 Research design two: Individual risk analysis (Fig. 4)

This part of the project consists of interviews with private households, firms and landowners in the study area. Information will be collected from about 300 private households using questionnaire surveys. The main issues are: damage to buildings caused by landslides, value of land and buildings, experiences with prevention, protection and safety measures, individual risk evaluation by the persons interviewed. Moreover, experts in administration, planning, politics, etc. will be interviewed. The expert interviews are intended to further the collection of additional background information and the determination of collective interests.

5 Analysis of potential losses

The methodology for the analysis and evaluation of natural risks has been improved considerably in the last decade (Fell, 2000; Heinimann et al., 1998, Hollenstein, 1997; Melching and Pilon, 1999; Peters Guarin, 2003; WBGU, 1998). Modern approaches are based on the triangle of relations between risk analysis – risk evaluation – risk management (BUWAL, 1999; Hollenstein, 1997; Kienholz, 1998).

Risk analysis focuses on the question "What can happen?". Risk analysis consists of three steps: the identification of danger, the analysis of relevant processes and the estimation of potential damage or loss and its consequences (Kienholz, 1994).

Risk evaluation deals with the question "What is allowed to happen?". The evaluation of risk is a "qualitative or quantitative characterization of damage in with regard to its likelihood and extent" (translated from Hollenstein, 1997). The results of risk analyses must be seen in the context of social, economic, cultural, historical and political conditions.

Table 1. Economic values in Lichtenstein-Unterhausen (at a distance of 500 m to the edge of the cuesta scarp).

land use	area (ha)	percentage	total land value (EUR)	total building value (EUR)
forest area	1027.12	77.69	5,135,610	
agricultural area	185.51	14,03	3,524,765	
residential area	49.15	3.72	122,883,461	264,345,797
mixed use area	12.30	0.93	25,209,858	
industrial area	2.54	0.19	1,779,104	
other land use	45.43	3.44		
total	1322.05	100.0	0 158,532,798	–

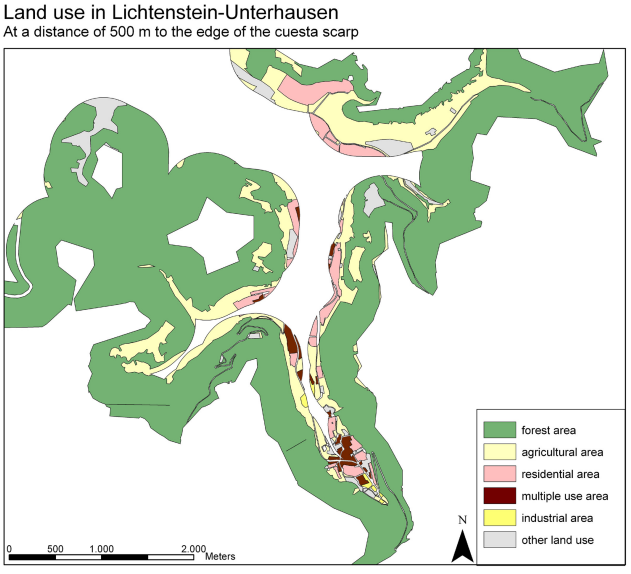


Fig. 5. Land-use in Lichtenstein-Unterhausen.

Risk management asks “What has to be done?”. It comprises all the preventive measures for reducing, controlling and regulating natural risks.

Most approaches in risk analysis and evaluation have a strongly theoretical background. More practical studies can enhance the quality of risk analysis and evaluation. In most instances studies are at a regional or local level (see Hofstede and Hamann, 2000; Liebermann and May 2000). One central aim of InterRisk Assess is the development of methods for the systematic analysis of landslide risk at a regional and local scale. It is an attempt to close the gap between the object (landslide) and the regional context. This problem is especially evident in the case of landslide risks which are mostly local and selective.

According to Kienholz (1994), the analysis of potential losses is an integral part of risk analysis. InterRisk Analysis is responsible for the initial steps “identification of danger” and “analysis of relevant processes”. InterRisk Assess carries out a financial analysis of potential losses. This is the basis for a model of risk assessment which takes patterns of individual and collective evaluation of landslide hazards into account.

