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Paolo Canuti · Kyoji Sassa
Editors

Landslide Science and Practice

Volume 7
Social and Economic Impact and Policies

Springer

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Volume 7: Social and Economic Impact and Policies

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Preface

Landslide Science and Practice

Proceedings of the Second World Landslide Forum

The Second World Landslide Forum (**WLF**) was organized at the headquarters of the Food and Agriculture Organization of the United Nations (FAO), Rome, Italy, on 3–9 October 2011. WLF is a triennial mainstream conference of the International Programme on Landslides (**IPL**) which is jointly managed by the IPL Global Promotion Committee consisting of the International Consortium on Landslides (**ICL**), the United Nations Educational, Scientific and Cultural Organization (UNESCO), the World Meteorological Organization (WMO), the Food and Agriculture Organization of the United Nations (FAO), the United Nations International Strategy for Disaster Risk Reduction (UNISDR), the United Nations University (UNU), the International Council for Science (ICSU), and the World Federation of Engineering Organizations (WFEO).

Background to the World Landslide Forums

The International Consortium on Landslides (ICL) was established by the 2002 Kyoto Declaration "Establishment of an International Consortium on Landslides," with the Statutes adopted in January 2002. The Statutes defined the **General Assembly** of ICL: In order to report and disseminate the activities and achievements of the consortium, a General Assembly shall be convened every 3 years by inviting Members of the International Consortium on Landslides, individual members within those organizations, and all levels of cooperating organizations and individual researchers, engineers, and administrators. The General Assembly will receive reports on Consortium activities and provide a forum for open discussion and new initiatives from all participants.

The First General Assembly 2005 to the First World Landslide Forum 2008

The First General Assembly was organized at the Keck Center of the National Academy of Sciences in Washington D.C., USA, on 12–14 October 2005. At this Assembly, the first full-color book reporting consortium activities for the initial 3 years, 2002–2005, was published as "Landslides-Risk analysis and sustainable disaster management" through Springer. The 2006 Tokyo Round-Table Discussion – "Strengthening Research and Learning on Earth System Risk Analysis and Sustainable Disaster Management within UN-ISDR as Regards Landslides" – toward a dynamic global network of the International Programme on Landslides (IPL) was held at the United Nations University, Tokyo, on 18–20 January 2006. **The 2006 Tokyo**

Action Plan – ***Strengthening research and learning on landslides and related earth system disasters for global risk preparedness*** **–** was adopted. The Tokyo Action Plan established a new global International Programme on Landslides (IPL) including holding World Landslide Forums. Accordingly, the Second General Assembly 2008 was replaced by the **First World Landslide Forum** and held at the United Nations University, Tokyo, Japan, on 18–21 November 2008.

Report of the Second World Landslide Forum

The Second World Landslide Forum – *Putting Science into Practice* – was organized at the Headquarters of the Food and Agriculture Organization of the United Nations (FAO) on 3–9 October 2011. It was jointly organized by the IPL Global Promotion Committee (ICL, UNESCO, WMO, FAO, UNISDR, UNU, ICSU, WFEO) and two ICL members in Italy: the Italian Institute for Environmental Protection and Research (ISPRA) and the Earth Science Department of the University of Florence with support from the Government of Italy and many Italian landslide-related organizations.

- 864 people from 63 countries participated. Attendance was larger than expected, and twice the attendance at the First World Landslide Forum 2008 in Tokyo (430 participants: 175 from Japan and 255 from abroad).
- 25 technical sessions were held, and 465 full papers were submitted. All accepted papers were edited in 7 volumes including this volume:
  1. Landslide Inventory and Susceptibility and Hazard Zoning
  2. Early Warning, Instrumentation and Monitoring
  3. Spatial Analysis and Modeling
  4. Global Environmental Change
  5. Complex Environment
  6. Risk Assessment, Management and Mitigation
  7. **Social and Economic Impact and Policies – this volume**

Requests of Cooperation for Further Development of ICL and IPL

ICL and IPL are global multidisciplinary and cross-sectoral initiatives to promote landslide science and capacity-development to reduce landslide disasters. The core activities of ICL and IPL are ***Landslides:*** Journal of International Consortium on Landslides, World Landslide Forum, and IPL projects. Thanks to worldwide support of the journal, the Impact Factor of ***Landslides*** was 2.216 for 2011 which is the highest within 30 ISI journals in category of Engineering, Geological. The journal will develop from a quarterly journal to a bimonthly journal from Vol. 10 in 2013. The Third World Landslide Forum – Landslide risk mitigation toward a safer geo-environment – at the China National Convention Center, Beijing, China, on 2–6 June (conference) and 7–11 June (Field Trip) 2014. The ICL entered into the second decade of its activities and organized a 10th anniversary Conference on 17–20 January 2012, in Kyoto, Japan. ICL adopted the ICL Strategic Plan 2012–2021, *To create a safer geo-environment-* as an outcome of this conference.

ICL is an international nongovernmental and nonprofit scientific organization promoting landslide research and capacity-building for the benefit of society and the environment, and is the thematic landslides platform in the UNISDR Global Platform for Disaster Risk Reduction. ICL activities are supported by voluntary efforts of ICL members and supporting organizations. All people involving in landslide research and landslide disaster mitigation activities are requested to cooperate for the development of this initiative through its second decade 2012–2021. (http://www.iplhq.org/ *and* http://icl.iplhq.org/).

We are deeply appreciative of all e Second World Landslide Forum participants and of the contributions from our UNESCO, WMO, FAO, UNISDR, UNU, ICSU, WFEO partners and all of our colleagues in ICL for the development of IPL up to now. Finally we address our sincere thanks to Filippo Catani and Alessandro Trigila (the associate editors) for their extensive efforts covering the technical sessions, and reviewing and editing the papers.

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Forum Chair

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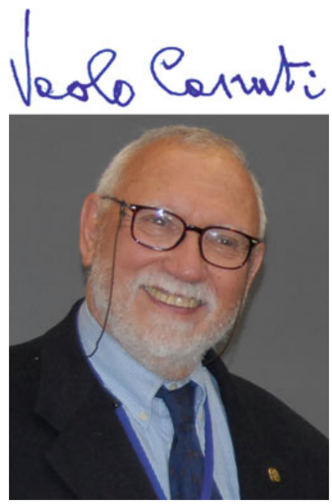
President of ICL



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Organizational Structure of the Second World Landslide Forum

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IPL Global Promotion Committee including:
- International Consortium on Landslides (ICL) *
- United Nations Educational, Scientific and Cultural Organization (UNESCO)
- World Meteorological Organization (WMO)
- Food and Agriculture Organization of the United Nations (FAO)
- United Nations International Strategy for Disaster Risk Reduction (UNISDR)
- United Nations University (UNU)
- International Council for Science (ICSU)
- World Federation of Engineering Organizations (WFEO)
- Italian Institute for Environmental Protection and Research (ISPRA)
  (* Members are listed in the last page of this book)

Co-sponsors

- International Union of Geological Sciences (IUGS)
- International Union of Geodesy and Geophysics (IUGG)
- International Geographical Union (IGU)
- International Flood Initiative (IFI)

Under the Auspices of

- International Association for Engineering Geology and the Environment, Italian Section (IAEG)
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Contents

Part I

Risk Management in a Multi-Hazard Environment

Introduction by Peter Bobrowsky[1], Salvano Briceno[2], Peter Lyttle[3], and Giuseppe Delmonaco[4]

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Session Description

In the last decades, landslides have caused increasing damage to people, urban areas and environment in developed and developing countries. This as a consequence of many factors such as hazard underestimation, lack of spatial planning policies versus natural hazards, poor risk reduction measures, application of single-hazard and risk methods and approaches. Effective and long-term structural landslide risk reduction measures and/or planning strategies at various scales should take into account the correlation among landslides and other climate-related and geophysical events that, along with mass movements, usually affect mountainous areas, in a multi-hazard perspective. The session aims to promote interaction among Earth scientists, land-use planners, risk managers, policy makers and providing experiences, recent developments and innovative cultural and technological approaches in several subjects, from integration and optimisation of methodologies for: multi-hazard analysis at various; vulnerability aspects (physical, social, economic); sustainable land use and spatial planning versus natural hazards; Na-Tech hazards; decision support systems; and IT tools to support stakeholders in risk management and mitigation policies.

Major Achievements and Outcomes

In the session, 18 papers were accepted for oral presentation and poster session. The papers have reported most of the numerous issues and potential objectives proposed for the session, by considering and analysing: (1) the theoretical approach of Landslide Risk Analysis (LRA); (2) occurrence and mutual interaction of several natural hazards (Multi-Hazard Assessment) and their effects on society; (3) transfer of knowledge to society (e.g. population, policy makers, stakeholders) also by developing IT tools for risk analysis and assessment; (4) development of LRA and MHA following a multi-scale analysis.

Several papers dealing with LRA have focused on some aspects of the theoretical methodological approach to landslide risk and/or multi-risk that are still underestimated such as: interaction of landslides with other natural and technological hazards as well as domino effects; assessment of quantitative risk (instead of qualitative/subjective analysis); analysis of vulnerability or fragility of the elements at risk, calibrated on single landslide type and specific typology of element at risk; integration and connection of different types of vulnerabilities (i.e. physical, economic, cultural, social and systemic) by means of indexes/matrices, at different spatial scales; development of probabilistic approaches for the assessment of spatial and temporal probability of hazard and consequences; development of risk scenarios, especially in a multi-hazard perspective, from site to regional-scale analysis, also in the light of Climate Change perspective.

Some works have presented results of funded programmes and projects mainly dealing with landslide risk management and mitigation (from site to national-scale) mainly focused on the necessity to promote basic knowledge of risk types and their awareness to society in order to improve correct policies aimed to risk reduction (i.e. exposure, coping capacity, resilience, adaptation) also by means of Information Technology tools available (i.e. through the Web-GIS) to several key stakeholders, such as Civil Protection, policy makers, public administration, general public.

Risk Profiles and Hazards for the Black Sea Area

Boyko Ranguelov

Abstract

The multihazard study area is located along the North Bulgarian Black Sea coast and is threatened by earthquakes, landslides and tsunamis, which occasionally act simultaneously. Four main factors are considered in our use of multi-risk assessment: natural hazards, exposure, vulnerability and coping capacity. The general algorithm of the methodology used for the multi-risk assessment comprises several consecutive operations. Several multi-risk maps have been produced covering the coastal zone of the North East Bulgarian Black Sea coast. The region has been separated into three sub regions (1, 2 and 3) and mapped for multi-risk. The risk profiles for each zone (sub region 1, 2 and 3) have also been calculated.

Keywords

Marine hazards • Risk profiles • Multirisk mapping

Introduction

The different methodologies used for multi-risk assessment usually results in different values, scenarios, decisions and management solutions, etc. (Ranguelov 2011). Each methodology has its own specifics, which makes the results and issues incompatible. Similar approaches are mostly preferred (Frantzova et al. 2005) and are used to compare and assess the results. The main task of this study is to cover a larger number of elements and parameters influencing the final outcome – most frequently – the multi-risk maps (Frantzova et al. 2005). The results obtained and the sensitivity of the methodology shows the influence of the different parameters and indicators. They have been represented in the form of maps – the most visible product of such an approach.

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Method and Materials

The main basis of the suggested and applied methodology is the last version of the methodology of.3 the Inter-American Development Bank for multi-risk assessment (WMO 1999; Hahn 2003; Ranguelov 2011). The modifications done by us are targeted to adapt the differences in the different parameters, and the data and information sources necessary for their assessment. The existence (or lack) of basic parameters due to different economic conditions in Bulgaria and the USA has been used for the changes made for the adaptation to the differing European economic environment.

Four main factors are considered in the application of multi-risk assessment:

1. Natural hazards;
2. Exposure;
3. Vulnerability;
4. Coping capacity.

For each factor the indicators are attributed for quantitative assessment:

(a) ***Natural hazards*** include the behaviour of the respective hazards in the past and the possible expected effects (the indices used consider the observed maximum magnitudes and intensities and the extrapolated expected

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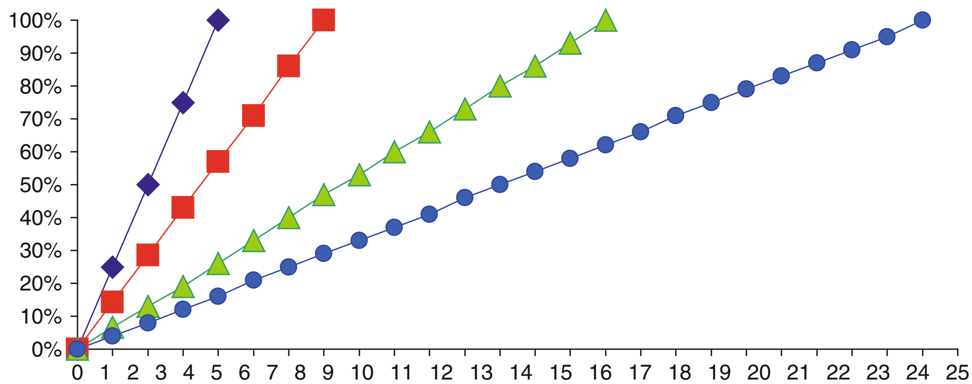

Fig. 1 Percentage of the number of indicators according the main risk factors: H (hazards – *blue diamonds*); E (exposure – *red diamonds*); V (vulnerability – *green triangles*); C (coping capacity – *blue dots*)

possibilities about earthquakes – for example). The indicators are H1–H4 and the values are extracted by the recurrences in time (4 indicators – 8 % of the total numbers used).

(b) ***Exposure*** – the indicators consider economical and infrastructure elements: buildings and facilities, roads, ports, total population and local GDP. The values of the indices are mainly based on derived statistics (7 indicators – E1–E7) – 14 % of the total number).

(c) ***Vulnerability*** – the indicators V1–V15 consider economic and social vulnerability unemployed/employed density of population, social security etc. (Dwyer et al. 2004). The indexes are based on derived statistics. (15 indicators – 30 %),

(d) ***Coping capacity*** – the indicators C1–C24 indicate reinforcement and codes applications, economical and management elements (24 indicators – 48 %).

It is clear that from one factor to the other the number of indicators increases approximately by a factor of 2 – Fig. 1. The total number is about 50. This means that a detailed picture could be reached, if the data to fill all indicators is available and reliable. It is important to mention that the collection of reliable data is rather difficult. Most of the municipalities do not have all the necessary information in the suitable form and frequently the expert judgment is essential. Sometimes the local statistics could be useful if the data are presented for long time intervals. The high number of factors, indices and weighting coefficients frequently lead to confusion that is why they must be carefully separated. The use of Excel as a tool in such cases is useful and applicable.

General Algorithm

The general algorithm for the multi-risk assessment is a set of consecutive operations (Ranguelov 2011):

1. General and priority hazards assessment of the selected region. Usually 2–3–4 hazards are of greatest importance (there are no limitations for their number, but for the better visualization 3–4 are enough).
2. Assessment of the main indicators. Usually this is done on the basis of available data and information.
3. Assessment of the weighting coefficients for the different factors of the complex risk. Formally they are equal to 0.25. It is an important operation because this is one of the most influential values to the results of the four factors (hazards).
4. Assessment of the scaled indicators values. Usually they are qualitative and there are three levels: low (1), medium (2) and high (3).
5. Completing the risk tables – one of the most important operations – needs expert judgment and careful assessment of the indices.
6. Calculations of the factor scores – by multiplication of the weighting coefficients and the scaled indicator values.
7. Calculations of the "risk" values by the formulae:

$$R = 0,25.H + 0,25.E + 0,25.V - 0,25.C \qquad (1)$$

where,

H are the values about the hazards indicators
E – values about the exposure of the different elements to the natural hazards
V – vulnerability values
C – coping capacity values.

8. Sensitivity assessment of the methodology in terms of the influence of different factors and weighting coefficients.
9. Risk profile construction.
10. Multi-risk mapping.

Application to the Northeast Bulgarian Clack Sea Coast

The area selection is based on the multifactor analysis considering many and different elements and factors. The region is affected by many natural hazards with a large range of impact (earthquakes, landslides, tsunami, erosion, abrasion,

Fig. 2 Multi-risk map for region 1. Hatched areas are seismic prone, lunar symbols – landslide prone and white line – tsunami prone areas

Fig. 3 Multi-risk map for Region 2. Hatched areas are seismic prone, lunar symbols – landslide (stonefals) prone and light line – tsunami prone areas

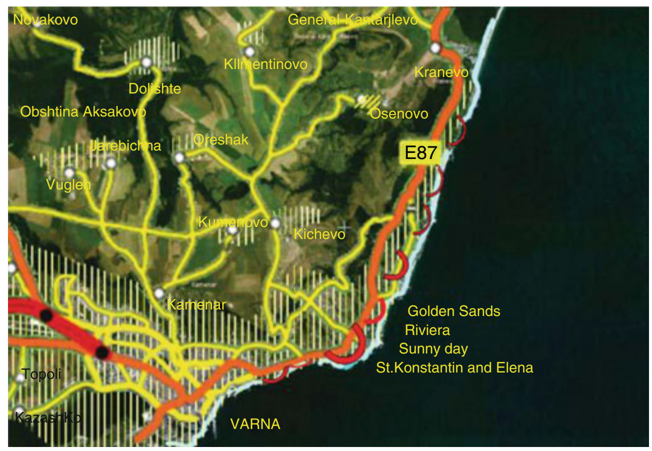

Fig. 4 Multi-risk map for Region 3. Hatched areas are seismic prone, lunar symbols – landslide prone and light line – tsunami prone areas

storms, floods, etc.) (Ranguelov et al. 2006). High probability of interaction between different hazards exists. Chains of consequences can also be expected.

After the multifactor analysis, the following natural hazards have been selected (earthquakes, tsunamis, landslide and stonefalls – called "landslides"). These hazards may interact during the same time or separately.

The region has a complicated infrastructure and develops various economic activities – tourism, agriculture, industry, larger and small inhabited areas, cultural heritage. Data and information availability is also an influencing factor for completing the risk table. An important element is the changing population density during the tourist season.

There is no other region in the vicinity with so variable list of parameters. Due to the tourist industry, the changes can be two or more times. The influence has different directions (increase and/or decrease), which can bring the effect of the "compensation" "inside" each factor.

By applying the described methodology, multi-risk maps have been created covering the coastal zone of the Northeast Bulgarian Black Sea Coast. The region has been separated into three sub regions covering the north part (from Cape Kaliakra up to the Bulgarian-Romanian border). The middle part covers the area from Kranevo to Cape Kaliakra and the south part – from the city ofVarna to the village of Kranevo. (Figs. 2, 3, and 4).The main reason for this separation was the different influence by the main hazards – earthquakes, landslides and tsunamis.

Sensitivity Analysis

The sensitivity analysis for the suggested methodology is developed given the influencing factors and their affect on the analysis output. The weighting coefficients are equal to all elements of the risk.

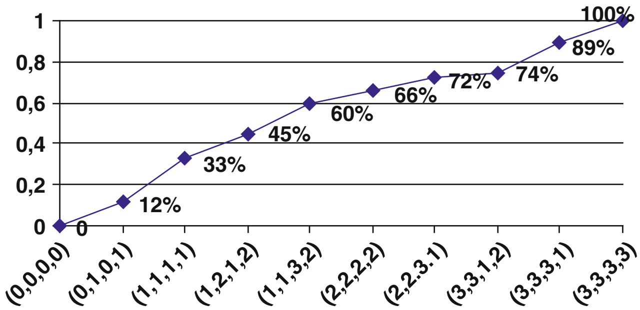

Fig. 5 Influence of the scaled values combinations (fixed weighting coefficients) according to Table 1

Table 1 Values due to the combinations of the scaled values (weighting coefficients fixed, different values (4–8) and sum equal to 25)

Weighting coefficient	Scaled values combinations	Influencing values due to the scaled coefficients (%)
	0,0,0,0	0
	0,1,0,1	12
	1,1,1,1	33
8	1,2,1,2	45
5	1,1,3,2	60
8	2,2,2,2	66
4	2,2,3,1	72
(Total 25)	3,3,1,2	73
	3,3,3,1	89
	3,3,3,3	100

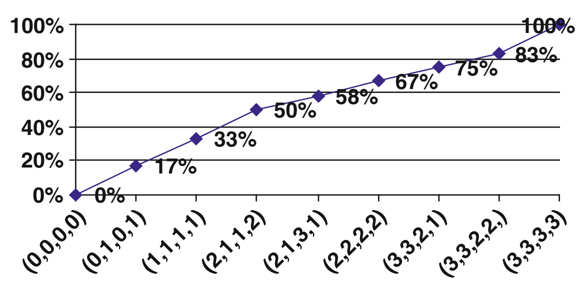

Fig. 6 Influence of the scaled values combinations (fixed and equal weighting coefficients) according to Table 2

The "scaled indicator values" are strongly influencing the "factor scores" – main risk quantity values. In our case, these values range from 1 – low, through 2 – medium, up to 3 – high. Several combinations of these values are presented on Figs. 5 and 6. Both graphs have the different combinations and different weighting coefficients. They are represented in Tables 19 and 20. The behavior is almost linear, but some fluctuations can be observed. The nonlinearities are insignificant, but can influence the final results, increasing or decreasing the total risk index. The weighting coefficients

Table 2 Values due to the combinations of the scale values (weighting coefficients, fixed – equal values (6.25) and sum equal to 25)

Weighting coefficient	Scaled values combinations	Influencing values due to the scaled coefficients (%)
	0,0,0,0	0
	0,1,0,1	17
	1,1,1,1	33
6.25	2,1,1,2	50
6.25	1,3,1,2	58
6.25	2,2,2,2	68
6.25	3,3,2,1	75
(Total 25)	3,3,2,2	83
	3,3,3,3	100

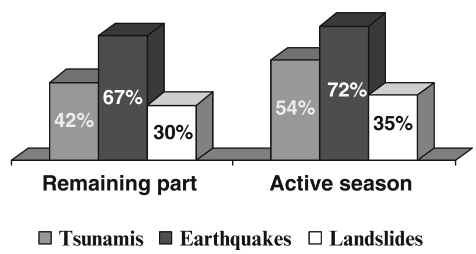

Fig. 7 Risk profile – Region 1

are important and also can influence the range of the final results. To obtain reliable values of the factors, weighting coefficients and the results themselves is an important task. These values can be obtained by statistics, expert judgment or direct calculations.

Discussion and Conclusions

The analysis of these results shows that greater influence can be expected from the hazards and vulnerability. The coping capacity and exposure are less influential. This means that the assessment of the hazards and the vulnerability need special attention and research in order to estimate their values. That is why these elements should be assessed more carefully to obtain more precise results. Neglecting these values can be confusing and can produce wrong results. The "seasonal factor" is about 10–15 % which in general means a significant influence. The same values can be expected also for the "day–night" effects, especially during the high (active) season.

The possible hazards zones due to the tsunamis, earthquakes and landslides have been outlined – Figs 7, 8, and 9 – and mapped.

The improved methodology of the Inter-American Development Bank for Multi-risk Assessment (IADBMA) has been successfully adapted to European conditions. The sensitivity analysis and the results obtained have shown that the influence

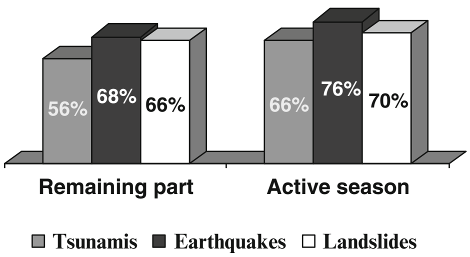

Fig. 8 Risk profile – Region 2

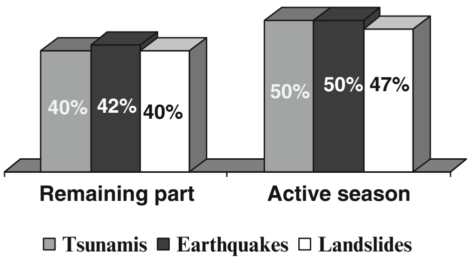

Fig. 9 Risk profile – Region 3

of the main parameters is essential. The lack of data and information for some less important indicators suggests they can be skipped, without significant impact to the result. But there is a "sanitary" minimum which cannot be eliminated. The assessment shows that the methodology "works" reliably up to about 50 % of the total number of indicators. After that the final results may not be correct, and maybe confusing. This was proven after many numerical experiments. The application to the North Bulgarian Black Sea coast shows that the obtained results are reliable and stable for multi-risk assessment and mapping. The "risk profiles" can help risk management institutions to take fast and reliable solutions to decrease the risk factors.

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Risk Concept Switzerland Hazard Analysis, Risk Evaluation and Protection Measures

Tobler Daniel and Bernhard Krummenacher

Abstract

The results of the hazard mapping system in Switzerland are visualized by three colours (red, blue and yellow) which indicate the general degree of danger PLANAT (Sicherheit vor Naturgefahren – Vision und Strategie der PLANAT. Nationale Plattform Naturgefahren, 2003). The narrative description of the three colours considers the degree by which people and assets of considerable material value are endangered. The hazard map is a primary management tool for land-use planning and regulation for settlement developments. For all other infrastructures (roads, lifelines) the risk map is the appropriate instrument to illustrate damage potential. The risk map is the basis for chronological and financial prioritisation of protection measures. It is the most appropriate tool for decision making about structural and non-structural measures. Based on the calculated risks, the cost effectiveness of protection measures can be evaluated. Switzerland developed the online-tool "EconoMe" to calculate the natural risks and cost-effectiveness of different protection measures BAFU (EconoMe – Wirtschaftlichkeit von Schutzmassnahmen gegen Naturgefahren, 2008). Today it is essential to invest funds with the most possible cost efficiency. Risk based decisions are therefore required.

Keywords

Swiss risk concept • Hazard assessment • Hazard analysis • Riske valuation • Cost-effectiveness

Introduction

Risks from natural hazards play an increasingly important role in our society (Lateltin et al. 2005; Latelin 2009). Major disasters in the past decades provide a wake-up call for authorities, insurance companies and the public at large. A review of the risk and disaster management system became evident (BUWAL 1998; Wilhelm 1999). The assessment of the prevailing hazards, vulnerabilities and risks was recognized as an important task. Therefore, hazard maps and related instruments have been developed at a federal level (PLANAT 2005a, b, 2011). The primary goal of all these instruments is to find answers to the following questions (see also Fig. 1):

– What can happen and where will it happen?
– How often and how intense will it be, and how large is the expected damage?
– What are the most efficient ways to protect people and assets?

Therefore the common denominator of these approaches is the understanding of natural hazard management as a threefold task (A) risk assessment, (B) risk evaluation, and

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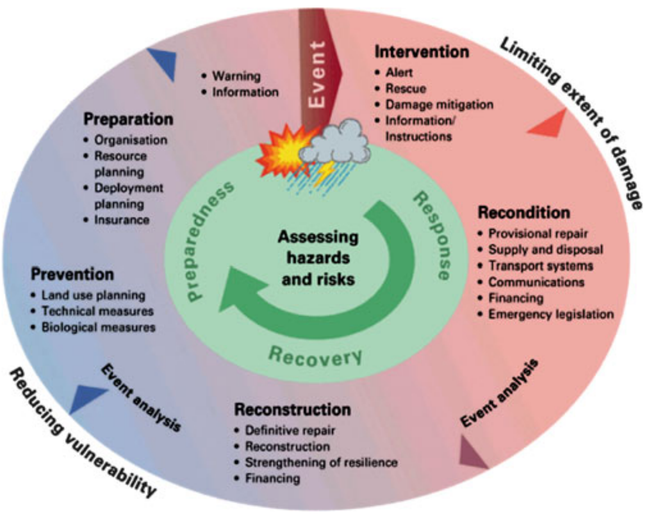


Fig. 1 Integrative risk management is understood as the systematic approach adopted within a cycle of preparedness, response and recovery (PLANAT 2011)

(C) planning of measures, applying an integrated approach (Frey and Krummenacher 2001; Bründl et al. 2009b).

The Swiss concept of risk aims at an optimised allocation of financial resources by reducing risk with a given relation of risk reduction cost, also called the marginal-cost criterion (Kienholz et al. 2004; Bründl et al. 2006; Fuchs et al. 2007). New political conditions for the subsidy of mitigation measures and limited public budgets have led to the development of a new software tool called EconoMe (Bründl et al. 2009a, b). The different tasks defined as major steps in the software are illustrated in Fig. 2. A detailed description of the different steps in the risk concept and the software EconoMe can be found in Bründl et al. (2009a).

This paper focuses on the risk analysis – especially the hazard assessment – as well on a few aspects in risk evaluation. The discussion of cost effective protection measures will be shown with a case study.

Risk Assessment

Risk assessment is the basis of decision-making for every type of involvement in disaster risk management (or disaster reduction). For this purpose several tools and instruments exist, some developed in Switzerland. They are currently being applied in a number of cases abroad (PLANAT 2005a).

Risk Analysis

The risk analysis is the heart of the risk concept. It consists of three major tasks, the hazard analysis, the exposure analysis and the consequence analysis.

Hazard Analysis

The key element of each risk analysis is the hazard analysis. The basic information about the different hazardous processes can be taken from field investigations, different kind of maps (e.g. geology, hydrogeology, topographic), event inventories and aerial photographs.

For further steps in the risk concept intensity maps are needed. They provide the spatial extent and the corresponding intensities of a natural event having a specific return period or probability (PLANAT 2005a). The intensities are normally classified into three classes (low, moderate, high). The physical impacts of the hazard can be enhanced by e.g. modelling or conclusions by analogies.

An important result of the hazard analysis is visualized in the hazard map by the three colors (red, blue and yellow), which indicate the degree of danger (Fig. 3).

The word “danger” (inappropriately used in the Swiss recommendations for hazards, due to the lack of an equivalent German term) or hazard thereby denotes the degree of exposure of persons, buildings and/or infrastructure to a potential hazard of a specified level. This three-color system is used for all types of hazards, i.e. debris flows, landslides (deep-seated, shallow), rock fall, and snow avalanches Raetzo et al. (2002). The classes of the return periods (or probability of occurrence) are the same for all hazards. The level of danger for all types of hazards is determined in a similar way: it is a combination of the magnitude (intensity) of the process in a particular location and its probability of occurrence (return period) in that location. The narrative description of the three colours considers the degree by which people and assets of considerable material value are endangered.

Exposure Analysis

In an exposure analysis the elements at risk have to be identified. These can be persons or assets, which varies in their number, type, value and probability of exposure to a certain process. The exposure for the different types of objects can be either permanent (roads, railway lines, buildings) or transient (traffic, persons). The selection of the elements at risk can easily be done using a GIS. The determination of the different probabilities of exposure follows the Swiss guidelines (BUWAL 1999).

Consequence Analysis

In the consequence analysis the expected damage for all exposed objects according to vulnerability and probability of presence has to be calculated. The consequences are

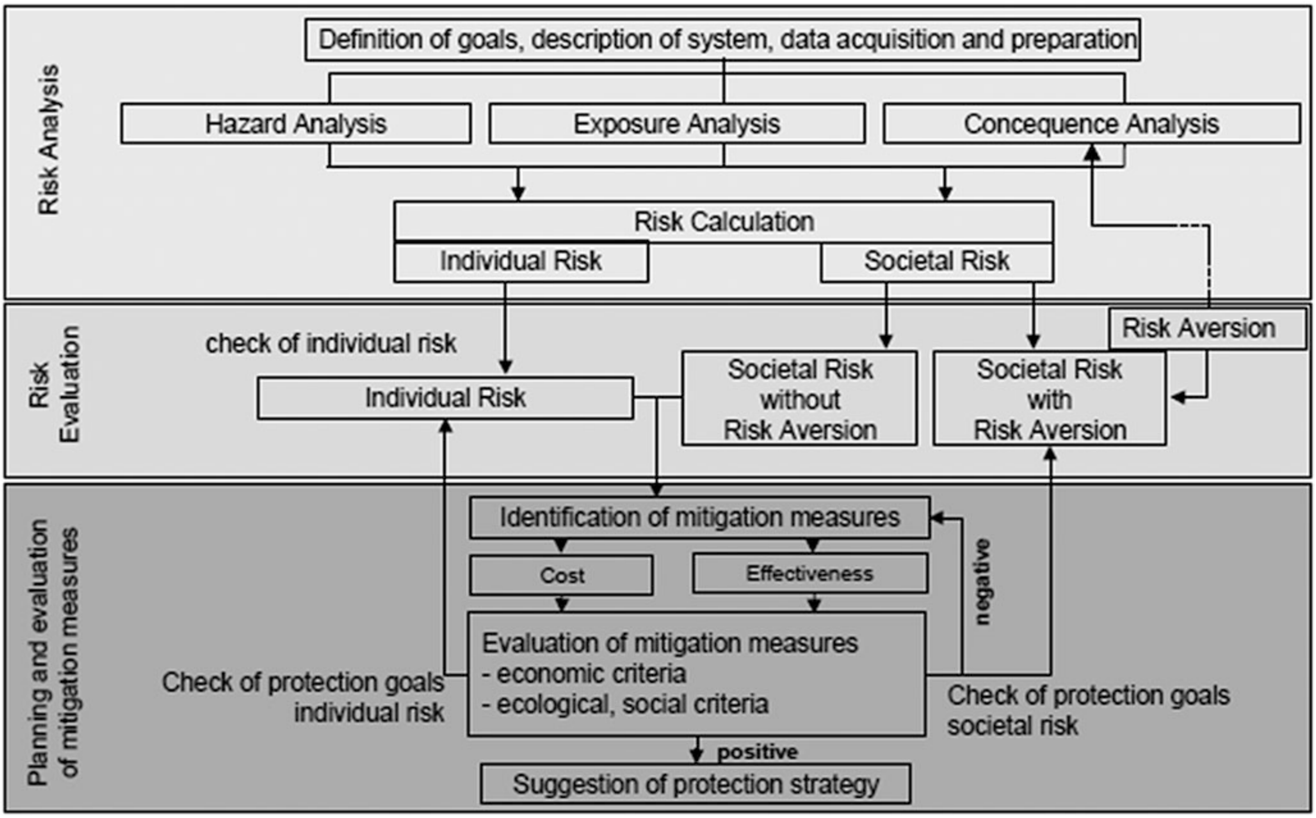


Fig. 2 Illustration of the risk concept Switzerland with the threefold task of risk analysis, risk evaluation and planning and evaluation of protection measures (Brundl et al. 2009b)

usually described in terms of different damage indicators (e.g. fatality, injury, physical loss, loss of production or income, etc.) and their vulnerability (e.g. the vulnerability of a person can be expressed as lethality).

This analysis combines the hazard and the exposure analysis yielding the expected damage or loss including all considered scenarios (Bründl et al. 2009a).

Risk Calculation

The basic definition of risk (R) can be expressed as probability (p) times consequences (C) of different outcome scenarios associated with a hazard (Bründl 2009).

$$R = p \times C \quad (1)$$

A specific person is primarily concerned with their own exposure to danger. The individual risk of a person can be defined as the probability of a specific consequence to this person. The probability of a consequence can be subdivided into the probability of the hazard scenario and the probability of the exposure to this scenario.

A hazard usually affects more than one person. The sum of the individual risks of the potentially affected people is referred to as their collective risk associated to this scenario.

Risk Evaluation

The collective as well as the individual risk are compared with predefined safety goals. The Swiss strategy of natural hazards (PLANAT 2005a) suggests safety goals for individual risks not higher than 10^{-5} for involuntarily taken risks.

To transform the different risk units into monetary risk units (e.g. fatalities/year → monetary value/year) the principle of marginal costs is applied. The marginal costs are equal to the willingness to pay for reducing the risk for one risk unit (Wegmann and Merz 2001). Persons are monetised by the value of statistical life, which expresses the amount of money a society is willing to pay for averting a fatality (Bründl et al. 2009a).

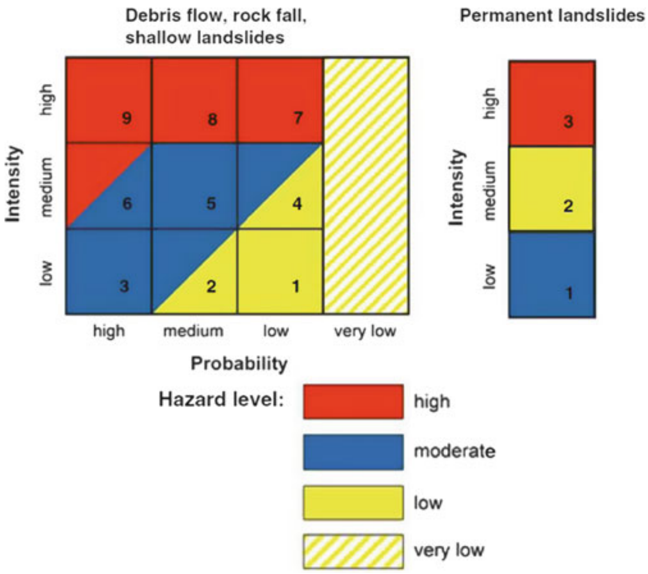


Fig. 3 Matrix for the determination of the danger level with the three colors *red*, *blue* and *yellow* (PLANAT 2005b)

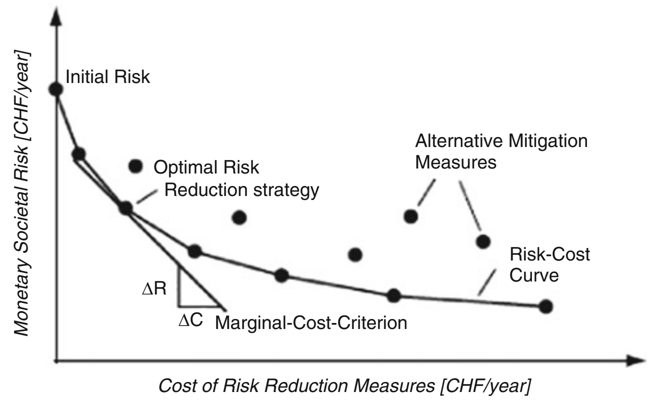


Fig. 4 Risk-cost diagram which illustrates the optimisation of mitigation measures by using the marginal-cost-criterion. Where the tangent touches the risk-cost curve the economical optimised combination of measures under the given assumptions is suggested (Bründl et al. 2009b)

Planning of Protection Measures

The risk-based planning of safety measures (risk management) is based on the risk assessment process. The following questions need to be answered: Are the risks acceptable? What options are available, and what are their associated trade-offs in terms of costs and benefit (risk reduction)? And, what is the impact of the current management decision on future options? Before it can be discussed whether a risk is acceptable or not, it is necessary to have an overview of the possible safety measures. The risk assessment gives valuable insights where to and where not to consider safety measures. The evaluation of different safety measures is basically a question of how much money can be paid to reduce the perceived risk. This question is linked to the problem of resource allocation and can be solved as an optimization task. The optimal solution minimizes the residual risk for the longest period at the cheapest price (Fig. 4).

Case Study, High Mountain Valley, Chile

Introduction

The traffic on a major motorable road in a high mountain valley in the Chilean Andes will increase due to the growth of nearby mining activities in the future. The steep slopes of solid rocks stand under a constant interaction with snow and ice and are under stress from temperature variations, producing intense jointing and generation of coarse debris with large block sizes of tens of m^3. Debris flows and rock falls from the partially altered volcanic and intrusive lithologies are present on most sites.

Hence, the risks of accidents caused by natural hazards such as rock fall, debris flows, landslides and avalanches will rise. As a first approach to reduce these risks, it is essential to carry out hazard assessments along the roads and lifelines. Second, measures to protect those locations with potential risks have to be proposed. Third, a periodization of the proposed protection measures has to be initiated on the base of the cost-effectiveness.

Hazard Analysis

The evaluation of rock fall and debris flow hazards is based on substantial on-site inspections by foot and by helicopter, on information from recorded and witnessed events, the DTM, on analysis of aerial photographs as well as the geological basics of lithology and tectonics. The existing protection measures have been taken in to consideration especially for debris flow processes.

Due to the given lithology and the strong tectonic stress of the rock, the assessed area shows strong weathering phenomena. Therefore it was challenging to define scenarios for the different processes.

The physical impacts of the hazards have been derived from a detailed process analysis, which was enhanced by physical modelling. For rock fall the model ROFMOD 3D (Tobler et al. 2009; Krummenacher and Keusen 1996; Figs. 5 and 6) and for debris flow processes the model RAMMS (Graf and McAdrell 2011; Scheuer et al. 2011; Fig. 7) have been used. Both models are well established in Switzerland.

Within the investigation area the process extensions and intensities for different scenarios have been defined. As a

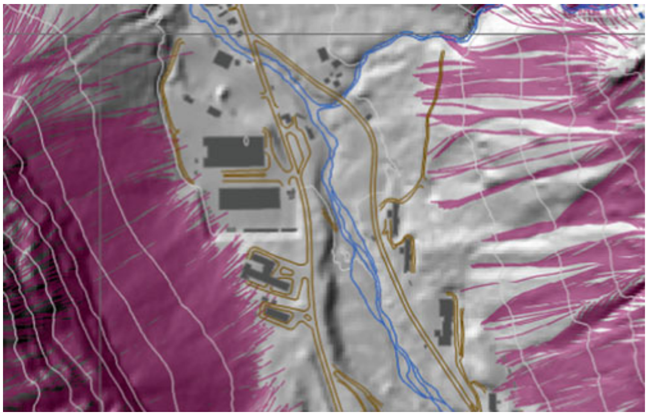


Fig. 5 Rock fall endangered area with trajectories of a 100 years scenario (block size approx. 3 m^3) derived from ROFMOD 3D

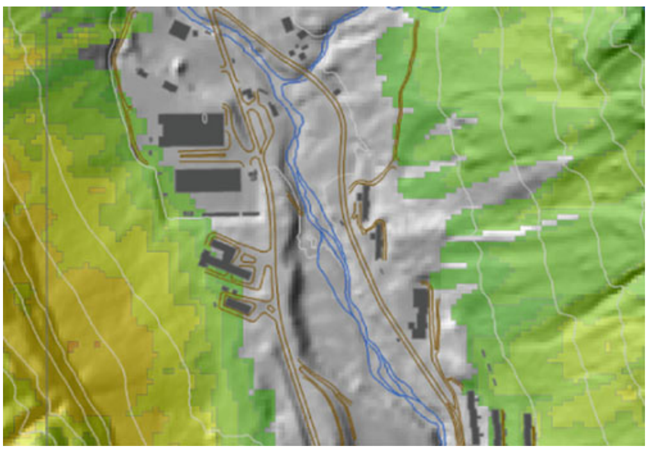


Fig. 6 Rock fall endangered area with energies of a 100 years scenario (block size approx. 3 m^3) derived from ROFMOD 3D

base for the risk calculation, intensity maps have been generated for all processes (debris flow and rock fall) and scenarios.

Exposure Analysis

In a first step the exposure analysis has been done only in a small part of the whole investigation area. Furthermore only infrastructures have been defined (Fig. 8). These operations can easily be done in a GIS. For every selected object the necessary parameters have to be specified. For a proper risk analysis it will be important to define all existing elements at risk. For this analysis the newly developed software tool EconoMe was used. All parameters were implemented in the software.

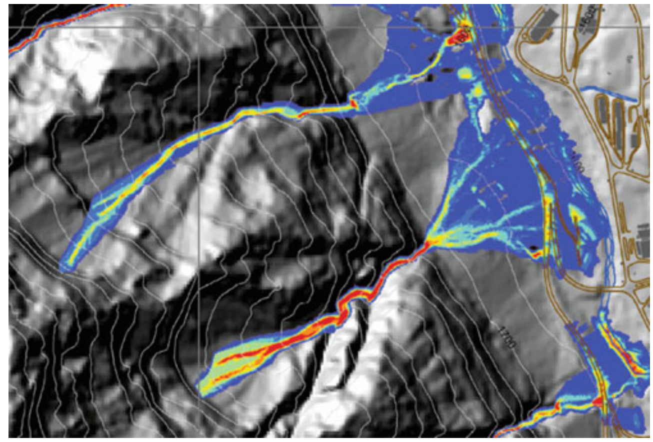


Fig. 7 Process areas with indication of flow heights of debris flows derived from the model RAMMS

Consequence Analysis and Risk Calculation

In a small test area the consequence analysis and the risk calculation have been completed. These steps are automatically done in the software tool EconoMe. The goal was to present the tool to the responsible persons and authorities. As a product the risk for every object at risk will be calculated.

Protection Measures

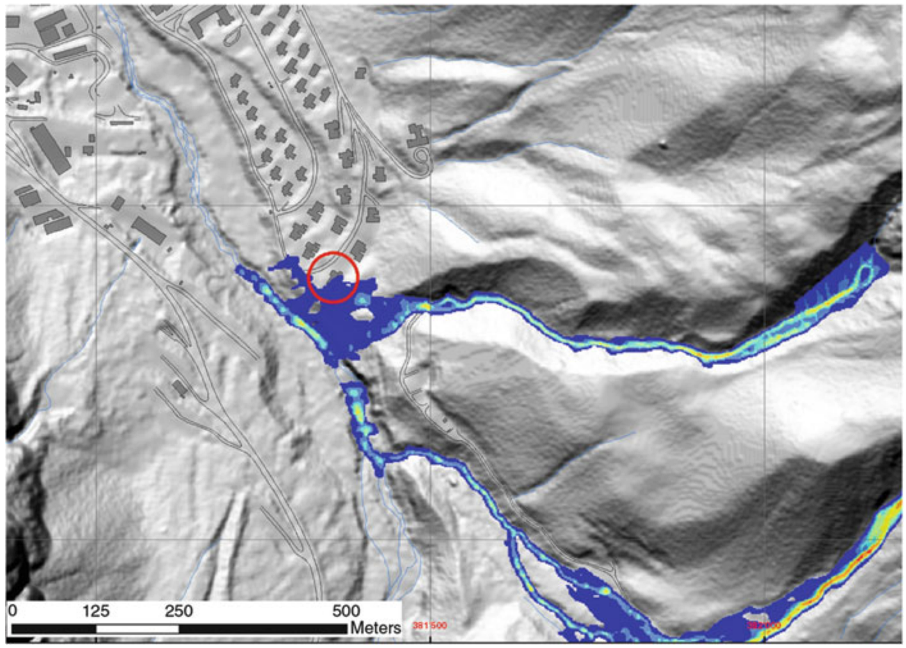
The measurement planning is based on the on-site findings, the model results and the long-term experience of the project team. As a first step, the measures are described only qualitatively with a rough dimensioning and cost estimation. The goal was the ranking of different types of measures in general for a basic discussion (Fig. 9).

Conclusions

The case study proved, that the proposed approach to quantify risk and rank different mitigation measures is suitable for long-term and regional planning. Based on the experience in the case-study the following qualities can be emphasized:

(a) The concept leads to an efficient and systematic assessment of risks and ranking of protection measures. It supports a long-term regional planning. All necessary data are collected and evaluated through field analysis, discussions with local experts, decision-makers, intervention and prevention specialists as well as local hazard experts.

Fig. 8 Debris flow affected area with one element at risk (*red circle*). This object can be selected automatically in a GIS when cutting the element with the process layer



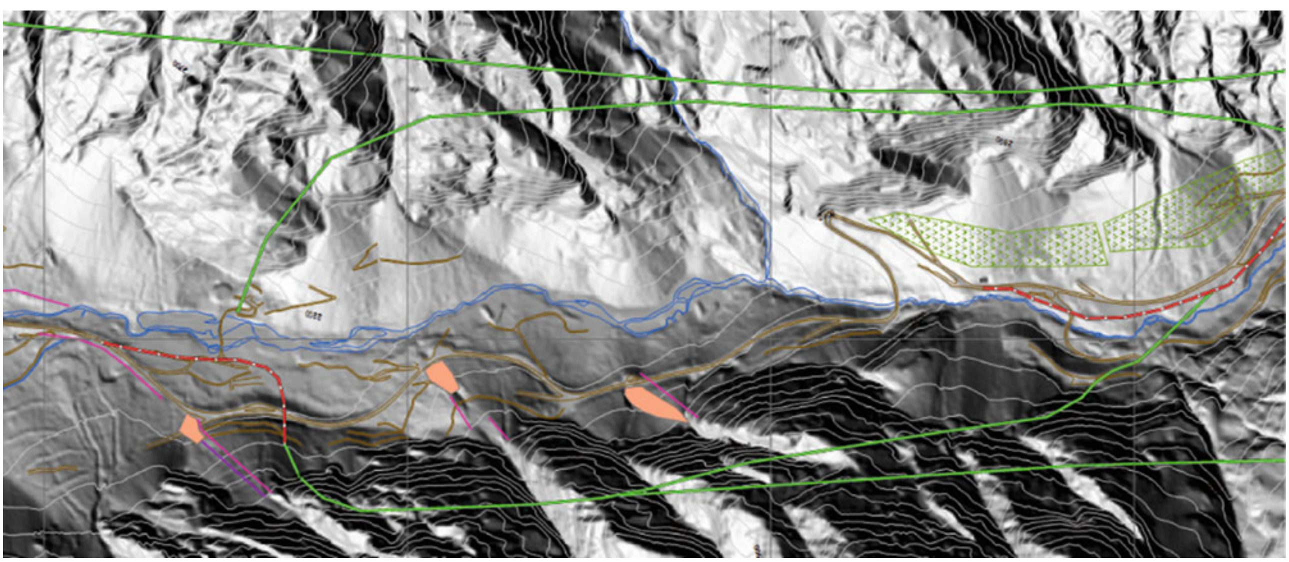


Fig. 9 Area along the analysed valley with different possible protection measures like tunnels (*green*), road relocations (*red*), retention basins for debris flows (*orange*) and deflection dams (*violet*)

(b) One of the most important parts of the whole concept is the risk analysis. The better the base dataset is, the more precise the output. A intensive field investigation is the fundamental part of every hazard analysis.
(c) A risk evaluation supports the decision-making process. The representation of risks and cost-effectiveness of protection measures allows the decision-makers to come to sound and informed decisions. The procedure is straightforward and efficient.
(d) The software EconoMe allows one to rank different protection measures with respect to their cost-effectiveness in a very efficient way. Furthermore it advocates the communication between those who are potentially affected by natural hazards and hazard

experts. It supports the efforts towards a holistic, transdisciplinary and risk based safety planning. Furthermore it supports the discussion about unsolved questions, uncertainties or disagreements in a transparent and efficient manner (see also Wegmann and Merz 2001).

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THE SECOND WORLD LANDSLIDE FORUM

Landslide Risk Assessment and Management Using IT Services and Tools: The EU BRISEIDE Project Approach

Giuseppe Delmonaco, Domenico Fiorenza, Luca Guerrieri, Carla Iadanza, Daniele Spizzichino, Alessandro Trigila, and Eutizio Vittori

Abstract

The increasing damage caused by natural hazards in the last decades in Europe, amplified by recent events including landslides (Messina, Sicily, September 2009), earthquakes (L'Aquila, Abruzzo, April 2009), forest fires (Greece, 2008) and floods (Central Europe) in the last years, points out the need for interoperable added-value services to support environmental safety and human protection. Many environmental analyses, e.g. monitoring seismic sequences, early warning systems for the evolution of intense rainstorms, the path of forest fires, cannot be performed without considering the evolution, over time, of geographic features. For this reason, providing access to harmonized data is only one of several steps towards delivering adequate support to risk assessment reduction and management. Scope of the present work is to present the implemented risk reduction and management pilots developed by BRISEIDE's team project.

Keywords

Landslide • Earthquake • ICT • WPS

Introduction

BRISEIDE "BRIdging SErvices, Information and Data for Europe" (www.briseide.eu) is an EU-funded ICT Policy Support Programme project. It involves 15 EU partners on the development of spatio-temporal Web Processing Services (WPS) for geospatial application within civil protection scenarios. The software architecture and IT tools infrastructure are deployed over a pan-European set of pilots, that provide a Decision Support System for emergency planning (before event) and emergency management (during the event).

Spatial analysis and spatio-temporal web processing services (WPS) are accessed through the web and made available by integrating them within existing open source frameworks through compatible WebGIS applications. One of the main results of BRISEIDE is the implementation of added-value spatio-temporal services based on potential final users and stakeholder needs and practices. For this reason, the project has a relevant number of user partners, such as Agencies and Public Administrations, dealing with urban planning, environmental management and risk management, that need spatio-temporal processing of Geographical Information to support decision making in critical situations. This ambitious goal is based on an articulated software architecture and IT tools infrastructure.