We work on the assumption of an economic worst case scenario. Therefore, the financial risk is the maximum possible loss or damage which can be caused by a natural event. In cooperation with InterRisk Analysis, potential losses and damage will be estimated using GIS. A financial risk map will be created which can be used by administrative authorities, planning institutions, engineers or insurance companies. It will show different degrees of risk in combination with categories of potential damage.

The risk map is to be based on a hazard map, which will be provided by InterRisk Analysis. Another important basis for the risk map is a map showing economic values potentially affected in the research area (value map), which will be developed by InterRisk Assess.

The value map to be produced by InterRisk Assess will be generated from existing statistical data and findings obtained from the questionnaire survey and the expert interviews. The statistical data available includes land prices provided by the municipalities, real estate prices (comparative price lists for real estate), infrastructure prices as given by supply companies and home contents values (insurance companies).

The questionnaire survey and the expert interviews will seek information about the market value of houses, insured values and construction costs. The data helps to relate different land-use categories (e.g. different types of residential areas, industrial land, infrastructure) to specific economic values.

The basis for this value map will be provided by local zoning plans and development plans which will be linked with statistical data (floor space ratio, standardized construction costs or “Normalherstellungskosten” = NHK) and computed values. For example, Fig. 5 and Table 1 show the economic values of a village in the research area as reflected in the values of different land-use types. At this stage of the study, overall values will be calculated for residential areas only. This approach can be used for other land-use types as well as for analyses at a local level. Since almost all zoning or land-use plans are only available in analogue format, most of the relevant plans have to be digitalized.

The final step in the compilation of an economic risk map involves combining the value map with the hazard map. The compilation of both maps will show zones of landslide hazards with specific endangered economic values. If the extent

Table 2. Vulnerability of buildings according to the type of damage through landslides (modified after Leone et al., 1996).

Element at risk	Damage intensity	Type of damage	Vulnerability (0–1)
Building	I	Slight non-structural damage, stability not affected, furnishing or fitting damaged	0.01–0.1
	II	Cracks in the wall, stability not affected, reparation not urgent	0.2–0.3
	III	Strong deformations, huge holes in wall, cracks in supporting structures, stability affected, doors and windows unusable, evacuation necessary	0.4–0.6
	IV	Structural breaks, partly destructed, evacuation necessary, reconstruction of destructed parts	0.7–0.8
	V	Partly or totally destructed, evacuation necessary, complete reconstruction	0.9–1

of a landslide can be forecasted the immediate material costs incurred in a specific area can be identified.

The method presented here only makes it possible to estimate the direct material costs of a landslide with regard to real estate. A second step will take account of indirect costs caused by production downtimes or increased storage or transport costs as a result of destroyed or damaged technical infrastructure or factory buildings.

6 The problem of vulnerability

In order to analyze risk the following risk formula can be applied:

$$R = H \times E \times V$$

(R = risk, H = probability of an event in space and time, E = elements at risk, V = vulnerability).

The identification of vulnerability is part of all three steps in risk assessment, and is especially important in risk analysis. From the natural sciences (and engineering sciences) point of view, vulnerability is an important element in the analysis of consequences. It is related to the extent of loss and damage to an element at risk (Glade, 2003).

Several authors have integrated the concept of vulnerability in landslide risk analyses and assessments (Brabb, 1984; Hearn and Griffith, 2001; Leone et al., 1996; Leroi, 1996; Micheal-Leiba et al., 2000). In the case of landslide risk it is extremely difficult to analyze vulnerability, because landslide processes are complex and may have very different consequences (Leroi, 1996).

However, it is important to integrate the concept of vulnerability into the risk analysis of InterRisk Assess. The worst case scenario is only one not very realistic possibility in a range of events that could occur. A first step of integrating vulnerability into our research concept would be to establish different categories of damage. In this regard the approach of Leone et al. (1996) is very useful for InterRisk Assess, as the data base for damage caused by landslides in the study area is small. Leone et al. (1996) determine five categories of damage to buildings, ranging from "no structural damage" to "partially or totally destroyed" (see Table 2).

Other perspectives are also important in the project. Another aim of InterRisk Assess is to integrate social and non-pecuniary aspects into risk assessment. Aspects which influence vulnerability are particularly interesting. For example, knowledge of natural hazards and endangering processes and their perception, or knowledge of and information about preventive measures affect the coping capacity and vulnerability of individuals and society as a whole. Initial work towards the integration of these facets into risk assessment has been carried out in the context of InterRisk Assess. The preliminary findings of this analysis will be presented in the following section.