In particular, this paper is focused on two specific BRISEIDE use cases focused on landslide risk (Delmonaco et al. 2011). One is dedicated to the evaluation of geological effects induced by earthquakes, including coseismic rock falls, on transportation networks (roads and railways), lifelines (gas and water pipelines) and critical facilities (high-risk industrial plants). The second use case addresses a simplified landslide risk mapping procedure that shows areas with landslides (using Italian landslide inventory, the IFFI project (Trigila 2007; Trigila and Iadanza 2008; Trigila et al. 2010), developed

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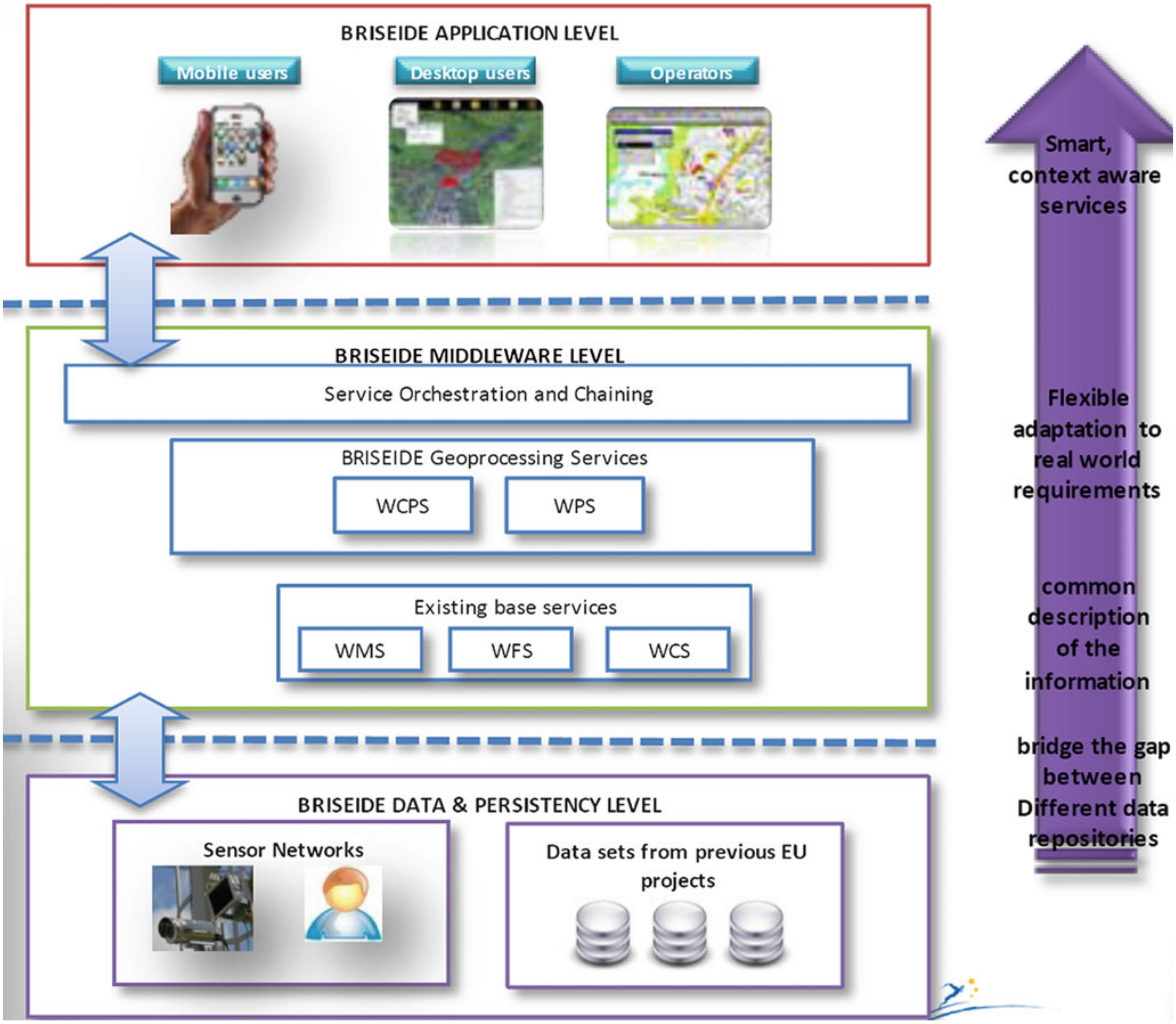

Fig. 1 Scheme of the BRISEIDE infrastructure

by ISPRA) overlapping areas with exposed infrastructure elements (derived from national datasets).

Methodology

The methodological approach developed in this research (Fig. 1) responds to a number of key requirements, namely improving access and reuse of existing OWS through new value added operational oriented services, introducing the time variable into the existing geo-databases, integrating existing geo-databases with operational databases, delivering query, processing and visualization services for spatio-temporal data and finally supporting easy orchestration of web processing services to create 3D geo-browsers complex simulations.

Landslides Induced by Earthquakes

The objective of the first pilot is to provide a scenario showing:

1. The most susceptible areas to seismic shaking, on the basis of geological and geomorphological characteristics, presence of landslides and capable faults (ITHACA – Database of Capable faults by ISPRA) and evidence of geological effects induced by past earthquakes;
2. The elements at risk, such as transportation networks (roads and railways), lifelines (gas and water pipelines) and critical facilities.

A surface faulting hazard map, which delineates the areas around capable faults where the surface faulting hazard is

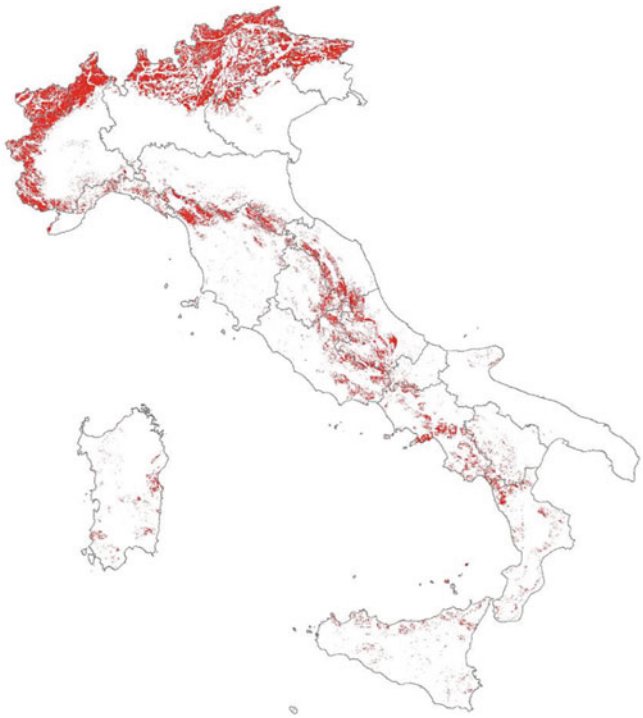

Fig. 2 Rockfall susceptibility map derived from IFFI database

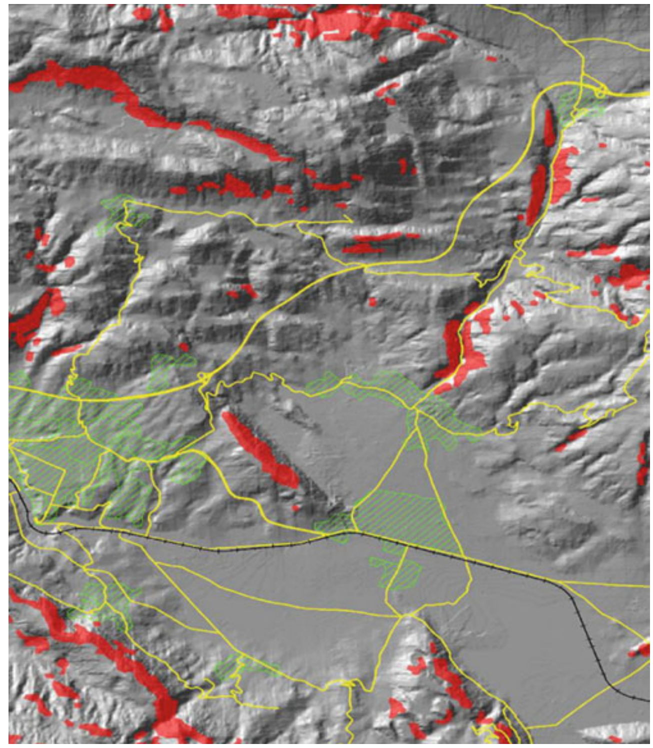

Fig. 3 Example of intersection between exposed elements (*green*: urban areas; *yellow*: road network) and rockfall susceptibility map (*red* areas)

relevant, and a rockfall susceptibility map, which identifies the areas where rockfalls are most likely to occur, have been created by ISPRA and are provided as input layer in the Table of Contents of BRISEIDE platform.

The system will show the area of interest represented by a circle/ellipse with radius proportional to the earthquake energy based on empirical relationship between size area and magnitude/peak ground acceleration (PGA).

The user will be able to identify in the area of interest:

- The areas susceptible to rockfalls (Fig. 2);
- The areas prone to surface faulting hazard (Fig. 3);
- The elements at risk like segments of transportation network, water pipelines, characterized by relevant surface faulting hazard and/or susceptible to the occurrence of coseismic rockfalls (Figs. 4 and 5).

The support system also provides analysis of the change in risk based on multi-temporal datasets of Corine Land Cover (Figs. 5 and 6, Tables 1 and 2).

Landslide Risk Assessment Use Case

The objective of the second pilot is to provide a landslide risk scenario for a selected NUTS3 or municipality, starting from information and dataset of the Italian Landslide Inventory (Progetto IFFI – www.sinanet.isprambiente.it/progettoiffi) based on:

- Number, area and type of movement of landslides occurred in the past;
- Urban settlements affected by landslides, population at risk, critical points along road network and railways (Figs. 7 and 8);
- Landslide risk change detection;
- Landslide and transportation network analysis.

In this pilot the operator can perform a number of Web geo-processing tasks (e.g. buffer, overlay, network analysis) in order to produce landslide risk maps and tables summarising information related to landslides and exposed elements.

Identification of Infrastructures at Risk

The user is able to create an appropriate buffer around the railway or road network through the buffer web process, (Fig. 9), and then to determine areas impacted by landslidesthrough the intersect tool (Fig. 10). The resulting intersection area is shown as a new layer provided as WFS (Web Feature Service).

Identification of Urban Areas and People at Risk

The user will be able to perform intersection between urban areas and landslides. The number of people potentially exposed is calculated multiplying the number of residents

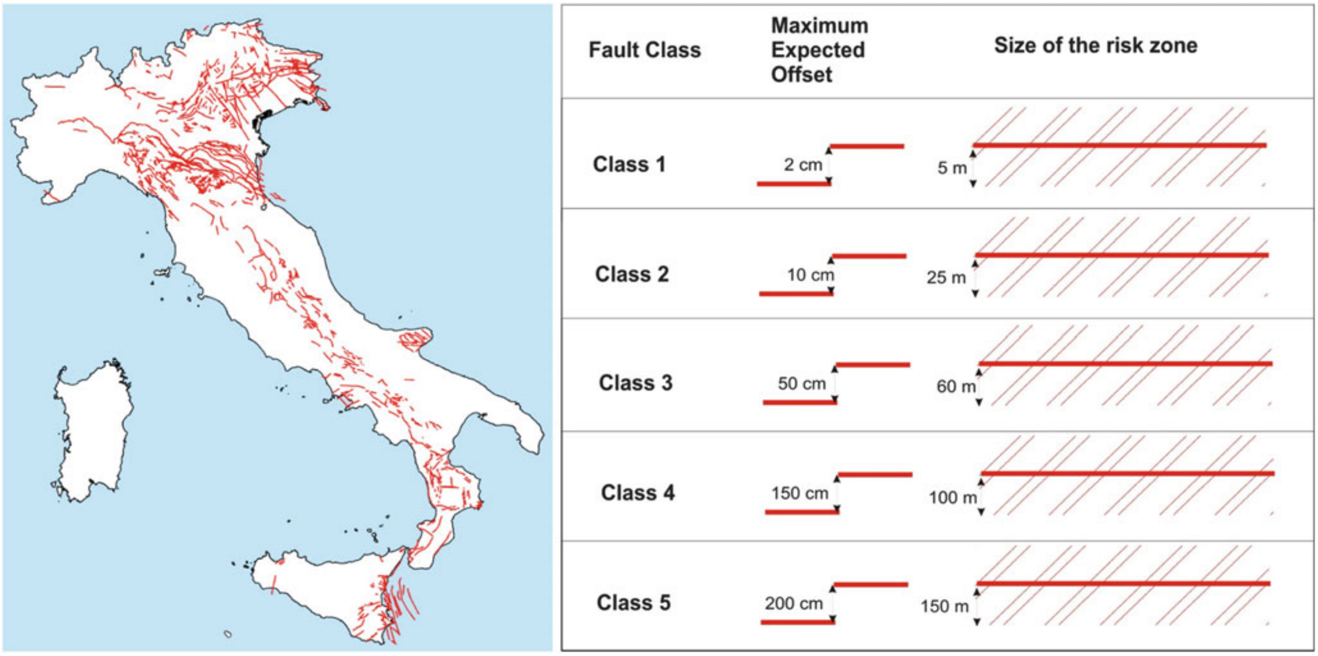

Fig. 4 Surface faulting hazard map in Italy. Capable faults have been classified into five classes on the basis of the expected displacement

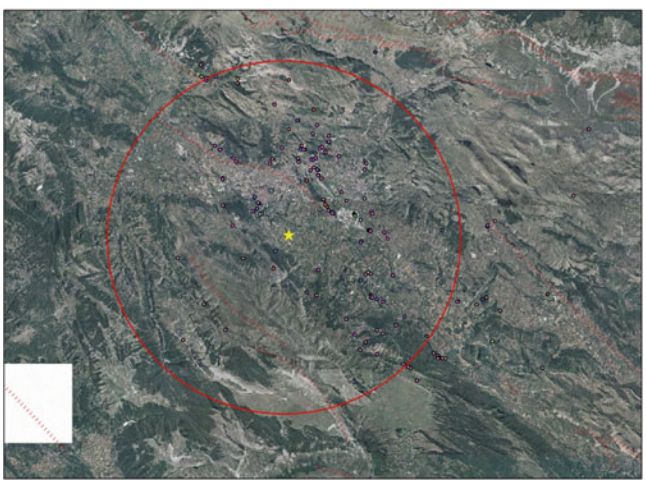

Fig. 5 The area of interest is represented by a *circle/ellipse* with radius proportional to the earthquake energy based on empirical relationship between size area and magnitude/PGA

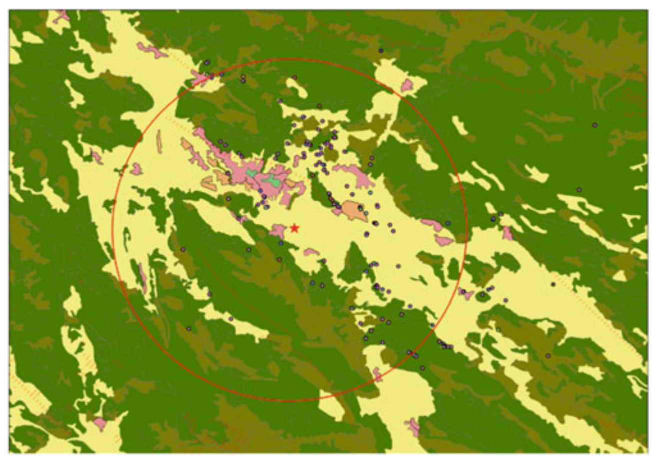

Fig. 6 Example of risk change detection on the basis of multi-temporal available datasets of Corine Land Cover

in the area from census population datasets by the percentage of urban area affected by landslides.

Transportation Network Analysis

The user is able to verify the connectivity between two villages by selecting the geo-process services for creating a route between two points of the road network and to display an optional path to connect the selected points avoiding landslide interruptions (Fig. 11).

Table 1 Example of table summarising landslide susceptibility map

Risk areas	Total extent (km^2)
Areas susceptible to rockfalls	2.6
Area prone to surface faulting	1.3

Table 2 Example of table summarising the element at risk

Risk areas	Total extent (km)
Highways	2.3
Primary roads	14.6
Railways	5.3

Fig. 7 A rapid landslide derails a train in Castebello – Merano (BZ, North Italy), April 12, 2010

Fig. 8 The village of San Fratello (ME, Sicily) damaged by a landslide, February 14, 2010

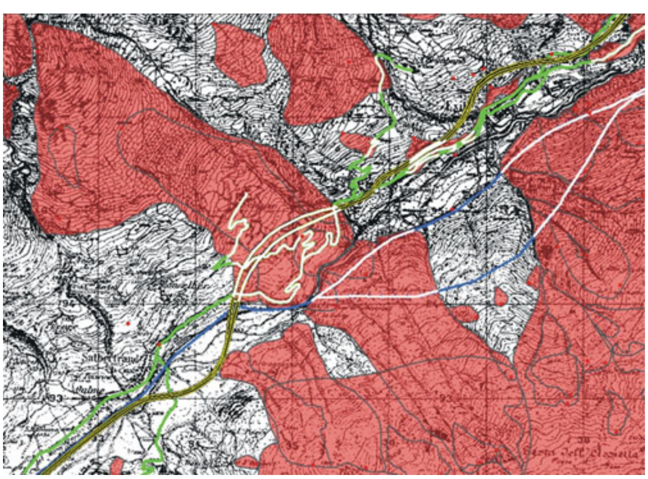

Fig. 9 Example of intersection between landslides dataset and transportation network

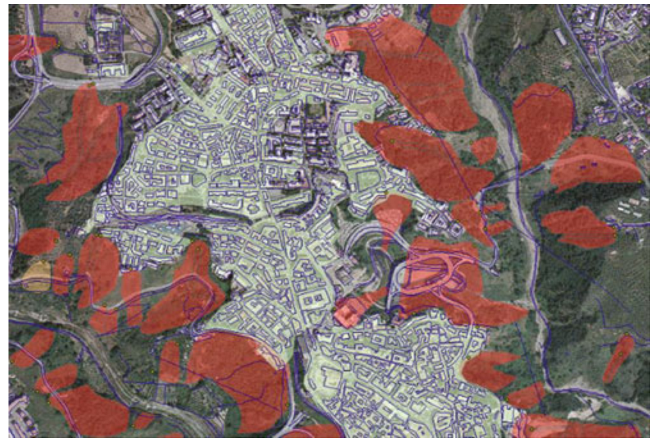

Fig. 10 Example of intersection between urban areas and landslides

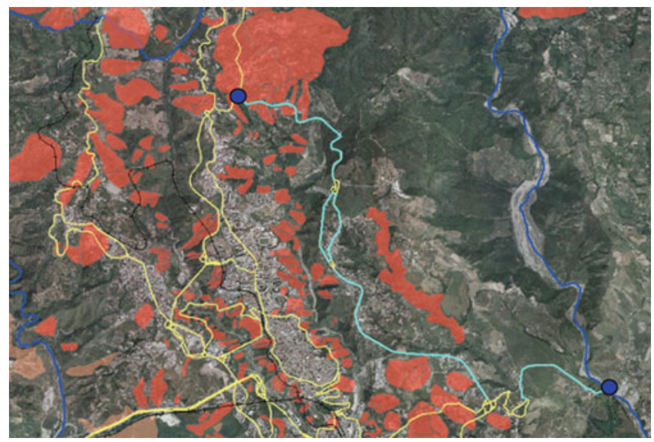

Fig. 11 Example of transportation network analysis to verify the connectivity

Conclusions

The EC BRISEIDE project is a first attempt to set up useful and operational tools for institutional and private end-users dealing with risk management, mainly operators from Environmental Agencies and Civil Protection Authoritiest. The project has successfully involved experts of different expertise in the field of ITC (PLEASE SPELL OUT)and Earth Sciences and public stakeholders in the sector of Civil Protection The project has provided them with several datasets and tools for spatio-temporal processing. Theses can be used both during critical situations and in implementing mitigation measures.

The project has developed two specific use cases dealing with landslide risk in Italy that have been described in detail. Both use cases allow, in almost real time, retrieval of the best available scenario in terms of hazard mapping and exposed elements. Potential risk scenarios can be analysed for different purposes such as in a post-event disaster (e.g. emergency management) but also for land management purposes.f (e.g. analysis of potential risk scenarios, implementation of plans for landslide risk mitigation measures).

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Landslide Consequences and Post Crisis Management Along the Coastal Slopes of Normandy, France

Lissak Candide, Maquaire Olivier, Anne Puissant, and Jean-Philippe Malet

Abstract

The coastal slopes of the Pays d'Auge plateau (Calvados, Normandy, France) are regularly affected by landslides mainly triggered by rainfall. The study area between Trouville and Honfleur has been subject to slow continuous displacements (5–10 cm.year^{-1}) for several centuries, punctually disturbed by episodes of acceleration with metric displacements. The landslides are located along a very touristic coastal area where increasing land pressure is evident.

Because of the potential for crisis and the seasonal landslide activity, direct or indirect, immediate and delayed impact have been identified. Since the first reactivation of the largest landslide in 1982, direct damages to infrastructures (roads, buildings...) and indirect damages to the economy have been observed.

The objective of this work is to present the risk assessment carried along the Normandy coasts through the: (1) evaluation of the long-term landslide consequences, (2) identification and value of the actual elements at risk including potential consequences and (3) analysis of the policy responses during the past 30 years.

Keywords

Slow moving landslide • Risk assessment • Potential consequences • Element at risk • Risk management • Resilience

Morphostructural Specificities an Occurrence of Coastal Landslides in Normandy

The investigation of landslide risk analysis first requires the conceptualization of the hazard (Alexander 2005). On the edges of the Pays d'Auge plateau, between Trouville-sur-mer and Honfleur (Fig. 1), several slope instabilities are notable. We focus this paper on the 'Cirque des Graves' landslide, the most important rotational translational landslide occurring on this coast. Mass movements have occurred quite low on convexo-concave slopes but are very heterogeneous in their stratigraphy and their morphology. Previous studies highlighted the role of hydro-climatic conditions in the landslide triggering and the importance of the nested chalk panel derived from the plateau (major component of the landslide) as well as the superficial deposits in the landslide dynamics (Flageollet and Helluin 1987; Maquaire 1990).

Along 7 km of coastline, five active landslides (Varnes 1978) are visible of which two (*Cirque des Graves, Fosses du Macre*) are characterized by a seasonal velocity pattern (5–10 cm.year^{-1}) sometimes affected by acceleration episodes inducing several meters of displacement, large cracks and high scarp emergence. Since the first instability of these

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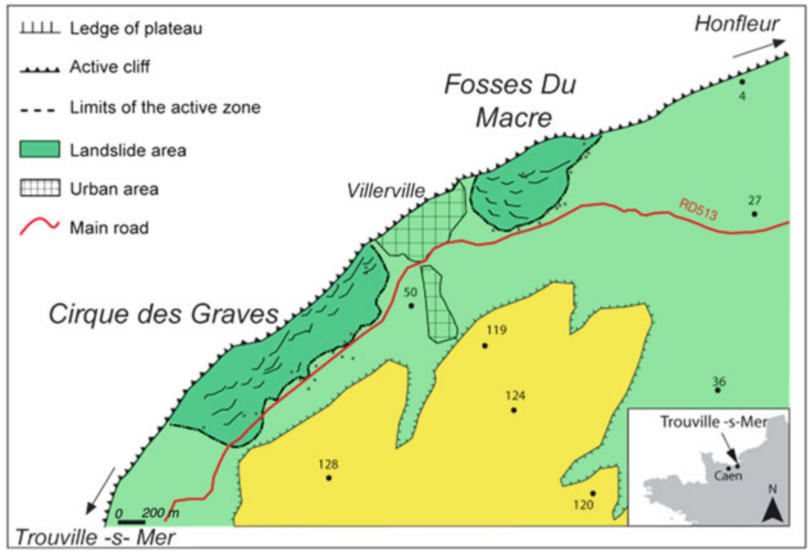

Fig. 1 Location of the two biggest landslides between Trouville-sur-mer and Honfleur

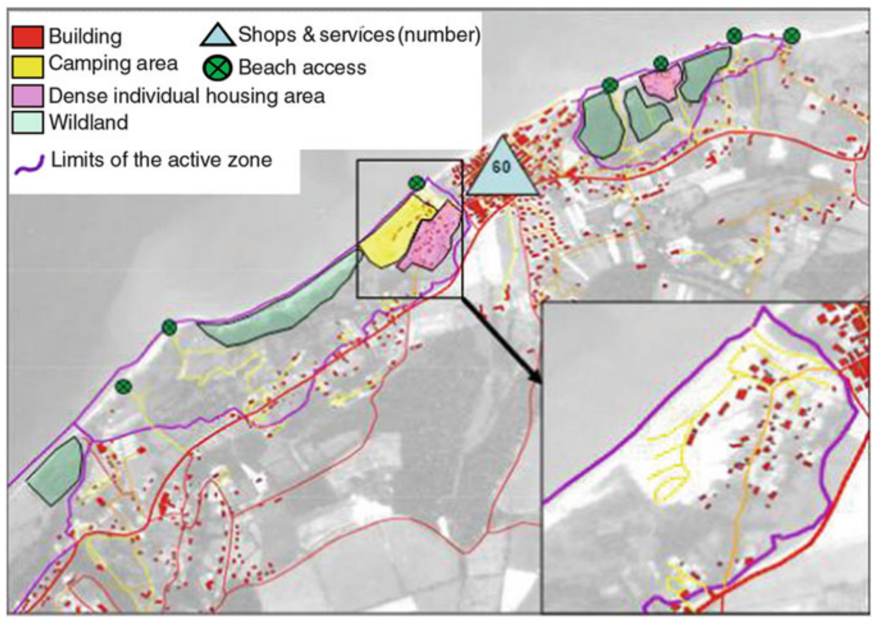

Fig. 2 Before the crisis situation of the *Cirque des Graves* and the *Fosses du Macre* landslide site development

two landslides (not precisely dated during Holocene period) several accelerations occurred in the last two centuries (Ballais et al. 1984) but all the events remain undated until the end of nineteenth century (1880). The multiple accelerations, particularly the recent reactivations (January 1982, February 1988, January 1995 and March 2001), occurred during the rainy season and have generated successive scarps that are several meters high (2–5 m) with toppled blocks and significant collapses (5 m fell down in 1982 at the “Cirque des Graves”) (Flageollet and Helluin 1987; Maquaire 1994).

Local Scale Consequences and Management Analysis

Pre-Crisis Situation

Because many landslides have been triggered in the past 30 years and in order to define the overall landslide impact since the first occurrence, it is necessary to identify the state of the area (economic system with activities, urban extension…) in existence prior to the impact in order to

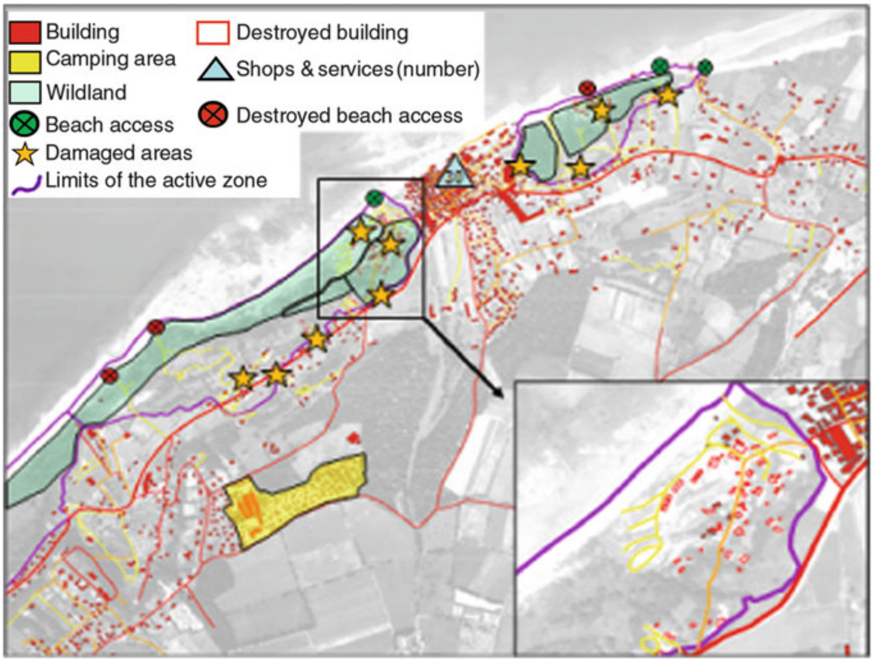

Fig. 3 Situation of the *Cirque des Graves* and the *Fosses du Macre* landslides after four reactivations and location of the landslides impacts

Fig. 4 East part of the main scarp of the *Cirque des Graves* landslide in 1982. On the toe of the landslide, several houses and tourist accommodation, now completely destroyed

define the historical damages. Historical documents, archives, pictures, cadastral maps and aerial photographs, etc. indicate the location and state of buildings and the land-use before the first acceleration took place at the end of the nineteenth century. To complete the information, interviews with local authorities or residents was undertaken regarding the spatial and the economical dynamics of the area (Fig. 2) before the events. Research indicates an attractive area for residents and tourists with access to the sandy beach, tourist infrastructures on the active zones, and shops and services (Fig. 2).

Direct and Immediate Consequences

At the time of the failure, networks such as lifelines and roads would have been cut at several points by the landslide. The most affected road was the departmental road, the principal route (in red) connecting several towns and cities. During the various events, the road has been cut at four points causing its closure for several days (Fig. 3) and thus disrupting traffic.

For the *Cirque des Graves* landslide*,* most of the damage occurred during the 1982 reactivation. Before the catastrophic event, despite the slope morphology which suggested the slope instability (scarps, counter slopes. . .), the most active part of the landslide was consequently developed by contractors. This first big reactivation resulted in the destruction or the damage of about 80 buildings (Fig. 4, Table 1). We can distinguish the affected buildings by their height with the number of levels and their construction material (Table 1). Among all these losses and fatalities, very important tourist infrastructures were destroyed at the toe of *Cirque des Graves* landslide. A famous camping area whose capacity was about 2000 tourists per month in the summer season was completely destroyed. Because of its economic importance to the municipality of Villerville, the camp site was relocated upstream, on a stable part of the slope, on municipality parcels, to minimize the socio-economical impact of the landslide.

Table 1 Physical injuries induced by accelerations crisis

Building Floor NB	Building material	Function	Number
R + 2 or 3	Traditional masonry	Residential	8
R + 1	Traditional masonry	Residential	9
R + 0	Traditional masonry	Residential	11
R + 0	Traditional masonry	Leisure	5
R + 0	Traditional masonry	Annex	6
R + 0	Wood	Residential	48
R + 0	Wood	Leisure	2
R + 0	Wood	Annex	14
Destroyed			**103**
R + 2 or 3	Traditional masonry		19
Damaged			**19**
TOTAL			***122***

On the *Fosses du Macre* landslide the first important reactivation of 1988 caused the destruction of several buildings (Table 1) located at the landslide toe. But during the 2001 event, several multistage and typical Norman homes were damaged because of the main scarp regression.

Indirect Consequences

Beyond the physical and direct impact of the landslides on the infrastructure, we focused our study on the indirect and long-term consequences of the hazard on the economic dynamics and the functioning of the affected area.

At first, analysis focused on the post-crisis consequences, a few years ($< 10\text{year}^{-1}$) after the first landslide reactivation. The relocation of the tourism facilities and the building destruction had consequences: (1) the abandonment of land by owners with the conversion of gardens into wasteland (shrub), (2) the closure of access to the beach, (3) the closure of many shops and services in the town, (4) a decrease of tourism for the town, (5) the relocation of tourism infrastructure upstream, and (6) the departure of many residents.

The Villerville village with the *Cirque des Graves* landslide was the most affected area of the 1980 events, with numerous socio-economical consequences on the territorial dynamics. Concerning the population, although the trend of the department is a negative net migration of coastal towns, departures of residents in the municipality of Villerville were more important between 1982 and 1990 than compared to other villages (Fig. 5).

Next we focused on the long-term consequences, several decades after the 1982 reactivation.

The first administrative measure was to establish a decree on the plots located on the active zone. Consequently the zoning of lands in the red zone of the PPR (areas with specific restriction to planning according to the hazard) (Fig. 6) induced an important financial depreciation of the plots and the buildings regulations, in and near the active zone.

Following this decree, a conversion of the land-use in the east part of active zone was noticed (where the largest structural damages were reported) with the development of open spaces, recreational areas with leisure facilities mixed with ecological conservation zones as Protected Natural Areas (ponds…).

For the Villerville town, after the closure of several stores and shops (about 60 shops and businesses in 1982 against 30 in 2009), the economic center (shops and basic services) was moved to the top part of the village, on both sides of the departmental road (Fig. 7).

Policies Management

Risk Prevention

Landslides, as one of the major natural hazards, account each year for enormous property damage in terms of both direct and indirect costs. Planning control is one of the effective and economical ways to reduce landslide losses (Dai et al. 2002). In Europe, national legislation and guidance for the most part provide a strategic framework for land-use and development (Mc Innes 2005). In France, in order to reduce the number of elements at risk and for preventing natural hazards, the adjustment policies for risk management are based on two mapping tools conventionally used as support for planning control. On the one hand, the hazard maps at 1/5,000 or 1/10,000 scales to integrate the Local Development Plan (Plan Local d'Urbanisme – PLU). This document is necessary for municipalities to take into account natural hazards in their planning policy. Generally, risk assessments are considered by delineation of affected zones, then by their restriction regarding their use (Hollenstein 2005). On the other hand, the Prevention Plan Natural Hazards (Plan de Prévention des Risques – PPR) established since 1995 to simplify the display of the risk and substitute several existing documents as PER (Risk Exposure Plans) since 1982, or ZERMOS maps for instabilities (areas at risk of ground motion and basement) in 1975. By the various documents, new developments can be prohibited, restricted or regulated in areas prone to landslides. Nevertheless sometimes these documents are not sufficient to protect civilians from disaster and damages still occur with direct and indirect losses. Consequently we wonder about the stakeholders' response to adapt to the disaster.

Post Crisis Intervention

In response to the various events, the management strategy has been progressive, involving multiscale stakeholders to acquire a steady state of the socio-economic planning. Since the 1982 event, interventions in response to disaster were

Fig. 5 Actual situation of the study area development

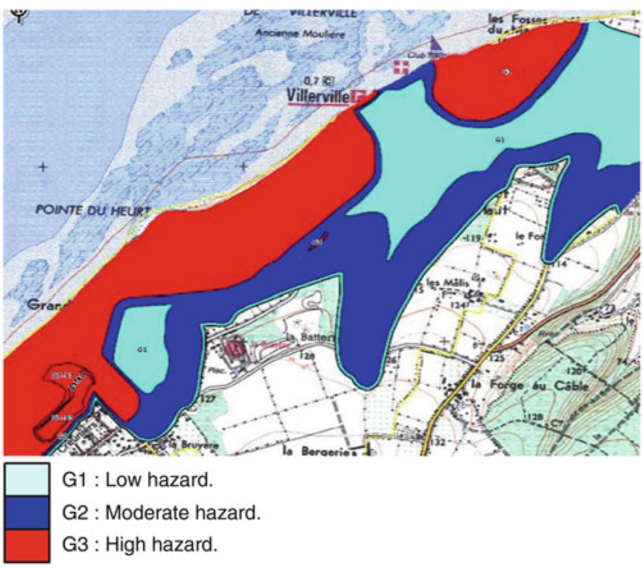

Fig. 6 Actual PPR in progress

Fig. 7 Illustration of the actual park where leisure facilities and tourism infrastructures are next to ecological protection areas

progressive (Fig. 8): (1) with, at first, a non-integrated management by local stakeholders and departmental planners and recently (2) an integrated land management with a collaborative decision making between actors.

The first step of the post-crisis management consisted in (Fig. 8):

- Immediate public policy and decrees institution with dangerous building ordinance, legal ruling on almost all properties of the active zone of the *Cirque des Graves*, and the relocation of the camping on the plateau,
- Acquisition of affected plots by the government and the municipality, land-use restriction
- Latency period between hazard occurrence, decision-making strategies to alter, define, and reshape economical activities in particular ways – Reflection on the site conversion possibilities
- Destruction of the damaged houses and clean up abandoned plots to rehabilitate the unstable area.

The last step of the governance consists in the rehabilitation of the area by decision-makers. The final step defines an ability to restore and improve the area after a crisis. The various stakeholders (mayor, department, region. . .) are involved in different scales on the territorial dynamics and in the planning and building control (Fig. 8) through: (1) The restriction of the urban development whereas the land pressure is increasing, (2) the rehabilitation and conversion of the land-use to inflate the local economy. This readjustment is based on tourism activities as a principal economical agent, with the development of tourist facilities (camp facilities relocated to the plateau on a municipality parcel), grant of trades, and the rehabilitation of abandoned land in open space, parks, woodland and recreational area.

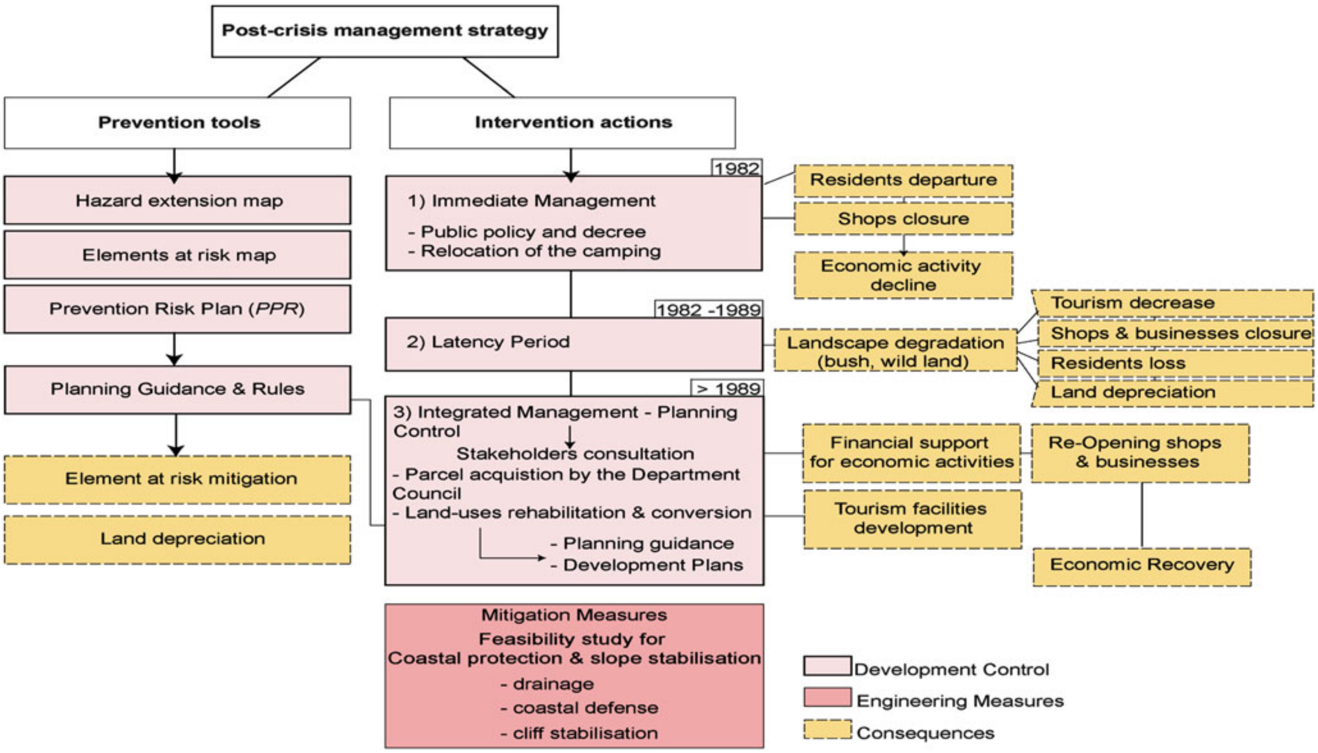

Fig. 8 Villerville municipality: '*Cirque des Graves* Landslide Management Strategy'

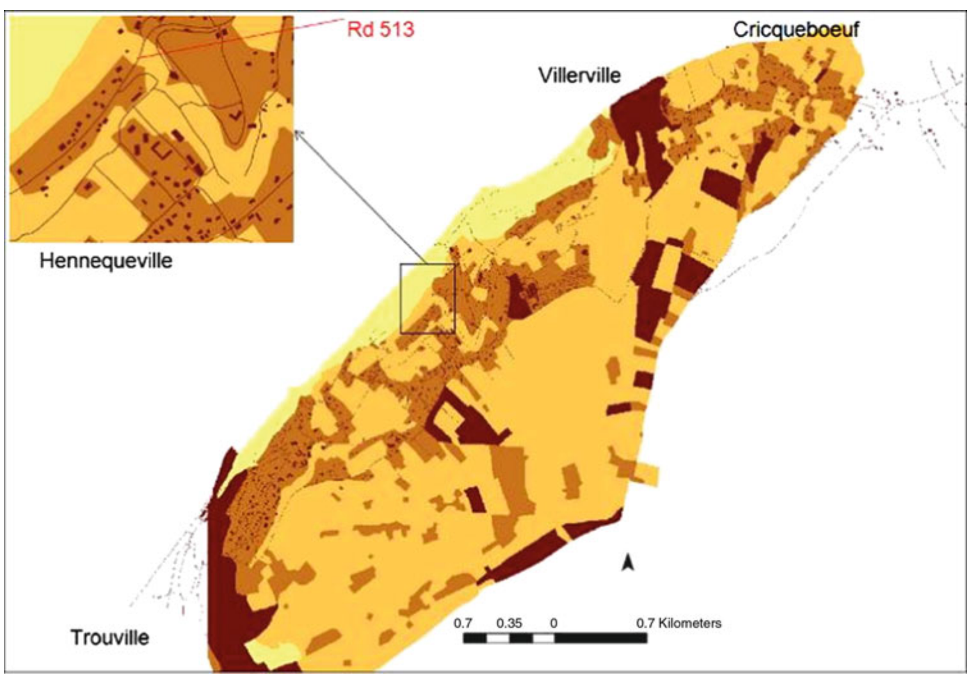

Fig. 9 Element at risk identified around the fourth major landslides between Trouville-s-mer and Honfleur. Class (1) Very low potential consequences (*clear color*), Class (4) High potential consequences (*dark color*)

In the absence of sufficient funding, no specific measures have yet been adopted to reduce the hazard. Only, some owners have installed a surficial drainage system. At the *Fosses du Macre*, a sea wall has been constructed in the middle of 1980s, but landslides still occurred three times (1988, 1995 and 2001) so that it was necessary to evaluate the actual potential consequences in case of landslide reactivation.

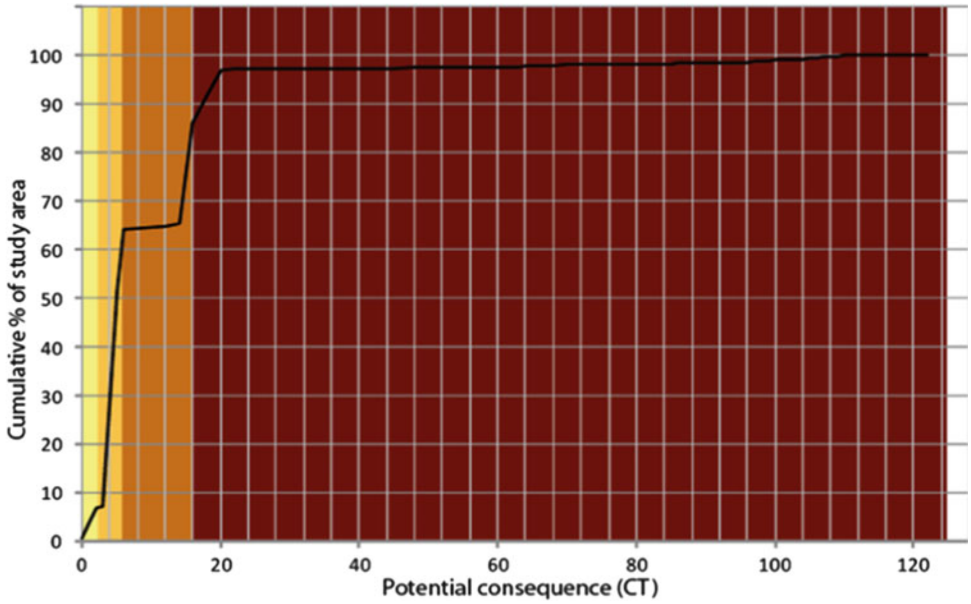

Fig. 10 Classification of element at risk (four classes) and percentage of affected area between Trouville-s-mer and Honfleur

Regional Scale Potential Consequence

Exposed Element at Risk: Identification and Value

Thus, to define the global impact of the landslides on the territory system we focused our attention on the current regional elements at risk and on the potential consequences and losses in case of landslide extension. The consequences are linked to elements at risk and their vulnerability (Glade 2005). Several approaches and methodologies have been developed to quantitatively evaluate the potential consequences of the hazard from the identification of exposed elements. The elements at risk, considered as issues, are classified and assigned a value (Leone 2008; Abella and Westen 2007; Castellanos et al. 2007; Puissant et al. 2006; Glade 2005; Bonnard 2004) according to their potential consequence typology and importance.

At a regional scale, elements at risk are identified beyond the geometric boundaries of the active zone, in case of the extension of the landslide. Using an index to value elements at risk according to their vulnerability and potential consequence is a widely used method because of difficulties to obtain real economic data (Leone et al. 1996). Using GIS technology, the potential consequences of elements are firstly based on the knowledge of historical landslides losses and fatalities.

The elements at risk are associated with a coefficient index expressing the relative value of the object (Amatruda 2004; Maquaire et al. 2004) and classified in different categories according to the nature of the vulnerability (Puissant et al. 2006): Physical injury, structural and functional injury and socio-economic effects (Figs. 9 and 10). This study is based on a preexisting semi-quantitative method (Puissant 2006). The aim of this new application is to adapt the semi-empirical model developed into mountainous environment (French south Alps) to a coastal environment, in order to provide comparable results based on the same methodology. For the elements at risk characterization, some parameters have been adapted to the coastal location as tourism infrastructures and importance of road networks.

Exposed Element at Risk: Computation

Once all indexes are defined for each element at risk, the vulnerability is expressed according to the potential landslide consequences. These potential consequences (physical, structural, functional and socio-economical) as direct and indirect effects of the landslide are combined (Fig. 9) to highlight the importance of networks and the building function on the - socio-economic dynamic of the area.

Conclusion

Landslides can result in many casualties and significant economic losses (Dai et al. 2002) but fortunately, large permanent slow moving landslides are not a risk to life (Hollenstein 2005). A global risk assessment is usually performed through hazard analysis and then by a vulnerability assessment. But if the disaster has already occurred, inducing catastrophic damages; losses have to be defined for preventing damages in case of landslide reactivation. In our case study, to evaluate the total consequences of a mass-movement on the society, first, we compiled historical damage assessment and actual elements at risk analysis. Because, risk managers and authorities need sufficient knowledge about past and potential impacts of the hazard and possible consequences of the different decision options to control the risks (Renn and Schweizer 2009). Secondly, our study focused on the post-crisis management developed by authorities characterized initially by a 'day by day' management with a few consultations between actors, and without any real global strategy. But gradually, an integrated risk management with collaboration of the different scale stakeholders allowed us to develop new economic activities in the areas affected by landslides and to reduce the potential consequences.

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Landslides and New Lakes in Deglaciating Areas: A Risk Management Framework

Yvonne Schaub, Wilfried Haeberli, Christian Huggel, Matthias Künzler, and Michael Bründl

Abstract

New lakes forming in high-mountain areas due to climate-driven glacier shrinkage are likely to be located in areas of potentially unstable slopes. Therefore they are prone to impacts from rock/ice-avalanches and other types of landslides, which might trigger outburst floods causing damage farther down valley. In view of an integral lake management, a risk management concept for the Swiss Alps is proposed in this study, which consists of risk analysis, risk evaluation and the integral planning of risk reduction measures. The pertinent question is how risk, resulting from natural hazard process chains involved with landslides and new lakes, can be assessed. The present knowledge basis together with currently available models, methods and tools is herein reviewed. Knowledge gaps are mainly identified in the determination of future landslide detachement zones and in the evaluation of changes in landuse and damage potential.

Keywords

Integral lake management • Natural hazards • Rock failure • Glacier lake outburst floods • Landuse change • Risk assessment

High-Mountain Lakes in a Changing Environment

Glaciers worldwide are shrinking at an accelerating rate as a consequence of climate change (Kaser et al. 2006; Solomon et al. 2007; Zemp et al. 2009, 2008). Correspondingly, the volume of the Alpine glaciers is annually decreasing by 2–3 % (Haeberli et al. 2007). Relying on realistic warming scenarios, 75 % of the glaciated area of the end of the twentieth century could vanish by the middle of this century (OcCc 2007; Zemp et al. 2006).

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To illustrate this effect, first deglaciation scenarios for the entire Alps have been modeled by Haeberli and Hoelzle (1995). In the meantime more detailed models for large glacier ensembles have been developed (Paul et al. 2007; Zemp et al. 2006). New approaches allow the digital calculation of the terrain of the Swiss Alps without glaciers (Farinotti et al. 2009; Huss et al. 2008; Linsbauer et al. 2009). A method to model the glacier bed material is also available (Zemp et al. 2005). Taking these terrain models as a basis, GIS-based models show that at certain locations retreating glaciers uncover overdeepenings. These overdeepenings are considered as potential sites of future lakes (Fig. 1) (Frey et al. 2010b; Linsbauer 2008). So far, glacier lakes have mainly received scientific attention in terms of outburst floods (Clague and Evans 2000; Haeberli et al. 2010a; Hubbard et al. 2005). Such glacier lake outburst floods have the potential to wreak havoc; several severe events have been reported (Haeberli et al. 2010c; Hancox et al. 2005; Korup and Tweed 2007; Reynolds 1998; Richardson and Reynolds 2000; Vuichard and Zimmermann 1987).

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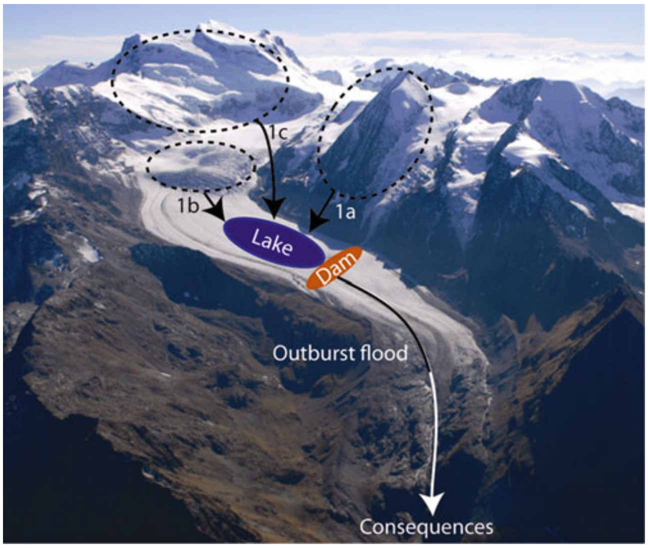

Fig. 1 Scheme of the investigated process chain, illustrated with the example of the potential future lake Corbassière, Switzerland. *Dashed lines* = possible detachment zones of rock- (*1a*), ice- (*1b*) or combined rock/ice-avalanches (*1c*). Picture: U. Bläsi (www.airbox.ch/air/)

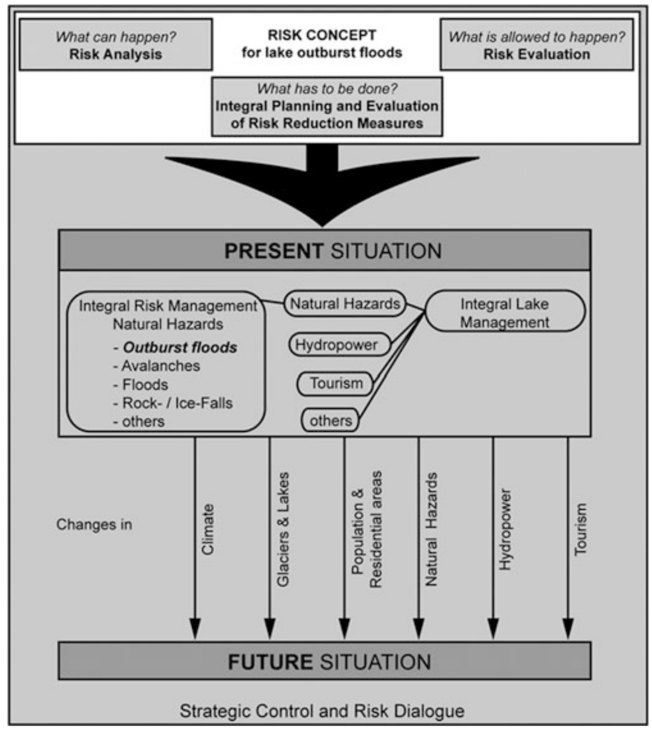

Fig. 2 The concept of integral lake management

Reducing newly forming high-mountain lakes to a hazard source would be inappropriate, as such lakes not only pose risks but may also offer opportunities, for example for hydropower generation or as a tourist attraction. This study proposes the development of a framework for an integral lake management (IM) in order to equally assess chances and risks posed by new high-mountain lakes. The main focus of this publication is thereby on integral risk management (IRM) regarding natural hazard process chains, such as landslides impacting lakes and triggering destructive outburst floods (Fig. 1). The research question is: What information exists to assess the risks resulting from future high-mountain lakes through impacts of rock/ice-avalanches? The results will be discussed in the context of IM and knowledge gaps will be identified. Although generally applicable, the approach presented here was developed for the situation in the Swiss Alps and illustrated using a case study of a potential new lake at Corbassière glacier (Valais, Switzerland).