7 Preliminary empirical results

A first qualitative survey carried out in March 2004 comprised 19 households in Mössingen-Öschingen (12 km south of Tübingen). A more extended questionnaire survey started in September 2004. Up to now, 225 interviews have been conducted with private households. The questionnaire survey focuses on residential areas on slopes in Reutlingen, Lichtenstein-Unterhausen and Mössingen-Öschingen.

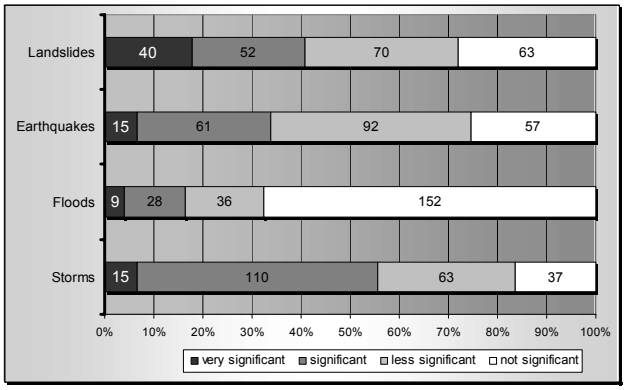
The study areas were selected using the following criteria: Firstly, all areas studied were to be on landslide-prone slopes of the Swabian Alb. The research areas range from the foot of the slope up to the upper limit of settlement. Secondly, we selected areas in different spatial contexts: in highly urbanized areas (Reutlingen), in suburban areas (Lichtenstein-Unterhausen) and in semi-rural areas (Mössingen-Öschingen). In all three areas, the housing studied consists largely of detached single-family residences.

Some buildings already show perceptible damage. Damage and losses arising from landslides can include cracks in masonry, damage to the electricity and water supply, subsidence or, at worst, the complete collapse of buildings (Fig. 6).

Some tentative results of the household survey are:

– The average market value of buildings (including the price of the land) ranges from EUR 350 000 to EUR 850 000 in the different research areas. Almost all house owners are insured against damage by the elements including landslides. The costs of reconstruction or repair

Fig. 6. House damaged by a landslide in Reutlingen. The photograph shows cracks between the main building and an extension.



(Source: Household survey September - December 2004, n = 225)

Fig. 7. Significance of selected natural hazards from the perspective of the local population.

are covered by the insurance companies (Finanztest, 2001).

– Landslides are seen as relevant natural hazards by the local population. Figure 7 shows the perceived relevance of landslides as a risk for the interviewees' houses in comparison with other hazards (earthquake, floods, and storms). 42% of the interviewees categorize landslides as relevant or very relevant for their homes.

– Landslide events are well-known, but in most cases only smaller local events were mentioned by the interviewees. The only landslide which was frequently mentioned in all three study areas was the event at Mössingen (Hirschkopf) in 1983.

– In 17% of the cases, damage to buildings was observed. About the same percentage of households was also affected indirectly by damage to infrastructure.

– Preventive measures were taken by many house owners (39%) with costs ranging from a few hundred Euro to EUR 50 000.

– Perception of landslide risks differs considerably from place to place and from household to household. Landslide risks are seen as a predominantly small-scale problem by most of the interviewees.

In addition to the questionnaire surveys we conducted 14 semi-structured interviews with local experts from administrative authorities (e.g. municipal administration, road construction office), regional planning (e.g. engineers, architects, stress analysts) and the real estate sector in May and July 2004. The main topics were recent experiences with landslides (location of areas, buildings, facilities or persons affected), protection, safety measures and prevention, the responsibilities of different organizations and institutions, risk management and assessment/evaluation patterns from the these experts' point of view.

Nearly all the experts knew of only a few cases of landslides. Three groups of experts can be identified:

Firstly, experts for whom landslides are only of minor importance. Their portfolio is rarely touched by landslide hazards. This group mainly consists of people in administration and real estate agencies.

Secondly, planners, architects and engineers who are well-informed about the problems and processes of landslides. They perceive the risk, but often underrate its dimensions.

The third group comprises people who deal with the problem almost every day. Road construction departments often belong to this group, as the transport system is vulnerable to landslides.