Integral Lake Management

Application of the Concept of Integral Risk Management for Impact Waves from Rock/Ice-Avalanches

IRM is one of the aspects of IM, which correspondingly implies all possible kinds of hazards (Ammann 2004). The conceptual use of IRM is widespread, and Switzerland has taken a leading position worldwide regarding the implementation into practice (Bischof et al. 2008; DARA 2011).

The core of IRM is the risk-concept, which consists of the risk analysis, the risk evaluation and the integral planning of measures (Fig. 2). The following general definition of risk is the basis for the risk analysis (Bründl et al. 2009):

$$r_{ij} = p_j \times p_{ij} \times A_i \times V_{ij} \quad (1)$$

$$R = \sum r_{ij} \quad (2)$$

where r_{ij} = risk of object *i* in scenario *j*; R = societal risk; p_j = frequency of a hazardous process depending on scenario *j*; p_{ij} = probability of object *i* being affected by hazardous process depending on scenario *j*; A_i = value or type of object *i* and V_{ij} = vulnerability depending on object affected *i* and on scenario *j*.

The eventuality of a rock/ice-avalanche triggering an impact wave is often underestimated, even though historical ice or rock/ice-avalanches are documented (Huggel et al. 2002a; Raymond et al. 2003). Recent cases of impacts into lakes have also been reported (Fischer 2009; Haeberli et al. 2010b; Kershaw et al. 2005). In Fig. 3 an assessment scheme regarding the scenario of a lake outburst flood due to an impact wave triggered by a rock/ice-avalanche is presented. For the assessment, use can be made of existing knowledge or similar case studies, for example the assessment of a tsunamigenic rockslide in Åknes, Norway (Eidsvig et al. 2011; Lacasse et al. 2008) or the hazard analysis of glacier lake outburst floods in Bhutan (Richardson and Reynolds 2000).

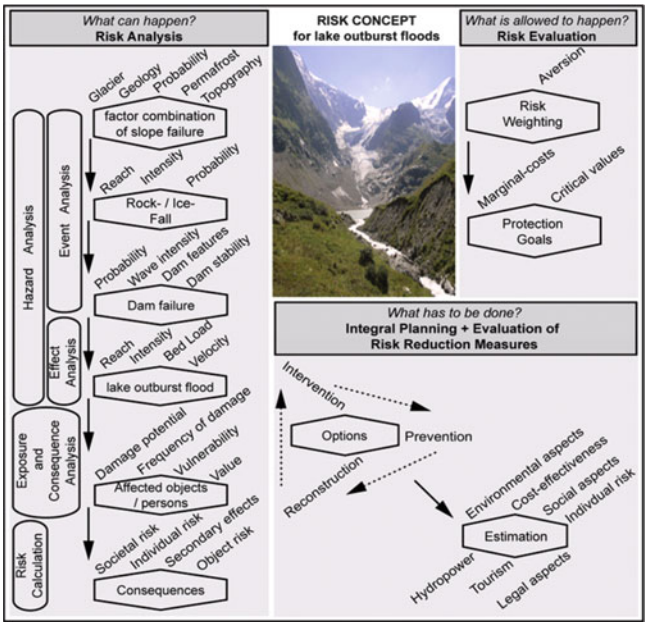

Fig. 3 The risk concept adapted to the question of glacier lake outburst floods

Risk Analysis

Standards for assessing glacier-related hazard potentials in high-mountain regions are well developed (Haeberli et al. 1989, 2006; Huggel et al. 2004, 2005; Kääb et al. 2005). For instance, a multilevel strategy for anticipating lake formation and hazard potential has been elaborated elsewhere (Frey et al. 2010a). Methods for hazard assessment of potential ice-avalanches using remote sensing and Geographic information systems are also available (Huggel et al. 2002b; Salzmann et al. 2004).

In an event analysis (Fig. 3), critical factors have to be identified, in order to estimate the susceptibility of a slope to failure. In Table 1, an overview of recent studies summarising the most important factors influencing slope stability is provided. Permafrost distribution, as one factor affecting slope strength, can be estimated based on simulations of surface and subsurface thermal conditions (Nötzli and Gruber 2009; Nötzli et al. 2007). In Switzerland a permafrost map is officially available (Gruber et al. 2006). Based on the evaluation of different factors, potential detachment zones can be identified, followed by the assessment of the runout distance of a potential rock/ice-avalanche. Widely used approaches consider the angle of reach for both, rock-avalanches (Evans and Clague 1994; Heim 1932; Nötzli et al. 2006; Romstad et al. 2009; Rothenbühler 2006) and ice-avalanches (Huggel et al. 2004; Rothenbühler 2006). Avalanche volume, ice content, sliding over a low-friction glacier surface or flow transformation into more mobile debris flows influencing the runout distance and the extent of impact can be assessed (Schneider et al. 2011). Romstad et al. (2009) have developed a GIS-based rock-avalanche runout-approach, which can be applied in alpine conditions. In addition to magnitude, the frequency is an important determinant of landslide hazards (Raetzo et al. 2002). Landslide frequency is influenced by factors such as topography, rock strength and structure, proximity of glaciers or presence of permafrost (Fischer 2009; Gruber and Haeberli 2007; Harris et al. 2009). In the case of ice-avalanches, the glacier type (cliff or ramp) is an important factor determining avalanche volume and frequency (Alean 1985; Huggel et al. 2004). Probability distributions of all type of landslide volumes (Brunetti et al. 2009) and relationships between magnitude and frequency (Korup and Clague 2009) have been established and can be used as references. Hazard assessment schemes that integrate several of the aforementioned steps into a comprehensive approach are particularly useful for the purpose of this study. Frattini et al. (2008) presented such an assessment scheme for rockfall, applying the HY-STONE code (Agliardi and Crosta 2003) for rockfall modeling. Santi et al. (2009) explain a rockfall hazard rating system. For ice-avalanches, aprroaches were presented by Margreth and Funk (1999) and by Wegmann et al. (2004). These approaches provide valuable input for estimations of rock/ice-avalanches, but the most generic assessment procedure for several types of glacier hazards was developed by Huggel et al. (2004).

Once it is assessed that a rock/ice-avalanche potentially can reach a lake, the effect of the landslide impact into the lake has to be estimated. Research on impulse waves dates back to Russel (1837). More recent developments are presented by Heller et al. (2008) and Zweifel and Minor (2004). Approaches to assess the effect of impact waves from landslides include: (a) empirical formulas, that have been established based on laboratory tests and field observation, (b) 1D models, which have been developed based on Saint-Venant or Bussines equations simulating the evolution of waves in space and time, (c) 2D models, which are required for more appropriate results. Normally they are also based on Saint-Venant equations (Leveque 2006), (d) 3D experiments, which further allow the modeling of the runup waves generated by landslides (Di Risio et al. 2009).

As an impact wave will hit the shoreline, the dam conditions of the lake have to be investigated for every case. Costa (1994) and Costa and Schuster (1988) presented a general survey on features of artificial and natural dams and on possible causes for their failures. The most common types of natural dams in high-mountain regions are ice dams, moraine dams, landslide dams and bedrock dams. Lakes in deglaciating areas are usually enclosed by moraine and bedrock dams. In order to estimate the susceptibility of moraine dams to failure, Huggel et al. (2004) and Xin et al.

Table 1 Factors mentioned in literature, which define the location of possible detachment zones of rock/ice-avalanches

Rock-avalanches		
Factor		Source
Topography	Gradient	(Fischer 2009; Frattini et al. 2008; Gruber and Haeberli 2007)
	Elevation	(Fischer 2009; Gruber and Haeberli 2007; Nötzli et al. 2003)
Geology	Transition zones	(Fischer 2009; Frattini et al. 2008; Gruber and Haeberli 2007)
	Lithology	(Fischer 2009; Frattini et al. 2008)
Hydrology	Fluid pressure	(Fischer 2009)
Glacier	Proximity	(Fischer 2009; Haeberli et al. 1997; Wegmann et al. 2004)
Permafrost	Distribution	(Fischer 2009; Gruber and Haeberli 2007)
	Surface temperature	(Gruber et al. 2004; Nötzli et al. 2003)
	Rock temperature	(Davies et al. 2001; Gruber et al. 2004; Nötzli and Gruber 2009)
Vegetation cover	Absence of vegetation	(Frattini et al. 2008)
Ice-avalanches		Source
Factor		
Topography	Gradient	(Alean 1985; Huggel et al. 2004; Rothenbühler 2006)
Glacier-permafrost	Interaction	(Huggel 2009)

(2008) give an overview on influencing parameters. A few recent approaches have furthermore developed probability-based schemes of dam failure of glacier lakes (Hegglin and Huggel 2008; McKillop and Clague 2007a, b). Moreover a number of numerical models simulating dam breaching do exist. BREACH (Fread 1991) was applied for several case studies, such as in New Zealand (Hancox et al. 2005) or in the Himalayas (Xin et al. 2008). Other programs to model moraine stability are SLOPE/W implemented by Hubbard et al. (2005) for a case study of a moraine dam in Peru and BASEMENT (Faeh 2007; Volz et al. 2010). Khan and Jamal (2000) used a probability approach for dam failure risk assessment, defining estimation factors for dam safety, whereas Lavallee et al. (2000) applied a multicriteria method on the same question.

The next investigation in the risk analysis procedure concerns outburst flood processes. Depending on the sediment entrainment, outburst floods vary within a range of flow rheologies. Different numerical models exist to estimate the reach and the spatial probability of flood occurrence, like MSF (Huggel et al. 2003) or FLO2D (O'Brien 2003). For the estimation of the hydrograph of a lake outburst flood, several empirical equations (Costa and Schuster 1988; Xin et al. 2008) can be considered, along with further quantitative hydrodynamic analysis (Hancox et al. 2005; Jakob and Friele 2010; Osti and Egashira 2009; Xin et al. 2008). The main challenge of our study will be to link these approaches into one framework.

If the hazard analysis indicates that an outburst flood is possible, the consequences farther downvalley have to be estimated. This includes the specification of the damage potential (possibly exposed people, objects or infrastructure) regarding its value, its probability of exposure and its vulnerability to the corresponding hazard scenario. Regarding today's vulnerability values, research has recently seen important progress (Carey 2005; Fuchs et al. 2007; Hegglin and Huggel 2008; Uzielli et al. 2008). In Switzerland these results were partly incorporated into software tools, such as EconoMe (BAFU 2010). However, little is known on how to estimate the vulnerability development of objects in the near future. Some efforts have now been undertaken (IRV 2007), but they did not provide the expected results yet.

Essential for the consequence analysis is the number and the value of possibly exposed objects. Whereas this information can easily be gained for present cases through field survey and census data, assumptions have to be taken for future landuse and settlement areas. These landuse changes can either be modeled by normative approaches, as done in a study in Switzerland (Perlik et al. 2008) or in the project "MOUNTLAND" for the Alpine region (Huber and Rigling 2010). These projections would need to be downscaled to the required local scale and interpreted for the present question. Landuse changes can furthermore be modeled by explorative studies, which refer to a defined region, such as conducted in ALPSCAPE (Walz 2006) or by Rothenbühler (2006).

Based on the accomplished hazard and consequence analysis, the societal risk can be calculated, summing up the risks for each individual person and object (2). Regarding the frequency of a hazardous process (1), it should be considered that high-mountain areas have undergone important climatically related changes and therefore risk assessment for future conditions cannot fully rely on former conditions. Thus, open questions in the risk analysis procedure with respect to future lakes remain regarding the location and characteristics of detachement zones and the probabilities of occurrence of different hazard processes. But also knowledge on changes in landuse and damage potential needs to be further deepened.

Risk Evaluation

Within an IRM approach, the assessed risk needs to be confronted with what is considered an acceptable level of risk. In Switzerland this is on the one hand done by rating the individual risk. A person should not face an individual risk higher than $4 \times 10^{-6} < r_i < 3 \times 10^{-5}$ for involuntarily taken risks, otherwise safety measures are considered the society's responsibility (Bründl et al. 2009). On the other hand the societal risk is analyzed using the concept of "proportional cost". This approach includes the willingness of the society to financially support risk reduction measures, which reduce the risk at proportional costs (PLANAT 2009).

A further weighting of risks by incorporating risk aversion might be adequate. This evaluation considers the phenomena, that rare and extreme events are often perceived as worse than small and frequent events causing the same cumulative amount of loss (PLANAT 2008). Hazardous process chains resulting from high-mountain lakes belong to the processes with high magnitude and low but increasing probability. Their management will further be analyzed regarding the integration of risk aversion.

Risk Reduction Measures

For an integral planning of risk reduction measures, all available measures have to be considered (PLANAT 2004). An overview over possible measures for glacier hazards, such as monitoring and prediction, drainage, tunnel, shelter or road blockage, was elaborated in the framework of the GLACIORISK project (Wegmann et al. 2004). Early warning systems are likely to be among the primary risk reduction measures for future glacier lakes, as they are recognized as a promising combination of technical instruments and human behavior (Huggel et al. 2010). In this regard, it can be drawn on recent experiences such as described in Huggel et al. (2010) or in Medina-Cetina and Nadim (2008). It should be emphasized that for each individual case the most appropriate risk reduction measures have to be evaluated and the public acceptance of measures has to be regarded at an early stage of the planning phase. In view of IM, the potential of risk reduction measures for other purposes (such as hydropower or touristic use) has not been sufficiently addressed yet.

Integral Lake Management: Illustrated with the Case of Lake Corbassière

Here we briefly highlight some aspects of the aforedescribed IM with the example of Corbassière glacier area. As indicated in Fig. 1, a lake is expected to form around the middle of this century with a volume of several tens of million m^3. The lake will be surrounded by several steep slopes with a potential for rock and ice-avalanches that can reach the lake. Glacial bed modeling indicates a rockbed, possibliy covered with some moraine material. Impact waves from landslides are projected to overtop the dam irrespectively of the dam stability and imply an outburst flood. The expected damage caused by the outburst flood depends on the volume and velocity of the landslide impact, and consequently on the amount of overtopping water. In case of a major impact, roads, buildings and other infrastructure in the Val de Bagnes will most likely be affected and consequences even in Martigny (at a distance of about 25 km with a current population of approx. 15,000) cannot be excluded. The effective amount of damage is difficult to assess at this stage, as the future degree of settlement and landuse of the region is not known.

Furthermore, a recent study has shown, that this lake might be interesting for hydropower generation by extending the existing Mauvoisin hydropower scheme (Terrier et al. 2011). In addition, the region is popular for hikers and mountaineers, and therefore the lake might also turn into a tourist attraction. This was for instance recently observed at the lake that formed in front of Trift glacier (central Swiss Alps). Against this background, IM could consist of implementing multi-functional installations, which meet the requirements of all the aspects of lake use (hazard mitigation, hydropower generation and touristic activities) to the degree possible.

Conclusions

Due to retreating glaciers, new lakes have been forming in the last years and further lakes will likely arise in the future in many high-mountain regions worldwide. These lakes will often be located near unstable slopes and will therefore be prone to impacts of rock/ice-avalanches and other landslides. A concept that considers existing knowledge and methodologies as a base for developing a framework for the analysis and evaluation of risks related to glacier lake outburst floods is presented here and outlined on the example of Switzerland. It is proposed to estimate potential risks and opportunities induced by the formation of new lakes in the framework of integral lake management. It is shown, that a good knowledge basis for the determination of present detachment zones as well as tools, methods and models for the investigation of rock/ice-avalanches, dam stability and outburst floods are available. Similarly, several landuse scenarios for Switzerland are known.

Current gaps in knowledge and methods, as well as open question are also pointed out: In order to fully analyze the future hazard potential, efforts have to be made on specifying future areas of potential detachment zones. Their location and characteristics are influenced by morphological changes in high-mountain landscape, by the existence of glaciers and by the climate. The changes and their influence on the probability of processes correspondingly have to be incorporated in the hazard process chain. Risk perception and acceptance, as well as management of low-probability/high-magnitude events have to be considered and will be subject to further studies.

For a regional comparison of the risk and the identification of priority areas, we will focus on the hazards caused by rock/ice-avalanches falling into lakes and the consequences further down-valley. Therefore the evaluation of landuse change and damage potential on a regional scale will also be a field of interest. This includes the downscaling of existing projections to the required local scale.

Another focus will be put on potential sinergies of risk reduction measures with other aspects of lake use, as for example tourism or hydropower.

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Long Term Strategies and Policies for Geological and Hydraulic Risk Mitigation in Italy: The ReNDiS Project

Claudio Campobasso, Giuseppe Delmonaco, Barbara Dessì, Pier Luigi Gallozzi, Benedetto Porfidia, Daniele Spizzichino, Francesco Traversa, and Giorgio Vizzini

Abstract

The ReNDiS project aims at implementing a database, collecting updated information about mitigation measures (engineering works as well as non-structural measures) funded for the reduction of geological and hydraulic risk, and monitored by ISPRA. The project is a web-GIS platform and the inventory comprises a main archive and two secondary interfaces: the first for direct data management (ReNDiS-ist) and the second (ReNDiS-web) for on-line access and public consultation.

Currently, ReNDiS database contains 4,710 records concerning those programs (funded at 4,472 M€) focused on risk mitigation works but including also information on phenomena typologies and processes.

Keywords

Landslides • ReNDiS • Risk mitigation

Introduction

Landslides in Italy are the most frequent and diffuse natural hazards and, after earthquakes, have caused the greatest number of fatalities and damage to urban areas and infrastructures.

After the devastating event in Sarno in 1998, which caused the loss of 160 lives, an extraordinary effort was conducted by the Italian government supported by River Basin Authorities in order to promote the implementation of preventive plans for the mitigation of landslide and flood risk in all of Italy.

This strategy, implemented in the frame of the 180/98 National Decree, was based on (1) identification of areas classified as high and very high risk (i.e. vulnerable areas prone to landslide hazard); (2) definition of risk reduction measures, mainly engineering works but also "non-structural" mitigations measures (i.e. instrumental monitoring, delocalization, low impact techniques).

In order to improve the knowledge, control activities on preventive policies against landslides and floods and better address future national funds, ISPRA (Italian National Institute for Environmental Protection and Research – Department of Land Protection and Georesources) promoted and developed the ReNDiS project (Repertory of mitigation measures for National Soil Protection) ISPRA (2012).

The ReNDiS project is a useful tool for monitoring, analysis and management of data coming from mitigation measures of geological and hydraulic risk reduction and has been developed by collecting all information about each mitigation work funded by Italian Ministry of the Environment (MATTM), from the initial funding phase through design activities, to the completion of the work.

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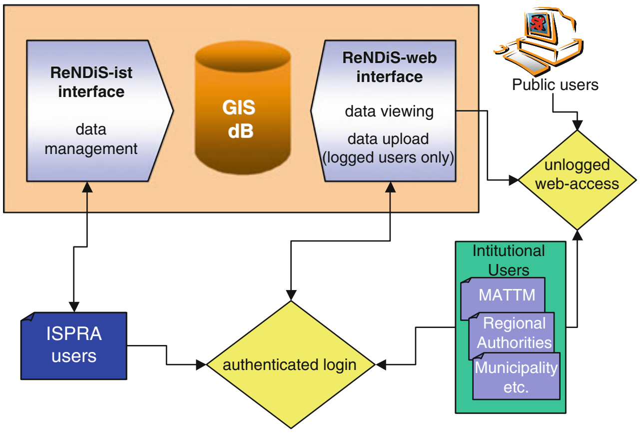

Fig. 1 ReNDiS database structure

Table 1 Financed amounts (Euros) for each Italian region

Region	Works nr.	Funding
Abruzzo	144	€ 117,910,460
Basilicata	214	€ 102,638,813
Calabria	449	€ 391,331,781
Campania	287	€ 384,108,787
Emilia-Romagna	300	€ 277,938,579
Friuli Venezia Giulia	72	€ 87,194,651
Lazio	275	€ 303,836,450
Liguria	115	€ 113,229,528
Lombardia	478	€ 422,057,781
Marche	248	€ 148,023,433
Molise	74	€ 53,035,212
Piemonte	458	€ 243,617,612
Puglia	212	€ 314,959,694
Sardegna	98	€ 148,957,593
Sicilia	407	€ 608,204,253
Toscana	528	€ 410,029,614
Trentino – Alto Adige	61	€ 38,516,374
Umbria	90	€ 100,844,868
Valle d'Aosta	29	€ 31,125,998
Veneto	171	€ 175,351,124
TOTAL	**4,710**	**€ 4,472,912,607**

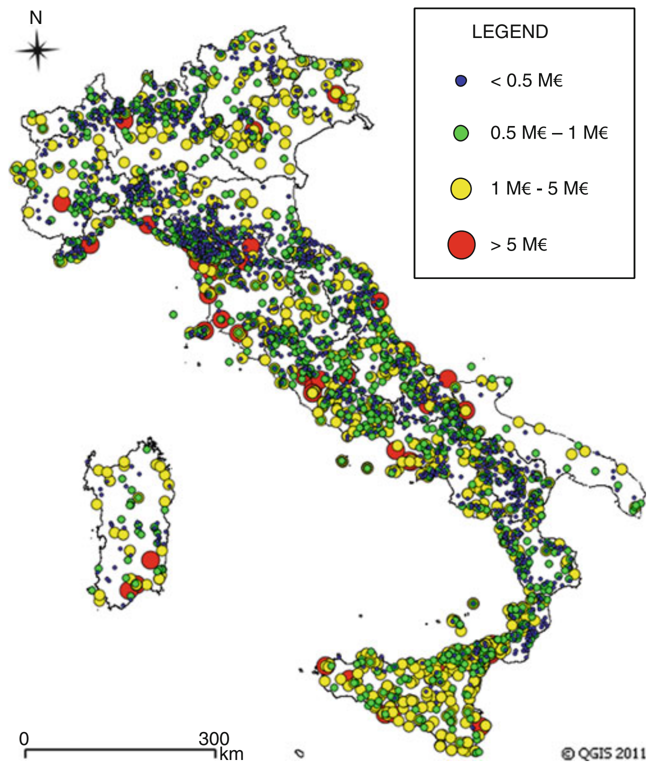

Fig. 2 Geographical position and funding class (Vizzini et al. 2009, modified)

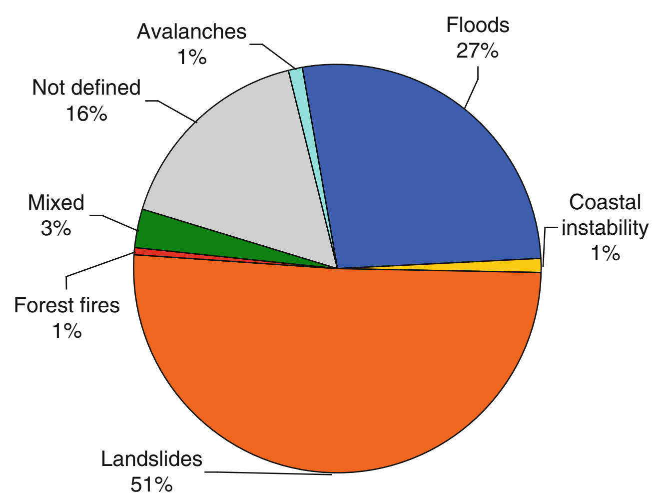

Fig. 3 Type of hazard related to funded mitigation works

Structure of the Inventory and Data Organization

Inside the ReNDiS DB, information is organized by single "mitigation works" meaning that for every intervention (identified respectively by progressive number and funding year) each stage from the financing action to design, work and accounting data are collected and stored. Moreover, the ReNDiS DB allows one to divide each intervention itself into several lots that usually have different design and work procedures.

Data are collected through continuous contacts by ISPRA technicians with the local authorities (contractors) responsible for the works in the whole Italian territory. Also, an on-site inspection is usually scheduled, especially in case of mitigation works undertaken in high and very risk areas. In order to manage heterogeneous data collected for each intervention, the choice of essential information has been restricted to: governmental funding measure, funding amount,

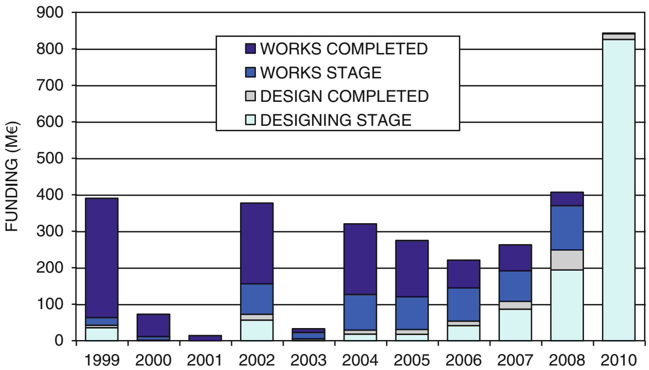

Fig. 4 Progress stage of the works (Gallozzi et al. 2010, modified)

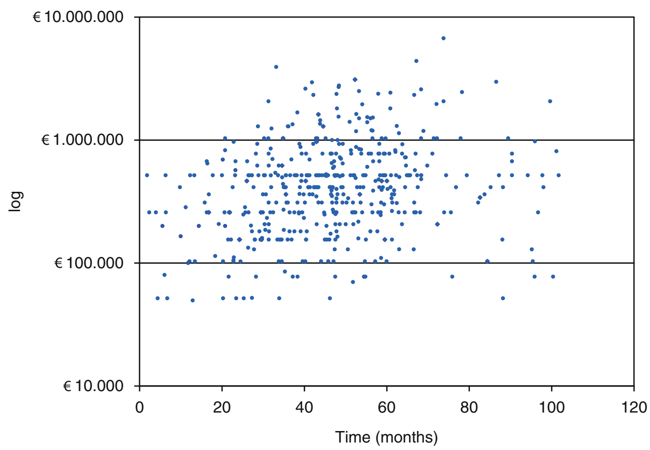

Fig. 5 Time of progress stage versus total amount funded of the works (Spizzichino et al. 2009a, modified)

local beneficiary authority, affected municipality, title of intervention, and position. Other important information regards: geological and hydraulic characterization of the phenomenon, risk mitigation measures adopted, economic accounting for design, works and management, as well as up to date information on the actual progress stage of the intervention.

Therefore, through the ReNDiS DB, the Italian Government can be informed in real-time on how their funds for risk mitigation works are being spent and how they are distributed across the country.

General Framework and Components

As mentioned before, the ReNDiS DB consists of a main archive (PostgreSQL spatially enabled by Postgis component) and two different interfaces: one for direct data management (ReNDiS-ist) and the other (ReNDiS-web) for web access (Fig. 1).

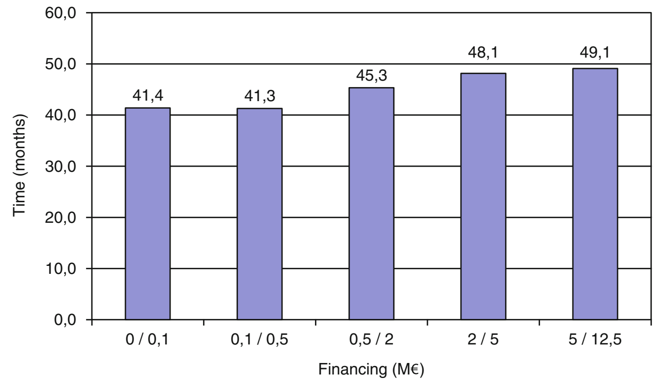

Fig. 6 Time of progress stage of the works (Spizzichino et al. 2009, modified)

The ReNDiS-ist interface allows data collection, entry and analyses, restricted to ISPRA users.

The ReNDiS-web interface allows web publication and sharing for users consultation and data uploading including external users (Gallozzi et al. 2009).

Data interoperability is available through WMS service at http://sgi.isprambiente.it/geoportal.

Data Analysis

As already mentioned, the ReNDiS DB collects all mitigation works funded by the Italian Ministry of the Environment (through urgent programs or plans aimed at mitigation of geological and hydraulic risks), starting from 1999 and including two programs dated 2001 for areas affected by forest fires.

In Table 1, funds allocated so far are summarized for each Italian Region. At present, 4,710 mitigation works have been financed across Italy, for more than four billion Euros. In Fig. 2 the geographical position and funding class are represented.

In Fig. 3 the financed works have been divided according to the type of instability: the works for landslide hazard risk reduction are about 51 % of the total data collected in the DB.

A statistical analysis has been carried out in order to highlight the congruity between the characteristics and type of the hazard (identified in a specific area) and the slope stability mitigation measures adopted for the risk reduction. Furthermore, the incidence of low-impact measures (i.e. naturalistic engineering works), with respect to the traditional civil engineering approach, has been estimated at national level and a specific project, on web-GIS, has been preliminarily implemented (Brustia et al. 2011).

Through specific queries, engineering works have been grouped in several categories that have been correlated to:

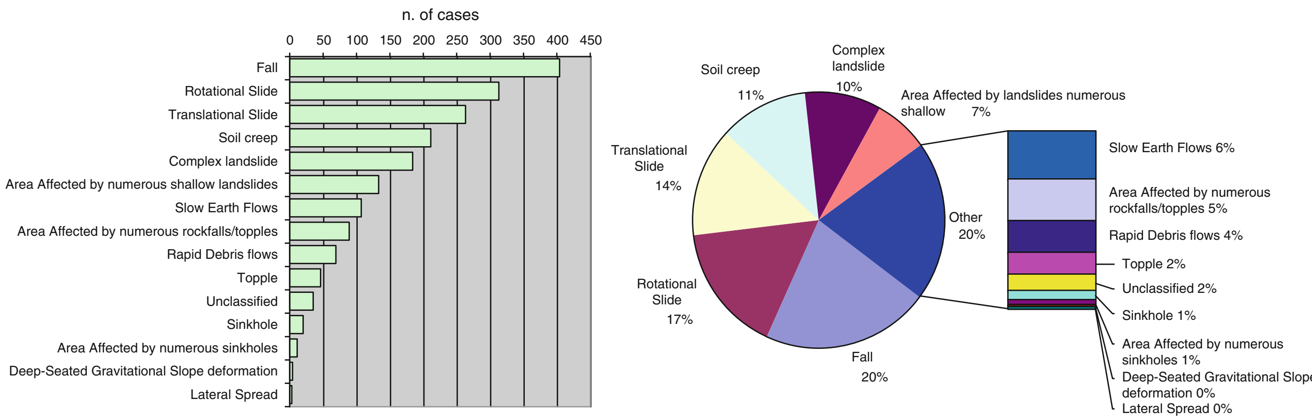

Fig. 7 Distribution of landslide typology

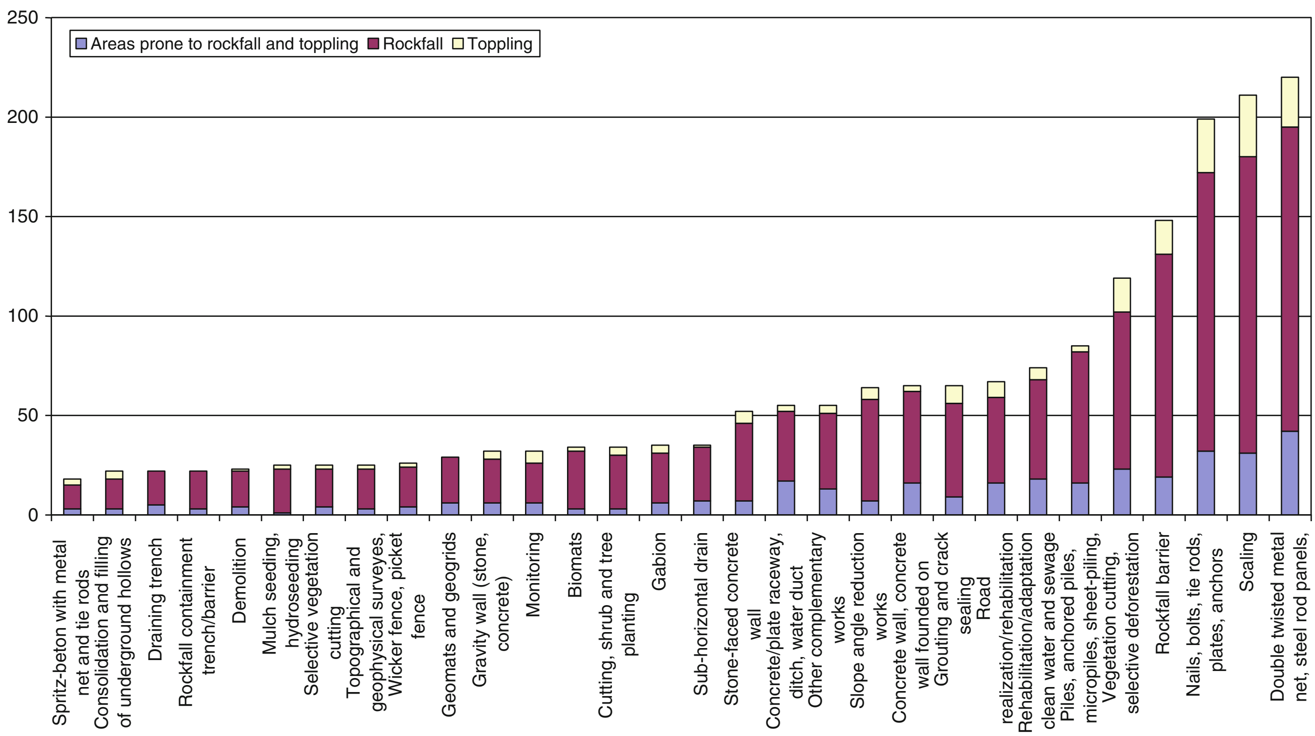

Fig. 8 Rock fall mitigation measures

1. Progress stage of the works (Fig. 4);
2. Time of progress stage (Fig. 5);
3. Timing and costs of each work (Fig. 6);
4. Distribution of landslide typology (Fig. 7);
5. Type of landslide versus typology of mitigation works adopted (Figs. 8, 9, 10, 11 and 12).

This study shows that, although the total amount of funds dedicated to preventive mitigations measures is not enough to remove or effectively solve the problem of risk so widespread in Italy, the response of Italian institutions has been, in general, well calibrated and constitutes an important step in reducing risk at least in some critical situations. Further efforts are needed to improve the knowledge on landslide prone areas and better address public investments where landslide risk is more crucial. The analysis also shows that low impact measures, such as naturalistic engineering techniques, are widely used, especially for the mitigation of superficial landslide processes.

The image above shows that more than 70 % of the works correlated to rockfall and toppling events are usually dealt with common techniques as nails, bolts, tie roads, anchors, metal nets, panels.

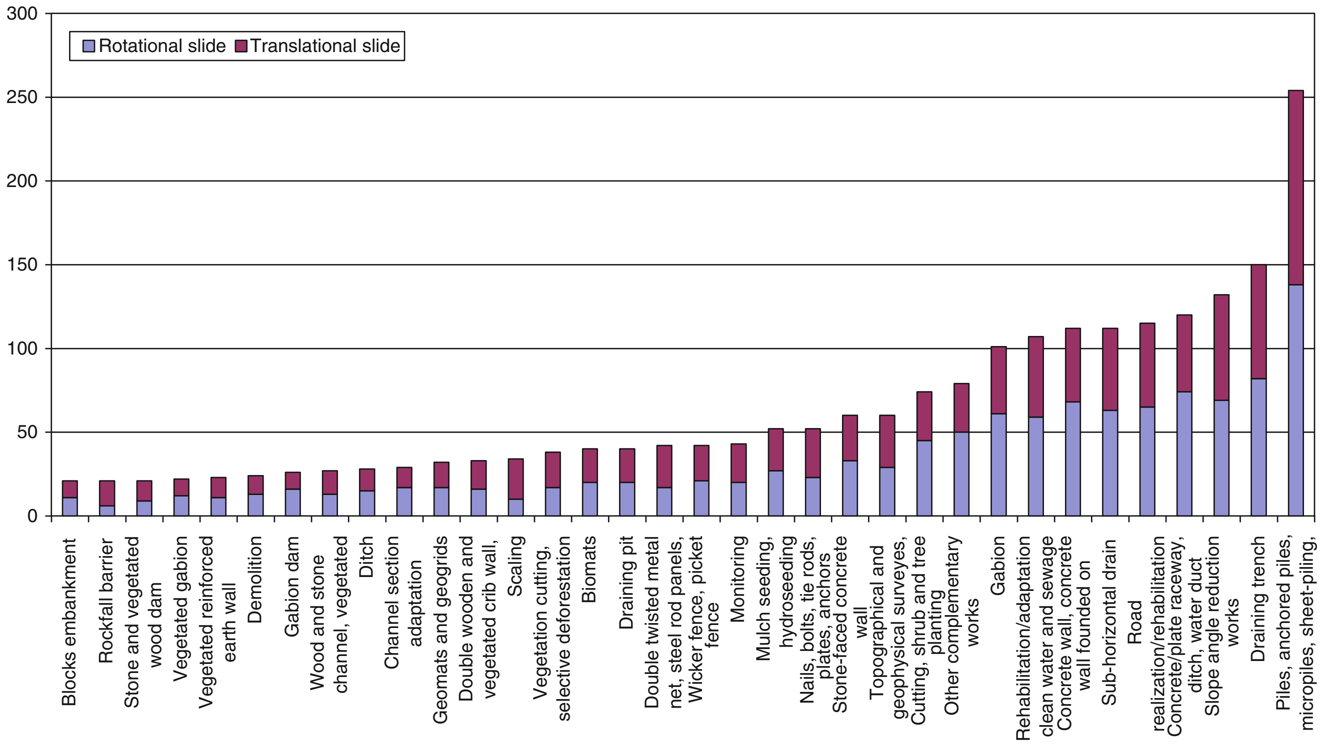

Fig. 9 Rotational/translational slide mitigation measures

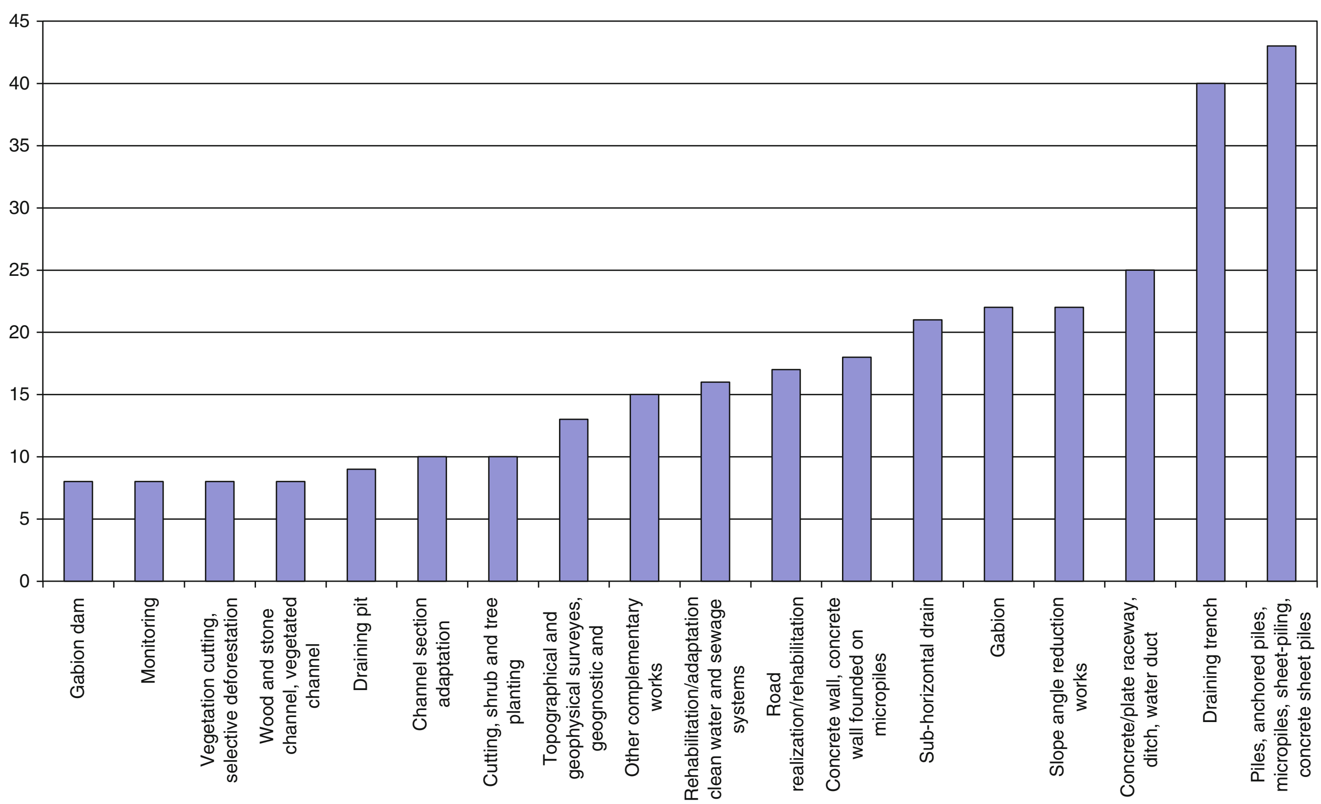

Fig. 10 Slow earth flows mitigation measures

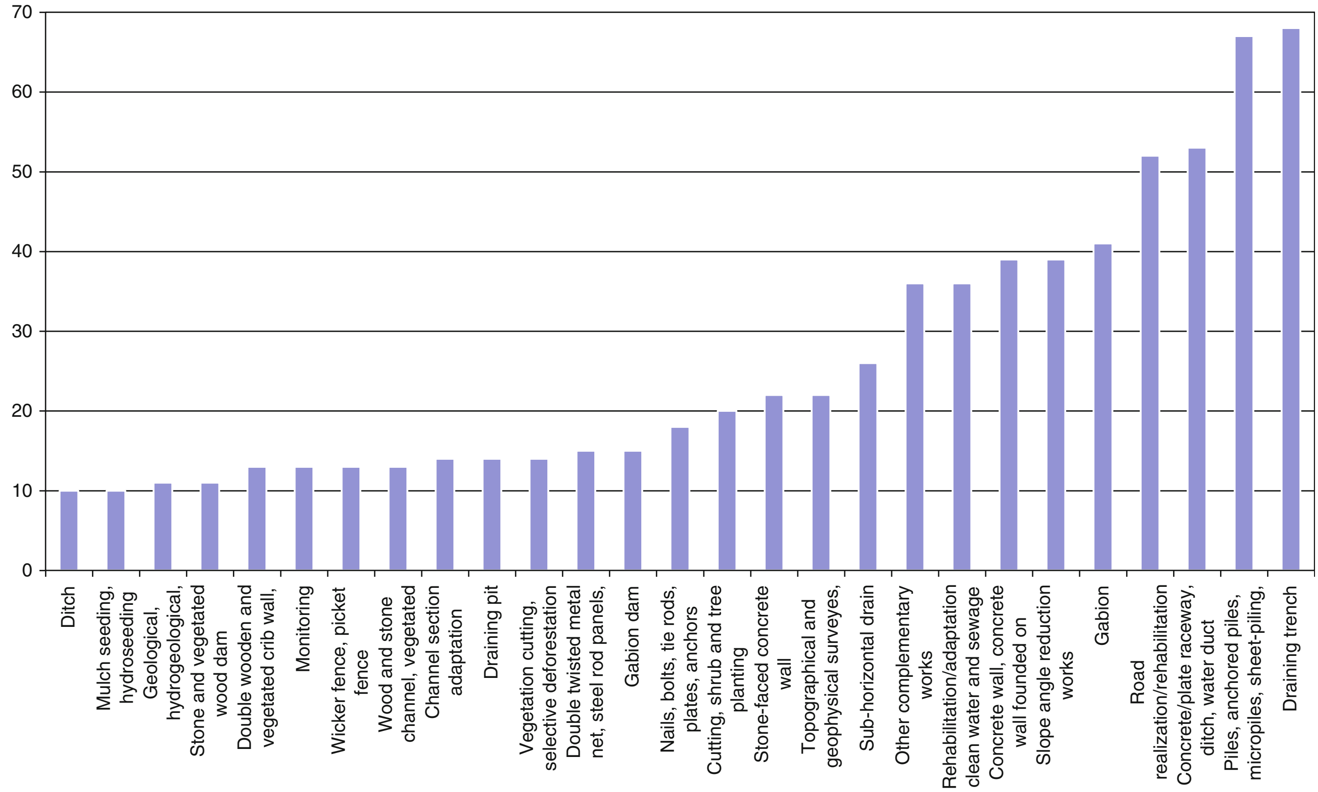

Fig. 11 Complex landslides mitigation measures

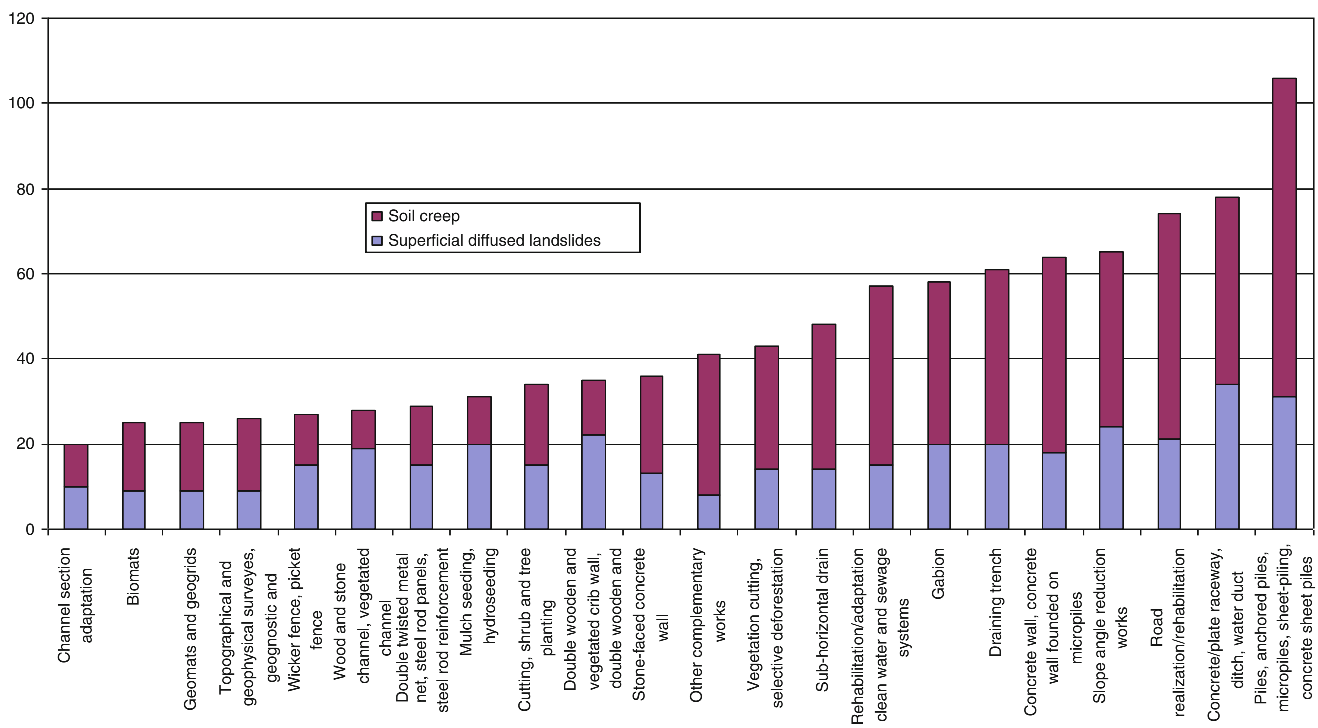

Fig. 12 Superficial diffused landslides mitigation measures

The mitigation measure more frequently used for rotational/translational slide involves the use of piles, which is the recommended technique for such events.

In the case of slow earth flows, mitigation measures appears to be vary even if we register the frequent use of systems of water draining.

In the case of both complex landslides and superficial diffused landslides, mitigation measures are distinguished according to geological and morphological characteristics of the area.

Conclusion

In summary, the ReNDiS project developed by ISPRA, can represent a useful tool for fulfilling various potentialities in the field of landslide and flood risk mitigation policy at national scale, such as planning activities, funding control addressed to public authorities and various stakeholders.

Moreover the ReNDiS project is an example, at a national scale, of knowledge-sharing of geological, morphological, and engineering data that are usually scattered in various sources of information, and often restricted to experts and the general public.

Acknowledgments Authors are grateful to all ISPRA colleagues involved in the ReNDiS project, for their active contribution on data implementation and analysis, and to local authorities for data collection, providing and kind support in field activities.

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Improve Information Provision for Disaster Management: MONITOR II, EU Project

Francesco Ronchetti, Alessandro Corsini, Stefan Kollarits, Diethard Leber, Joze Papez, Katrin Plunger, Tanja Preseren, Ingo Schnetzer, and Martina Stefani

Abstract

Management of natural hazards constitutes a common challenge in most countries of the world. Until now, neither hazard mapping nor contingency planning have been transnationally coordinated and defined. Such gaps will be addressed in the Monitor II project (founded by the EU – South East Transnational Cooperation Program) with the development of a common methodology dealing with risk assessment and risk management. The project partnership has so far carried out the following activities and achieved the following results: review of best practices in hazard mapping and contingency plans; definition of information needs and information flow in different phases of risk management; definition of novel concepts for the creation of simplified scenario models in the process, damage and intervention domains. In the project we will develop a Continuous Situation Awareness system, as software that supports disaster management in the different phases of the risk cycle. Within the broad range of hazards, Monitor II specifically deals with floods and landslides, but the concepts of the project could be applied to other types of hazards.

Keywords

Monitor II • Hazard map • Contingency plan • Hazard scenario • Continuous situation awareness system

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Introduction

Management of natural risk is a challenge in all countries of the world. In Europe, several EU and National projects have been dealing with this topic in the last few decades. This significant effort has led to the development of generally accepted schemes for analyzing hazard, vulnerability and risk (European Commission 2010). However, no real standardization of hazard and risk maps has been achieved, and this also applies to vulnerability assessment. Moreover, static hazard maps are not sufficient to effectively support contingency planning. This is principally because they cannot provide explicitly, information that is essential for efficiently managing an event, for instance the expected duration of an event, the timing and routing of processes during the event, etc. In other words, it can be stated that hazard and risk maps for land use planning are not fully adequate for contingency planning because they do not

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Fig. 1 Map of the SEE programme area with the abbreviations of the project partner names

provide a clear and simple vision of expected evolution, in space and time, of the event and damage scenarios.

Improving information provision for disaster management by bridging the gap between hazard maps and contingency plans is one of the goals of Monitor II project (MII). MII is a European Project (www.monitor2.org) funded by the South East Transnational Cooperation Program – SEE, involving 11 EU partners from the following countries (Fig. 1): Austria, Slovenia, Serbia, Italy, Romania, Bulgaria, and Greece.

The vision of MII is that a closer link can be created between hazard assessment and risk management by complementing hazard and risk maps with simplified scenario models regarding the expected course of the natural event itself and of the expected damages, and by developing a modular software suite, the CSA (Continuous Situation Awareness), that can guide risk analysis and contingency management through conceptually and practically consistent procedures based on shared ontology rules.

Within the broad range of hazards, MII specifically deals with floods and landslides and it is presently just beyond its midterm. The project partnership has so far carried out the following activities and achieved the following results: review of best practices in hazard mapping and contingency plans; definition of information needs and information flows in different phases of risk management improvement of ontology (from Monitor I); definition of novel concepts for the creation of simplified scenario models in the process, damage and intervention domain.

This paper provides an overview of the concepts and results obtained so far, that are more specifically constrained in a project brochure accessible via the web (Monitor II 2011).