It became clear from the expert interviews that individual cost-benefit analyses with regard to landslides play only a marginal role in decision-making. The only exception is the increase in construction costs due to preventive measures. More important reasons for choosing a house location, however, are the topographic situation, the scenic beauty, the social environment or prestige.

According to the experts, individual voluntary preventive measures are taken by a relatively small number of house owners. They range from planning measures such as geological engineering consultations to construction works such as walls, reinforced foundations or deeper foundations. The additional costs can account for up to 20% of total construction costs.

Many people in the research area are insured against damage caused by natural hazards (including landslides), because there was a mandatory insurance for buildings in Baden-Württemberg ("Gebäudepflichtversicherung") until 1994 which included damage caused by the elements. Since the privatization of this insurance company in mid-1994 this type of insurance is no longer mandatory. However, most house owners have not altered their contracts.

All the experts we interviewed stated that there is no general risk management with regard to landslide risks. Only a few of them believe that risk management can be established

by politics or administrative authorities. In the experts' opinion, risk management does not exist for the following reasons:

- Landslide risks are not perceived as significant dangers or hazards by the administrative authorities and many inhabitants of the region, because events with dramatic consequences are relatively rare.
- The knowledge of natural processes underlying landslides is rather poor.
- Communication between potential actors in risk management concerning landslide risks is poorly developed or non-existent.

In general, the experts assume that landslide risks do not play a significant role in the choice of construction sites. The only natural hazards that are seriously taken into account are floods and earthquakes. In most of the experts' opinion, people do not perceive landslides as a risk, although the phenomenon "landslide" is well-known in the Swabian Alb. Some people completely deny the existence of landslide risks, others underestimate it. However, our household survey shows that the view of these experts might be too pessimistic. The explanation for this inconsistency between some experts' and "ordinary people's" views will be studied in more detail in the next stage of our project.

8 Conclusions

Landslides are important geomorphological processes in low mountain ranges in Germany. They are especially frequent in the Swabian Alb. However, these processes are not recognized as major hazards or risks by the local population and many "experts". Bearing these facts in mind, one aim of InterRisk Assess is to strengthen the theoretical base of natural risk research. The economic rational approach is an important element, but on its own it is not sufficient to explain human behavior with regard to landslides. More sophisticated models have to be developed, revealing the interrelations between public and private actors' perceptions, behavior and decision-making.

Economic risk assessment is a fundamental part of comprehensive risk analysis. One function of risk management is to inform people about existing risks, even if the probability of their occurrence is relatively low.

The main aim of natural risk research is to improve risk management. Risk management is based on improved knowledge of natural and socio-economic interrelations. InterRisk Assess is working to develop a model of risk evaluation and tools for the practical evaluation of economic risk.

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References

Abbott, P. L.: Natural disaster, Dubuque, 1996.

Bibus, E.: Die Rutschung am Hirschkopf bei Mössingen (Schwäbische Alb) Geowissenschaftliche Rahmenbedingungen – Geoökologische Folgen. Geoökodynamik, 7, 333–360, 1986.

Bibus, E.: Massenverlagerungen in Baden-Württemberg (Bi 224/10-1 und 2) im Rahmen des MABIS-Forschungsverbundes, Tübingen, 1998.

Brabb, E. E.: Innovative approaches to landslide hazard and risk mapping. Proceed, IV Int. Sym. Landslides, Toronto, 1, 307–324, 1984.

Bundesamt für Umwelt, Wald und Landschaft: Risikoanalyse bei gravitativen Massenbewegungen, Umweltmaterialien, 107/1, Bern, 1999.

Dikau, R. and Glade, T.: Gefahren und Risiken durch Massenbewegungen, Geographische Rundschau, 54, 1, 38–45, 2002.

Finanztest: Total abgebrannt, Finanztest, 11, 66–70, 2001.

Fell, R.: Landslide risk management, Concepts and guidelines, Australian Geomechanics Society, Sub-committee on Landslide risk-management, 2000.

Glade, T.: Vulnerability assessment in landslide risk analysis, in: Die Erde, 134, 2, 123–146, 2003.

Hearn, G. J. and Griffiths, J. S.: Landslide hazard mapping and risk assessment, in: Land surface evaluation for engineering practice, Geological society engineering special publication, 18, 43–52, 2001.