	PREPAREDNESS	RESPONSE	
INFORMATION NEEDS	P) PREVENTION Planning–Technical measures (non-real-time information)	F) WARNING Alert – Pre-Alaram – Alarm (real-time information)	R) INTERVENTION Rescue – Damage miti gation (real-time information)
	InfoNeeds: to Assess – Define	InfoNeeds: to Forecast – Identify	InfoNeeds: to Appraise – Control
H) HAZARD	P.H.1) Hazard processes spatial distibution and extent P.H.2) Hazard processes long-term evolution-dynamic P.H.3) Triggering Conditions P.H.4) Predicted Event Scenarios P.H.5) Hazard Mitigation Alternatives	F.H.1) Hazard processes on going evolution-dynamic F.H.2) Hazard processes expected evolution-dynamic F.H.3) Triggering causes situation F.H.4) Triggering causes expected trends F.H.5) Expected Event scenarios F.H.6) Urgent – Contingent hazard mitigation measures	R.H.1) Hazard processes on going evolution-dynamic R.H.2) Status-efficacy of ongoing hazard mitigation measures R.H.3) Ongoing Event scenarios
V) VULNERABILITY	P.V.1) Exposure P.V.2) Vulnerability P.V.3) Value or Worth P.V.4) Vulnerability and/or Cost-worth Reduction Alternatives	F.V.1) Urgent-Contingent Vulnerability and/or cost reduction measures	R.V.1) Status-Efficacy of ongoing vulnerability and/or cost reduction measures
R) RISK	P.R.1) Predicted Damage Scenarios P.R.2) Predicted Loss Scenarios	F.R.1) Expected Damage Scenarios F.R.2) Expected Loss Scenarios	R.R.1) Ongoing Damage Scenarios R.R.2) Ongoing Loss Scenarios
Main information flow direction During an Emergency Event		Update	Update
Main information flow direction After an Emergency Event	Update		

Fig. 2 Information needs by disaster management phase

Information Needs and Information Flows

Information collection is essential in all risk management phases (preparedness, response, recovery). They produce supporting datasets that are used to meet information needs in the different risk management tasks (prevention, warning and intervention) regarding hazard, vulnerability and risk (Fig. 2).

Information flow is defined by the way in which datasets are used in a harmonised integrated manner in order to meet information needs. Information flows vary depending on the risk management task (Fig. 3).

The general framework links risk related terms (hazard-vulnerability-value-risk) to emergency related terms (event-damage-loss scenarios). Based on these general schemes flowcharts for the information flow during prevention, warning and intervention phases can be defined. These flowcharts hold direct reference to the main information needs defined and are built upon the review of practices among MII project partners (PPs).

During the prevention task, hazard-related data and models (including monitoring data) are aimed at defining – in non-real time and with reference to long term conditions – relevant characteristics of hazard processes; triggering conditions and thresholds (either related to causes or intensity of the hazard processes); and possible hazard mitigation alternatives.

During the warning phase, hazard-related monitoring data are primarily aimed at verifying, in real time and with reference to short-mid term conditions, if the thresholds defined during prevention (regarding causes and hazard processes) are likely to be reached or have been already reached.

During response, a timely update on the ongoing situation is essential. Response is carried out while forecasting is still ongoing, so to have a clear picture of what is actually going on and of what can happen next in the short term.

Hazard Mapping and Contingency Planning: State of Art

Hazard and risk mapping have the goal to represent a criteria-based evaluation of the data, information and results obtained from inventory and analysis phases. They are, generally, "pseudo-static" documents updated with an interval of perhaps 1–10 years (or even longer).

In the public sector they are produced for land-use planning purposes and are not intended for contingency planning. They are thus intended as risk reduction tools, reducing future exposure to risk of buildings and populations and also supporting planning and prioritization of technical and non technical measures.

Land-use planning requires maps to be used and interpreted by non experts and that can incorporate a dose of political-decisional subjectivity. For this reason a classes-based approach is fully justified, resulting in zonation maps which are more qualitative (pseudo-quantitative) than quantitative. Such maps are thus not able to represent the full information details of the hazard assessment procedure.

The full detail is usually available only as "official expertise", but this needs expert knowledge for interpretation. In the private sector, for instance in real estate insurance, the scope of hazard and risk maps is completely different, as they are tools to calculate probabilities of economic loss for the company. For this reason risk maps for the insurance sector need a truly quantitative scaling, in order to allow this calculation.

The analysis of practice among PPs has highlighted a number of common points between the maps and the methods used to combine risk variables: frequency of hazard processes is defined in classes by using return periods that are assessed on a statistical or expert-opinion basis; intensity of hazard processes is defined in classes that are determined on the basis of ranges of values of measurable physical variables; hazard potential of hazard processes is derived by a heuristic matrix-based combination of frequency and

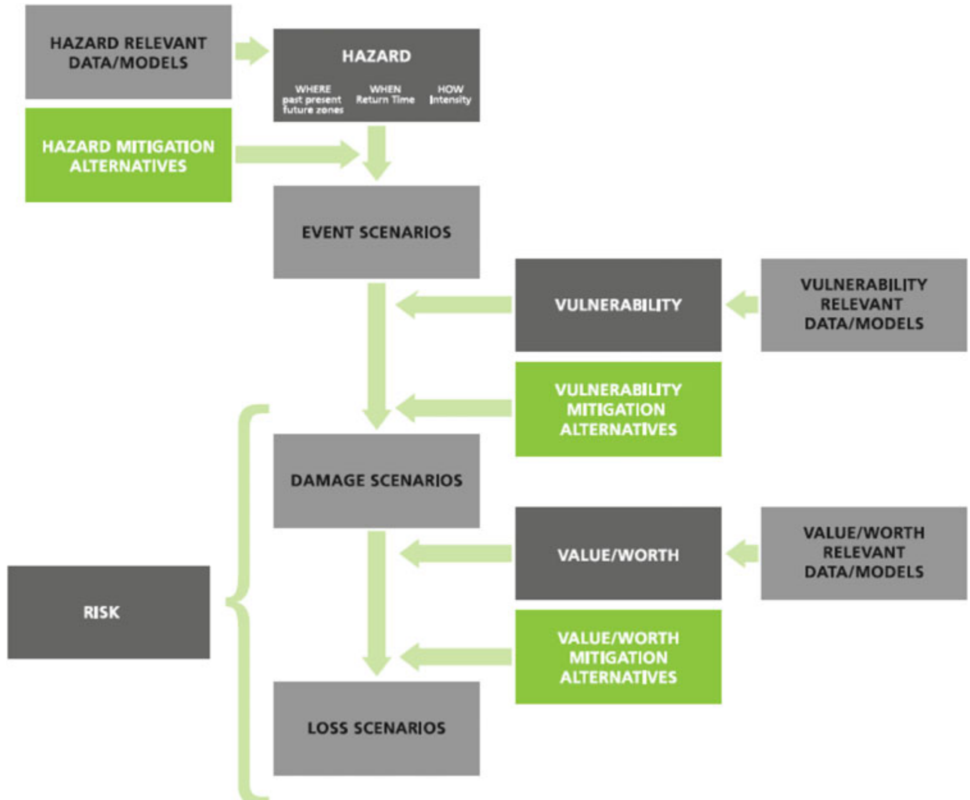

Fig. 3 Risk and emergency basics with relevant input

intensity classes; vulnerability of elements at risk is usually only defined on the basis of the function of structures, mainly buildings (with some regard to their sociopolitic-strategic importance).

There is no "true" information on actual vulnerability of single structures concerning hazardous events. This means that the capacity of structures to resist the impact of an event is not taken into account.

But vulnerability should not be restricted to the "resistance capacity" point of view, but must include the dimensions of "anticipation capacity", "coping capacity" and "recovery capacity" as well.

These matters are not touched today in risk assessment procedures; value of exposed elements is usually not defined separately, as it is already somehow incorporated in the utilised notion of vulnerability (function of structures).

The practice of vulnerability definition thus shows clear shortcomings and should be replaced by a transparent procedure for defining damage potential, which is calculated on the basis of vulnerability and value of elements at risk.

The general similarities described above contrast with great differences in details of approaches that lead top difficulties in adopting transnational approaches. For example, no common standard exist in the hazard and risk assessment matrices for floods (Fig. 4).

Hazard Mapping and Contingency Planning: Open Issue

The review of hazard and risk mapping practices among PPs has highlighted a number of open issues that are worthwhile being pinpointed with respect to two different perspectives, the harmonization of documents at an EU level and the usability of Hazard and Risk maps for contingency planning and management.

- Being Hazard generally defined by a combination of Return Period and Intensity parameters, should these parameters be ranked in descriptive "qualitative" or "pseudo-quantitative" classes (as in landuse planning practice among PPs), or should they rather be ranked on a continuous "quantitative" 0 to 1 basis (as in insurance practice)?
- Is it preferable to define Hazard levels combining Intensity and Return Period classes or values by using an heuristic "matrix-based" approach – so to include some "political" decisions – or by using an objective "math-based" combination approach?
- If descriptive "qualitative" or "pseudoquantitative" classes for Intensity and Return Period ranking are to be used, is standardization of classes possible and desirable?

	SLOVENIA (PP4)			ITALY (PP5)				AUSTRIA (PP1)	
HAZARD CLASS	FREQUENCY CLASS			FREQUENCY CLASS				FREQUENCY CLASS	
Intensity class	High	Medium	Low	High	Medium	Low	Very Low	High	Medium
High	High	High	residual	Very High	Very High	Very High	residual	High	High
Medium	High	Medium	residual		High		residual	Low	Low
Low	High	Low	residual	High		Medium	residual		

Fig. 4 Example of no common standard in the hazard assessment; hazard matrices for floods in Slovenia, Italy, Austria

- Should Vulnerability of elements at risk be ranked in descriptive "qualitative" or "pseudo-quantitative" classes based on its "strategic" or "social" worth (as in land-use planning practice among PPs), or should it rather be ranked on a continuous "quantitative" 0 to 1 basis considering it's constructional characteristics with respect to the occurring hazard (as in insurance practice)?
- If descriptive "qualitative" or "pseudoquantitative" classes for ranking Vulnerability are to be used, is standardization of classes possible and desirable?
- Is it preferable to define the "Risk level" of an area by combination of Hazard and Vulnerability classes or values using a heuristic "matrix-based" – so to include some "political" decisions – or to define it on the basis of an objective "mathbased" combination of these parameters?
- Could a "standard" of codes and colours for type of hazard process and Hazard-Risk levels favour?

At the same time, the review of contingency Planning practices among PPs has highlighted that contingency planning is confronted with quite a large number of issues, some of which are related to the non-existence of transnational standards. For this reason:

- Contingency plans are often not available in a harmonised form (if available at all);
- Contingency plans are usually not available in a structured digital form, thus links to GIS or hazard maps are not possible;
- Contingency plans are being prepared on different levels of competences, different hazard types, different organisations – and all this is not harmonised, and more often than, not integrated into common work-flows;
- Contingency plans need update in the event of any change relating to hazards or the availability of protection, rescue and relief forces but also taking into account new findings and experience gained in disaster management. Standardised procedures for this important task are not available; How can residual risk be dealt with in contingency plans?; How can the public be integrated in a risk dialogue, particularly in terms of how to treat residual risks – this should assure that all opportunities to manage and minimize residual risks are taken (e.g. property protection measures, emergency planning and insurance . . .); How to avoid or at least minimise risk aversion? Examples have shown that people tend to ignore (avert) risk, especially if "it has never happened before" (which means: in my remembrance), but even in case of previous disaster events the rate of ignorance is high.

Simplified Scenarios as a Missing Link Between Hazard Map and Contingency Plan

Although high quality information is available during the hazard assessment procedure itself, the information on hazard processes, process development and possible event scenarios is generally summarized in reports hardly readable by contingency planners and "condensed" in more or less simple hazard maps. During this process the necessary "simplification" of complex processes and process interactions, key information, required by contingency planners might end up being hidden or lost.

A more "process oriented approach" of contingency planning requires as input from advanced hazard mapping, answers to very basic questions about the development of hazard processes and about required actions and measures to be taken.

In order to fulfil these requirements, reference scenarios must be defined and included in the hazard maps and in tools like a "hazard manager" in Continuous Situation Awareness (CSA) systems to act as a link between hazard mapping and contingency planning procedure (Leber et al. 2012).

Reference Event Scenarios refer exclusively to the evolution in space and time of the hazardous process. Reference Risk Scenarios (divided into Damage Scenarios and Loss Scenarios) refer to the evolution in space and time of the reference event and of its effects, also considering eventual mitigation or response actions.

Reference scenarios should be structured according to simplified scenario models i.e. as a standardized description

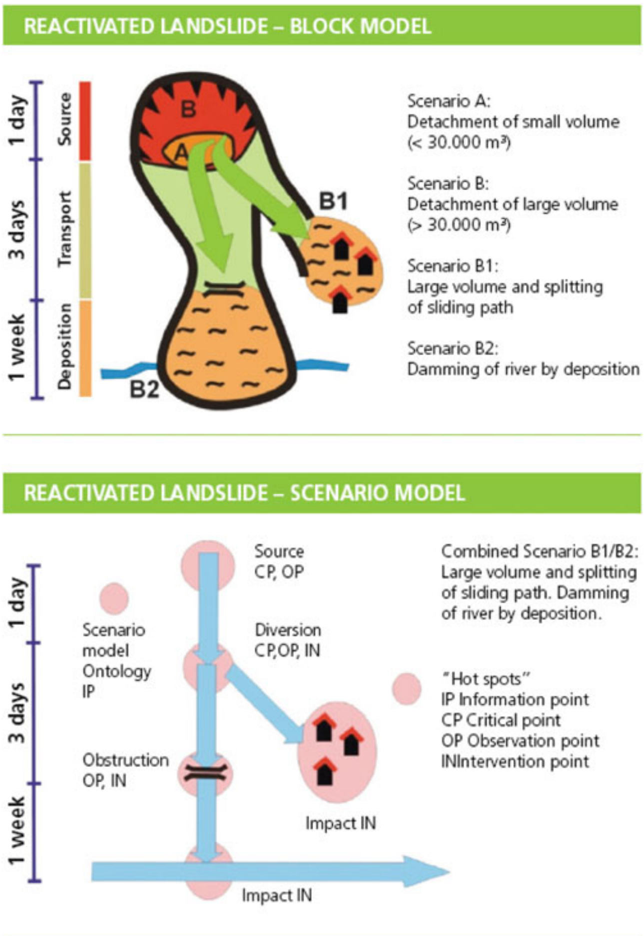

Fig. 5 The concept of scenario model and "hot spots" shown for a sliding event

of a course of future hazard events and of their impacts, based on a consistent and plausible set of assumptions about future conditions. Within contingency planning, scenario models can be used to describe reference scenarios both in preparedness phase and response phase.

Simplified scenarios models (used for "event" or "damage"/"loss" scenarios) should comprise the following key elements: Definition/Description of possible – eventually multiple – "reference" scenarios (mainly process oriented); evaluation of the efficiency of existing countermeasures ("protected" or "failure" "scenario"); definition of forecasting, observation, alert and intervention options; indication of the main elements and key situations regarding processes and countermeasures/interventions (using "critical", "observation", and "intervention"); comparison of the expected effects of these situations for endangered objects (i.e. damage and loss scenarios) (i.e. "basic", "protected" and – as worst case – a "total failure-of-countermeasures" scenarios). Simplified scenario models must be included in the hazard maps in CSA systems in short text and condensed,

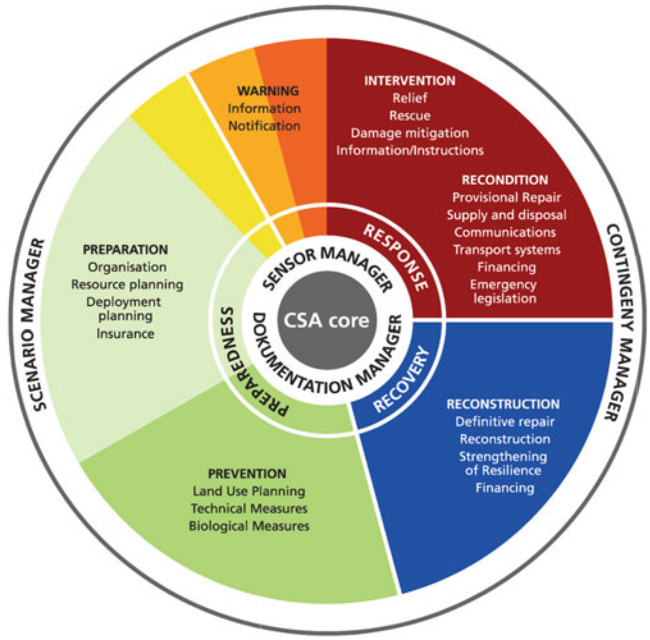

Fig. 6 Scheme of the Monitor II CSA modules within the risk management cycle

standardized and formalized using predefined ontology rules and syntax.

Within the co-operation of hazard experts and contingency planners "hot spots" can be defined in the process (p), damage/loss (d) and intervention (i) domains. These "hot spots" are indicators for information linking the hazard/process and the contingency/intervention fields by providing key process information or indications of required measures. These "hot spots" comprise information points, critical points, observation points and intervention points.

These points have some standardized information linked about possible processes, monitoring instruments, expect time of impact, countermeasures etc. These are indicators for standardized information linking the hazard process and the contingency intervention. The hot spots are "process oriented" and can be classified as follows: process oriented information point (p_info), depending on the event scenario; process oriented observation point (p_op), it indicates a location where the process can be observed or monitored; process oriented intervention point (p_ip), it is used during the preparedness phase indicate all technical and non technical prevention measures installed.

Based on the classical approach of hazard assessment and mapping and the concept of hazard scenarios, scenario maps can be developed. These maps show different zones and are giving additional details on hazard processes and possible mitigation or intervention strategies using the "hot spot" concept lined out above. Simplified scenario models and "hot spot information" included in hazard maps (in addition

Fig. 7 CSA – Monitor II scenario manager supports the definition of observation points for further use in contingency planning

to the zonation information) sustains the contingency planner in preparedness and intervention phase to gain a fast overview about principle process information in a standardized form and thus helps to improve process understanding.

The concept of scenario models and "hot spots" shown for a sliding event is presented in Fig. 5.

Toward a CSA (Continuous Situation Awareness) Software Tool

All the above discussed issues have been used as a start to defining the structure and the contents of a common Continuous Situation Awareness (CSA) system with modules for hazard scenario management, contingency management, situation assessment and relative documentation.

The CSA is a tool that will be developed in the MII project represented by a series of software components, allowing the easy integration, presentation and use of the disaster management information (Kollarits et al. 2011).

Seen from the perspective of a disaster event, the CSA will be usable in different risk management phases and recurrent activities (Fig. 6). For MII the current definitions of ClimChAlp (Strategic Interreg III B Alpine Space Project) (2008) were taken as a starting point.

The system architecture of the CSA takes into account the existence and well established use of legacy systems. This means that the components of the CSA follow some design rules: they are standards based, supporting OGC standard (like WMS, WFS or Sensor Web) and INSPIRE wherever feasible; they define open service oriented interfaces, allowing to integrate them with other components; their functionality is encapsulated so that they function independently of specific other components and/or information sources; their modular design is defined on thematic and interoperable units.

The CSA is designed to store event data in a special CSA database. Object data – like buildings or roads – are assumed to be stored in the local, regional or national GIS. The CSA can use these object data directly if they conform to the thematically corresponding INSPIRE implementation rules. Otherwise a transformation of data is necessary.

The CSA core module serves for services integration, as rule engine and for visualisation purposes. It includes all basic administration functionality (user administration, authorisation and security management, service configuration) and allows one to interface to GIS integration services (WMS, WFS). Basic user interaction – like mapping, querying and filtering and searching is provided via easy to use web client.

The sensor manager supports the integration of sensor information of various sources (by using standards like sensor web) and helps to configure and monitor sensors. Sensor generated information can be visualised (on maps, in charts) and analysed – together with other information sources provided via CSA core module.

Fig. 8 CSA – Monitor II documentation manager visualized all relevant parameters of an event in its development over time

The scenario manager supports the definition of hazard scenarios and to link them to hazard maps. This shall help to communicate scenarios and to provide an information base for contingency plans.

The contingency manager supports the definition of contingency plans (conforming to contingency planning guidelines as defined in MII) in a digital, GIS based way.

In the response phase these digital contingency plans support the monitoring and execution of contingency plans (the work-flow of measures) and after an event to evaluate the contingency plan and update the contingency plan.

The documentation manager provides mobile information viewing and mobile information. On platforms like smartphones or tablets the user is supported in mobile observation (with the help of augmented reality), reporting and information collection. All information can be interfaced with the core system and used for reporting and documentation purposes. An example of the CSA system, in developing in the project, is reported in the figure below (Figs. 7 and 8).

Conclusions

The paper describes the main mid-term achievements of the Monitor II project, funded by the South East Transnational Cooperation Program – SEE.

The project partnership has so far achieved the following results: review of best practices in hazard mapping and contingency plans; evaluation of their usability in risk management; definition of information needs and information flows in different phases of risk management; definition of novel concepts for the creation of simplified scenario models based on the identification of "hot spots" in the process, damage and intervention domain.

Simplified hazard and risk scenarios are considered the key missing link between hazard mapping and contingency planning. A structured geodatabase and the necessary ontology rules for standardizing scenarios construction are being integrated within the Continuous Situation Awareness software suite that Monitor II is committed to deliver by the end of the project.

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THE SECOND WORLD LANDSLIDE FORUM

Vulnerability Assessment and Risk Mitigation: The Case of Vulcano Island, Italy

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Abstract

This paper reports on a comprehensive vulnerability analysis based on a research work developed within the EC ENSURE Project (7FP) dealing with the assessment of different volcanic phenomena and induced mass-movements on Vulcano Island (S Italy) as a key tool for proactive efforts for multi-risk mitigation. The work is mainly focused on tephra sedimentation and lahar hazards and related physical, systemic and mitigation capacities.

Keywords

Tephra • Lahars • Integrated vulnerability analysis

Introduction

Volcanic eruptions are characterized by multiple hazards, which pose short and long-term threats to people and property. Responses to geological hazards by emergency management, and communities in general, that are reactive, rather than proactive, are likely to be severely ineffective. For example, most volcanic eruptions reach their peak intensity shortly after the onset of volcanic unrest, which leaves little to no time for anything but initiating predetermined plans of action. Consequently, experience has shown that successful management of volcanic and other induced hazards (e.g. lahars) strongly correlate with the degree to which proactive policies of risk reduction are in place before an eruption begins. A comprehensive vulnerability analysis of volcanic hazards at Vulcano Island, Italy, has been conducted to aid in the proactive management of future volcanic unrest at the type locality for Vulcanian explosions – transient eruptions producing mild to extreme hazards to people and property.

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Analysis of Elements at Risk

Information about site morphology and the built environment was gathered and input into a Geographical Information System (e.g., Fig. 1). Vulcano covers an area of 21 km^2 which belongs to the Municipality of Lipari.

In 2006, the official residential population reached 1,080 people (Comune Lipari 2008). However actual residents may number around 600, especially in wintertime, when touristic activities cease.

During the peak tourist season, from May to October, between 5,000 and 10,000 tourists visit the Island.

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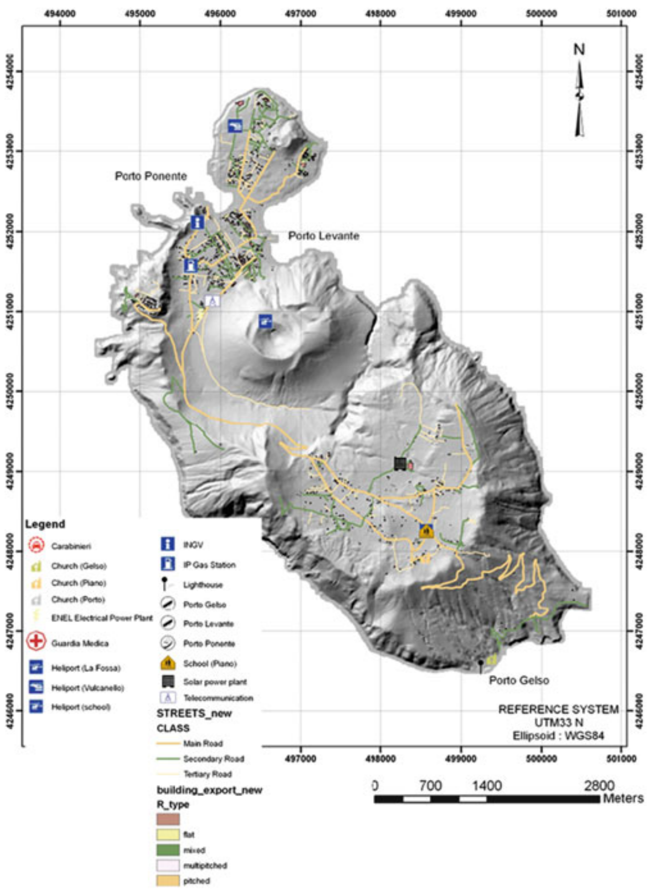

Fig. 1 Roads, buildings and facilities of Vulcano

Italians mainly visit in July- August, whereas foreigners and students visit in March-June and September-October. Moreover, some foreigners also come to work for hotels. This variability in origin should be considered when developing awareness to volcanic risk and with emergency procedures. The 2000 Census (ISTAT 2005) indicates that the majority of working population of Vulcano (72.3 %) works in tourism-related activities, shops or public administration, whereas 24.9 % works in construction and the remaining percentage in agriculture. Results of dedicated social science interviews of key stakeholders in 2007–2008 and an interview survey of the general public in 2009 (N = 91) indicate that awareness of the last volcanic eruption in the 1800s and expectations of a future eruption in <100 years are good but people are mixed about what the Civil Protection Authority advises in an eruption. Major problems of concern on the island were related to provision of public services and a lack of cultural and social activities and strategic development strategy, not “fear” of the volcano or presence of visitors. In fact, analysis of our survey data show that there is an expectation of a future eruption on island, but people’s attention is focused on concerns about short-term economic, social and service issues. These concerns result in people leaving the island for perceived greater opportunity (e.g., better jobs, entertainment and education). Increasing knowledge of protective actions and preparedness for an eruption or other hazards should focus on incentives for preparation. They should, for example, highlight the economic and social benefits and consequences for preparations. Benefits include an increased ability to cope with an eruption and its effects and hence a reduction in risk and personal loss during volcanic unrest. Consequences are an initial investment of time and resources in exchange for reduced impacts, feeling of greater security and control, and coping abilities in the near to long-term. However, the lack of expectations of an eruption in < 12 months means people are unlikely to use their short-term access to time and monetary and physical resources to undertake preparedness actions given other more pressing matters. Future efforts to connect with island residents as part of any risk reduction strategy will have to counter this position (i.e., that volcanic hazards do not represent a short-term threat) by focusing initial information on matters of island wide importance.