Heinimann, H. R., Hollenstein, K., Kienholz, H., Krummenacher, B., and Mani, P.: Methode zur Analyse und Bewertung von Naturgefahren, Eine risikoorientierte Betrachtungsweise, Umweltmaterialien, 85, BUWAL, Bern, 1998.

Highland, L. M.: An account of preliminary landslide damage and losses resulting from 28 February 2001, Nisqually, Washington, Earthquake, Open-File Report 03-211, U.S. Department of the Interior and U.S. Geological Survey, 2003.

Hofstede, J. and Hamann, M.: Wertermittlung sturmgefährdeter Gebiete in Schleswig-Holstein, in: Risikomanagement im Küstenraum. Beiträge zum internationalen Workshop 30./31. März 2000, Universität Hannover, edited by: Franzius-Institut für Wasserbau und Küsteningenieurswesen, 105–112, 2000.

Hollenstein, K.: Analyse, Bewertung und Management von Naturrisiken, Zürich, 1997.

Kienholz, H.: Naturgefahren – Naturrisiken im Gebirge, Schweizerische Zeitschrift für Forstwesen, 145, 1–25, 1994.

Kienholz, H.: Naturgefahren und -risiken in Gebirgsräumen, in: Nachhaltigkeit als Leitbild der Umwelt- und Raumentwicklung in Europa, 51, Deutscher Geographentag, edited by: Heinritz, G., Wießner, R., and Winiger, M., Stuttgart, 136–152, 1998.

Leone, F., Asté, J. P., and Leroi, E.: Vulnerability assessment of elements exposed to mass movements: working toward a better risk perception, in: Landslides, Glissements de terrain, Proceed. VII Int. Sym. Landslides, Trondheim, edited by: Senneset, K., Rotterdam, 263–270, 1996.

Leroi, E.: Landslides hazard – risk maps at different scales: objectives, tools and development, in: Landslides, Glissements de terrain, Proceed. VII Int. Sym. Landslides, Trondheim, Rotterdam, edited by: Senneset, K., Rotterdam, 35–51, 1996.

Lieberman von, N. and May, S.: Risikopotenziale für Nutzflächen und Infrastruktur, in: Risikomanagement im Küstenraum, Beiträge zum internationalen Workshop 30./31. März 2000, Universität Hannover, edited by: Franzius-Institut für Wasserbau und Küsteningenieurswesen, 97–104, 2000.

Melching, C. S. and Pilon, P. J.: Comprehensive risk assessment for natural hazards. World Meteorological Organization, WMO/TD, 955, Geneva, 1999.

Micheal-Leiba, M., Baynes, F., and Scott, G.: Quantitative landslide risk assessment of Cairns, Australia, in: Landslides: In research, theory and practice, Proceed. VIII Int. Sym. Landslides, Cardiff, edited by: Bromhead, E., Dixon, N., and Ibsen, M.-L., London, 1059–1064, 2000.

Münchener Rückversicherung: Topics 2000: Naturkatastrophen – Stand der Dinge, Special issue, München, 2000.

Münchener Rückversicherung: Topics geo. Jahresrückblick Naturkatastrophen 2003, München, 2004.

Peters Guarin, G.: Flood risk assessment for the town of San Sebastian in Guatemala, Enschede, 2003.

Schuster, R. L.: Socioeconomic significance of landslides, in: Landslides. Investigation and mitigation, edited by: Turner, A. K. and Schuster, R. L., Washington, D.C., 12–35, 1996.

Terhorst, B.: Formenschatz, Alter und Ursachenkomplexe von Massenverlagerungen an der schwäbischen Juraschichtstufe unter besonderer Berücksichtigung von Boden- und Deckschichtenentwicklung, Tübinger Geowissenschaftliche Arbeiten, Reihe D: Geoökologie und Quartärforschung, 2, Tübingen, 1997.

Thein, S.: Massenverlagerungen an der Schwäbischen Alb, Statistische Vorhersagemodelle und regionale Gefährdungskarten unter Anwendung eines Geographischen Informationssystems, Tübinger Geowissenschaftliche Arbeiten, Reihe D: Geoökologie und Quartärforschung, 6, Tübingen, 2000.

WBGU – Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen: Welt im Wandel, Strategien zur Bewältigung globaler Umweltrisiken, Jahresgutachten 1998, Berlin, 1999.