Regarding the built environment, the Census, done in 2000 (ISTAT 2005), distinguishes three different areas on Vulcano, defined on specific characteristics linked with house distributions and availability of services. These three types of areas are: (a) inhabited centre defined as cluster of houses with public infrastructures and services, (b) inhabited nucleus with a lower density of houses and with infrastructures less well maintained, (c) scattered houses with a distance sufficiently large enough not to be considered as a nucleus. Depending on hazard types, key building components need to be considered and, therefore, information related to type of materials, building ages and number of floors was described. As an example, in case of tephra falls, angle of roof, existence of large openings on roofs and main axes of buildings are also key parameters, as collapse of buildings under loading depends on strength of roofs. Data contained in the Census 2000 (ISTAT 2005) give information related to buildings such as use, number of floors, age of construction, but summarized for each pre-defined areas existing in Vulcano. In order to have additional in-depth information, a field campaign was carried out in order to look for specific indicators for building characterization and to collect data on road width and quality of construction. The survey was defined on a grid of 100 × 100 m. A representative building of the pixel was selected and assessed in as much detail as possible, depending on the accessibility. Two hundred and fifty five buildings were assessed. Most of these buildings are residential houses, occupied either on a yearly basis or more often during the peak season (May–October).

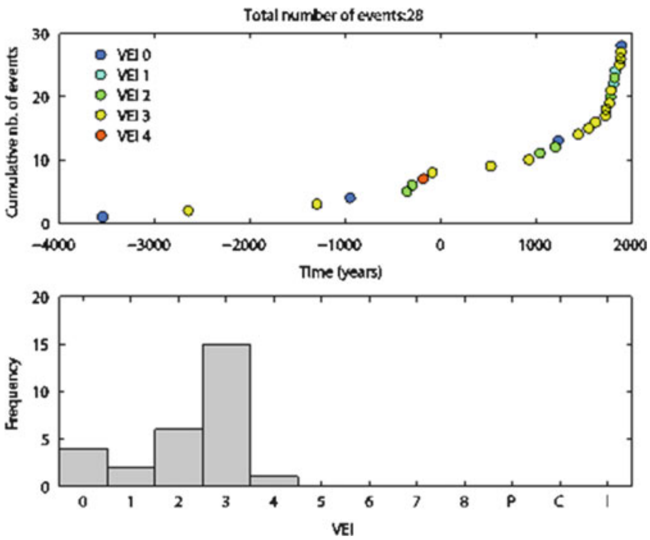

Fig. 2 Eruptive history of Vulcano according to GVP data (Siebert and Simkin 2002)

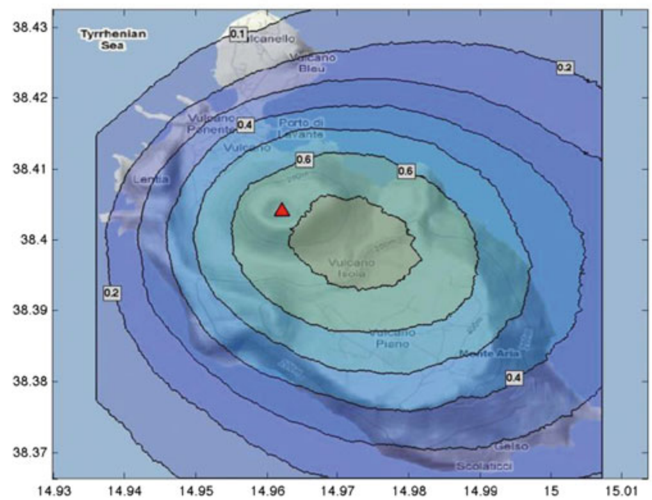

Fig. 3 Tephra hazard map showing the probability of reaching an accumulation of 300 kg/m^2

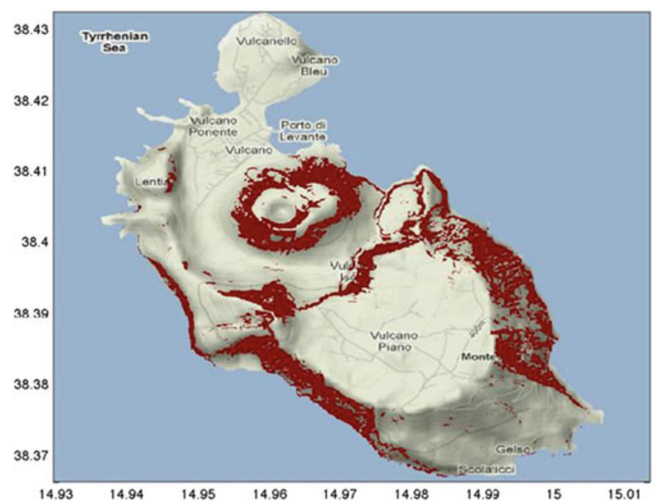

Fig. 4 Zones of slope instability assessed with a Mohr-Coulomb failure criterion on a water-saturated deposit

Tephra and Lahar Hazard Assessment

Hazard assessment was developed for tephra (including ballistic ejecta) and lahar phenomena related to a possible eruption with Volcanic Explosivity Index 3. In fact, assuming that future activity will be similar to past activity or will follow a present trend, eruptions of VEI 3 are considered as the most likely event to occur based on both field analysis and studies of the eruptive record from the Global Volcanism Program (GVP) of the Smithsonian Institution of the last 1,000 years of activity (Fig. 2).

Using the eruptive record of the GVP and simple Poisson models, a probability of occurrence of an eruption of VEI 3 in the next 100 years has been estimated to be around 45 %. Tephra hazard assessment was compiled using the advection-diffusion model TEPHRA2 coupled with probabilistic methods in order to account for the variability of eruptive parameters and atmospheric patterns (Bonadonna et al. 2005). Results show that for a VEI3 eruption, the areas of Porto Levante and Piano (characterized by the highest concentration of residential buildings and tourist facilities, Fig. 1) have about 50 % probability of reaching 300 kg/m^2 of tephra accumulation (i.e., threshold for roof collapse; Fig. 3). In contrast, Porto Gelso, on the most southern point of the island, shows a probability of about 20 % for the same mass loading. Considering that blockage of roads will occur with a tephra accumulation situated somewhere between 10 and 300 kg/m^2 (corresponding to thicknesses of 1 and 30 cm respectively, assuming a density of 1,000 kg/m^3), the main road joining Porto Levante to Porto Gelso has a probability between 60 % and 90 % to be paralysed, thus isolating the north and the south parts of the island.

Ballistic ejecta (i.e., rocks with diameters of at least 15–20 cm blown at velocities of tens to hundreds m/s) are common hazards in the vicinity of the active vent, which can affect surrounding populations in two main ways.

First, although rarely, ballistics are easily capable of causing lethal skull injuries due to their high terminal fall velocities. Second, hot ballistics commonly ignite fires due to their high temperature, thus threatening both properties and vegetation. Our hazard assessment for ballistics considers two possible scenarios elaborated from field observations. The first scenario considers an average ejection velocity of 50 m/s, which results in ejecta being localized to the area of the cone. However, when this ejection velocity is doubled, ballistics as big as 200 cm are dispersed in a radius of 1.5 km around the vent.

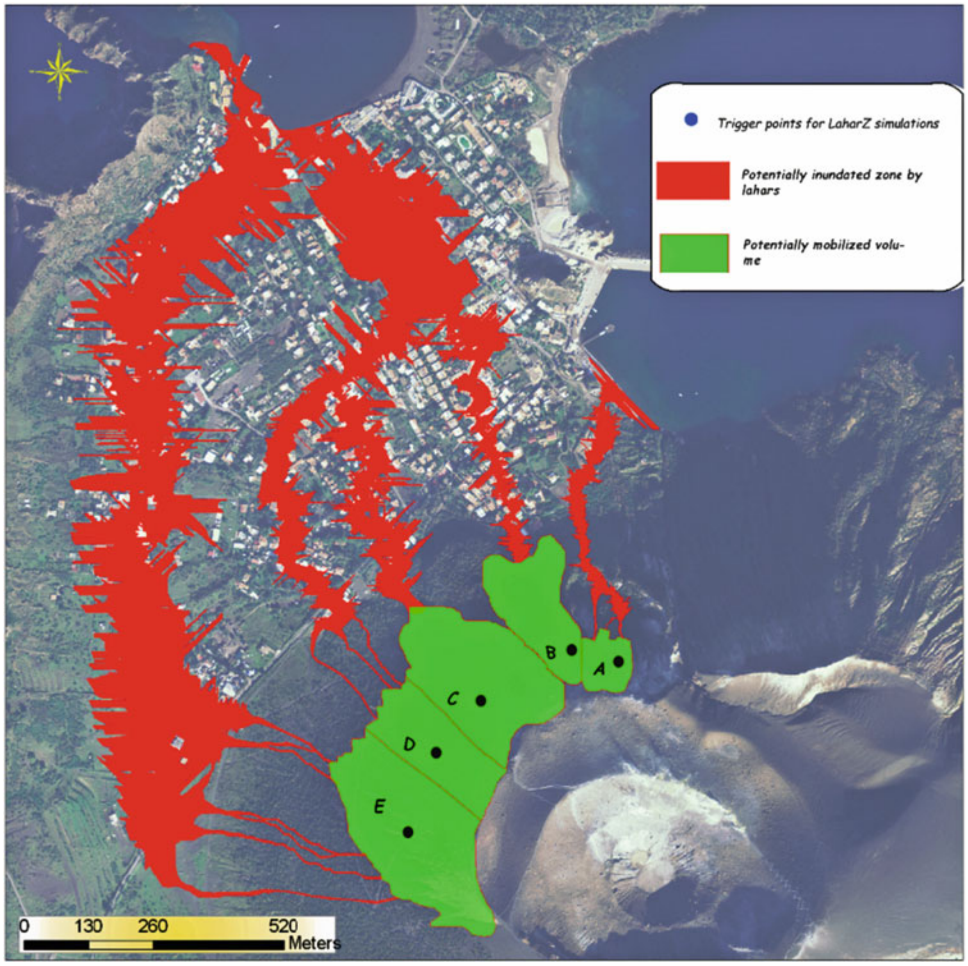

Fig. 5 Overall sketch of LAHARZ simulations including source areas, trigger points and inundated zones

Simulations of tephra dispersal were also carried out to identify volume and sources of lahars on the La Fossa cone. Using a 50 % probability of occurrence of tephra accumulation, the resulting assessment shows that the whole cone is unstable and represents a volume of 7.1 × 105 m^3 (Fig. 4).

Nevertheless, in terms of exposed area, the northern part of La Fossa cone is the most interesting to investigate due to the high density of residential buildings and the presence of critical infrastructural elements (e.g., main electrical power plant and port).

As regards the lahar hazard assessment, Vallance (2000) describes four conditions required for lahar generation: (1) an adequate water source, (2) abundant unconsolidated debris, (3) steep slopes and (4) a triggering mechanism.

Whereas conditions 2 and 3 are often fulfilled on volcanic edifices after an explosive eruption, condition 1 highly depends on atmospheric processes, which is closely related to the geographical situation and/or the season. Then, basing on an accumulation map of tephra deposition (as presented in Fig. 3), and on precise (2 m resolution) digital elevation model (DEM), analysis to define areas potentially inundated by lahars was carried out with the lahar-devoted software LAHARZ (Schilling 1998). Main hypothesis embodied into the model used by LAHARZ are: (1) a water saturation of the deposit, (2) a Mohr-Coulomb failure criterion to describe slope failure (Volentik et al. 2009; Iverson 2000; Pierson 1998).

According to the main objective of the ENSURE project, namely providing an integrated framework for the assessment of vulnerability of territories and communities, the attention of the analysis has been focused on the northern part of the island that is the most significant in terms of vulnerability, due to (1) the presence of some critical elements/targets (e.g. electrical power plant, harbour infrastructures of Porto di Levante), (2) the high building density and (3) the proximity of a group of buildings to the volcano, located at the foot of the volcanic cone along the line of a main valley.

Hence, starting from a selection of some likely trigger points that have been established based on topographic and land cover criteria within the identified lahar source area, and, according to some main drainage channels, the potential inundated zones by lahars including the above mentioned targets have been simulated using the model LAHARZ (Fig. 5).

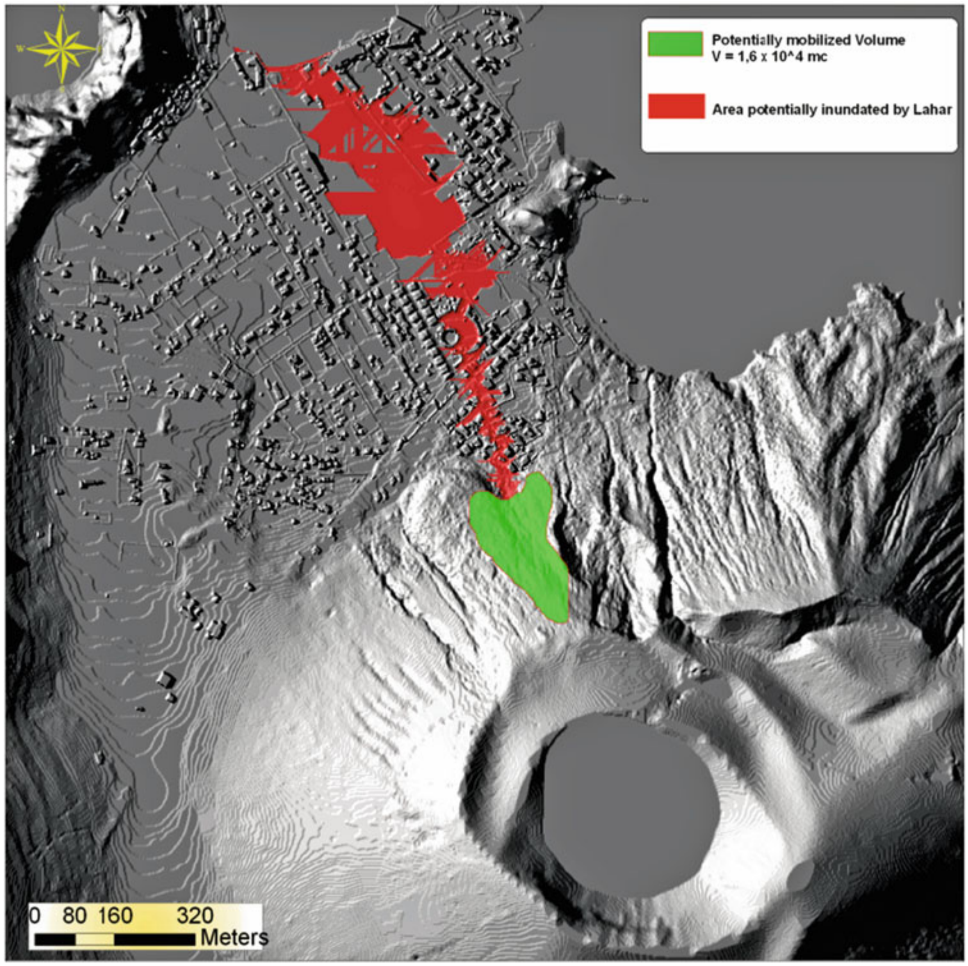

Fig. 6 Lahar path impacting the urban fabric at the toe of the cone (scenario "B")

The selected trigger points (A, B, C, D, E; Fig. 11) are closely and clearly linked to the main drainage channels (better defined starting from the central sector of the cone). Nevertheless, note that that the drainage networks in the upper part of the cone are characterized by secondary streams flowing into the main channels.

For this reason, the images provided as a result of LAHARZ elaboration have been later integrated with other (narrow) paths with the aim of showing the direct connection with the lahar source region. It is worth noting that lahars, as debris flows, might be multi-site phenomena with more than one trigger in the same span of time. Consequently, different flows can merge in the plain area if they are near to each other.

In terms of force of impact, the scenario "B" (Fig. 6) is expected to be the most severe due to the fact that lahar flow is supposed to have a high velocity determined by the narrow dimensions of the channel and to the sudden change of the gradient slope.

Vulnerability Analysis

Vulnerability of different areas and targets affected by tephra sedimentation and lahars has been analyzed with respect to physical and systemic aspects and to the capacity to prevent and/or mitigate risk. In detail, three sets of indicators have been applied, according to the matrices developed in the ENSURE Project. Set 1 refers to physical vulnerability and is necessary to identify the primary factors that make an urban area vulnerable to hazards. These factors refer on one hand to features of individual buildings (e.g., roofs, building typology, construction techniques) and on the other hand to features of urban fabric (e.g., morphology, compactness). Set 2 refers to systemic vulnerability and is mainly addressed to evaluate the capacity of critical equipment to continue functioning after some level of physical damage. Set 3 refers to mitigation capacities and is used to evaluate whether: (1) different components of risk (hazard and vulnerability of exposed elements and systems)

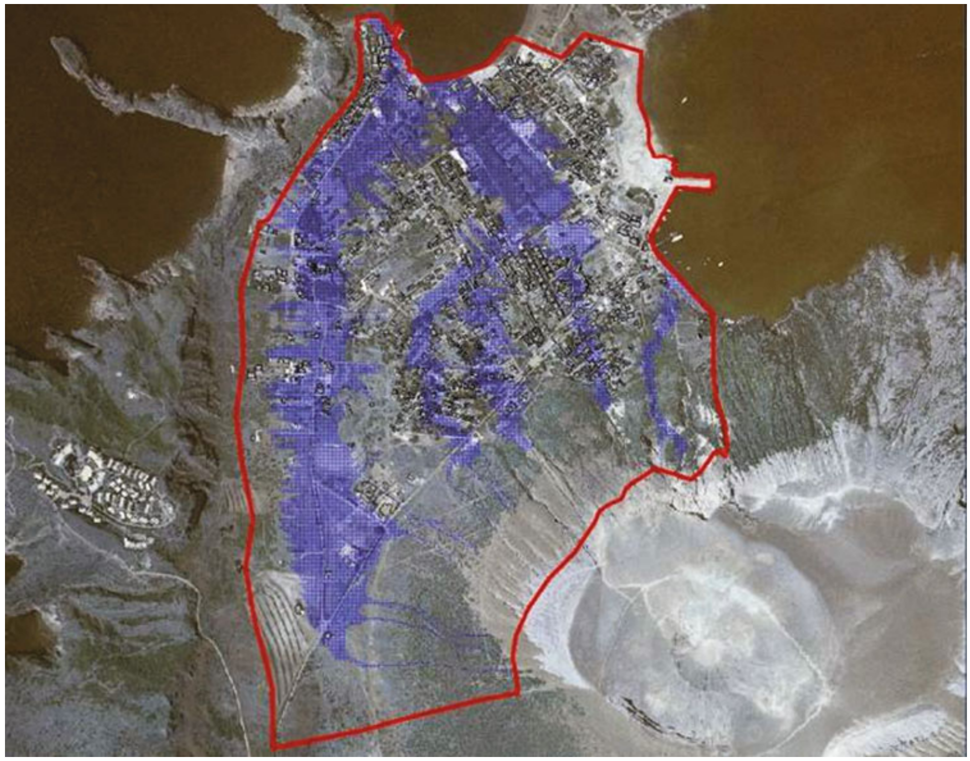

Fig. 7 Investigated area (in *red*) for the lahar hazard and vulnerability assessment, showing also the main inundation paths (in *blue*)

are currently known and assessed, (2) mitigation measures have been defined and/or implemented, and (3) different actors (individuals, communities, institutions) are adequately prepared for managing a hazardous event.

Physical vulnerability of the natural environment, built environment, critical infrastructures and social system associated with the lahar hazard has been assessed only in relation to the area north of the volcano (Fig. 7), which is the most populated area exposed to lahar inundation.

Physical vulnerability analyses have been developed within a GIS environment, which has been structured according to different types of spatial elements and units: the whole area of investigation, the urban fabrics, the census units, individual buildings and public facilities.

The assessment has been carried out with respect to different spatial elements and units (e.g. urban fabrics, census units) according to the peculiarities of each investigated system. It is worth noting that, in respect to all the considered systems, vulnerability levels do not represent absolute values but rather comparative ones. Thus, the obtained vulnerability levels provide a comparison among the exposed spatial elements, showing the ones that, in the context at stake, are more vulnerable than the others. Physical vulnerability analyses have been developed within a GIS environment, which has been structured according to different types of spatial elements and units: the whole area of investigation, the urban fabrics, the census units, individual buildings and public facilities.

Most of the work has been devoted to the assessment of physical vulnerability of the built environment to lahars. To this aim, vulnerability of individual buildings and of the different urban fabrics has been analyzed.

The main result can be identified in the map (Fig. 8) showing the different levels of vulnerability of the nine fabrics in which the investigation area has been articulated.

Systemic vulnerability to lahars has been assessed, focusing on the capacity of the main strategic equipment (e.g. the ports, the Medical centre, the heliport, the telecommunication centre the power plant) (Fig. 9) to continue functioning in case of a lahar event. To this aim, the potential loss of accessibility to such equipments due to the impact of lahars on the road network and the substitutability/transferability of the supply node (for example for the telecommunication tower and the power plant) have been taken into account.

The assessment of physical vulnerability related to tephra hazard has been carried out focusing both on the area south (Piano) and north (Porto) of the volcano, which are both exposed to tephra fall (e.g., Fig. 10). On the base of the parameters identified in the ENSURE WP4 matrix, the assessment was compiled with regard to different aspects, such as natural environment, built environment, and socio-economic, critical infrastructure.

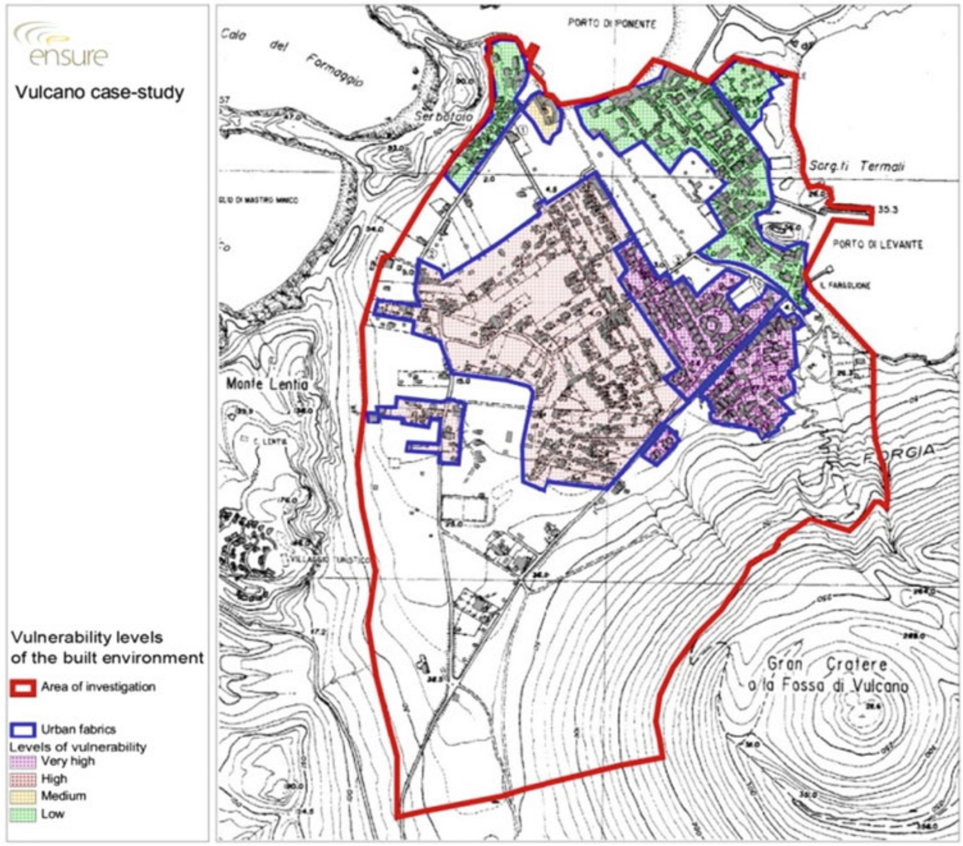

Fig. 8 Physical vulnerability of urban fabrics to lahars

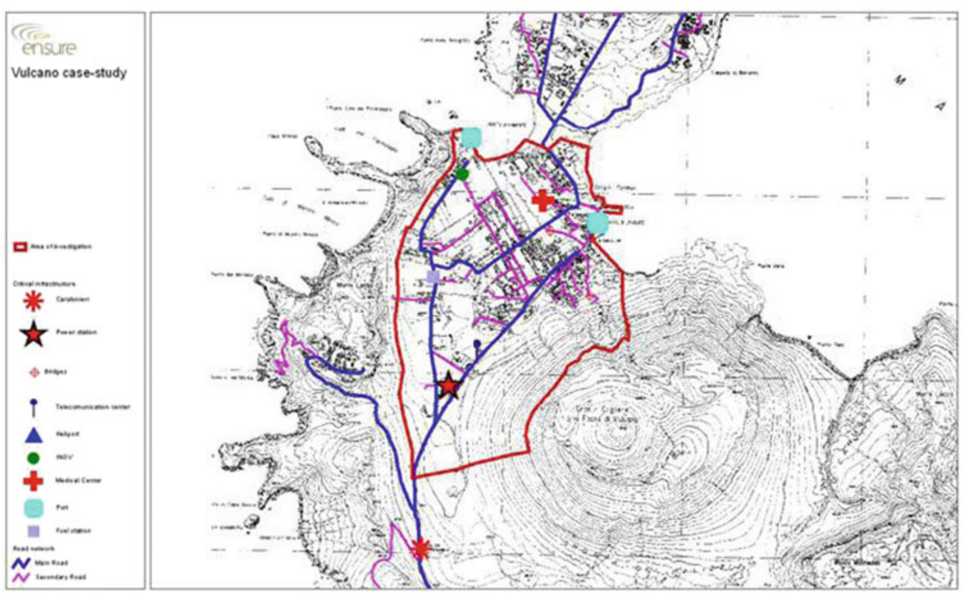

Fig. 9 Critical infrastructures in the investigation area

The latter has been assessed distinguishing between punctual infrastructures (e.g. the ports, the heliports, power plants, telecommunication centre, water tanks, etc.) and networks (electric and telephone lines).

Systemic vulnerability of the natural environment, built environment, critical infrastructures and social system associated with the tephra hazard has been assessed in relation to the whole island. The assessment of systemic vulnerability

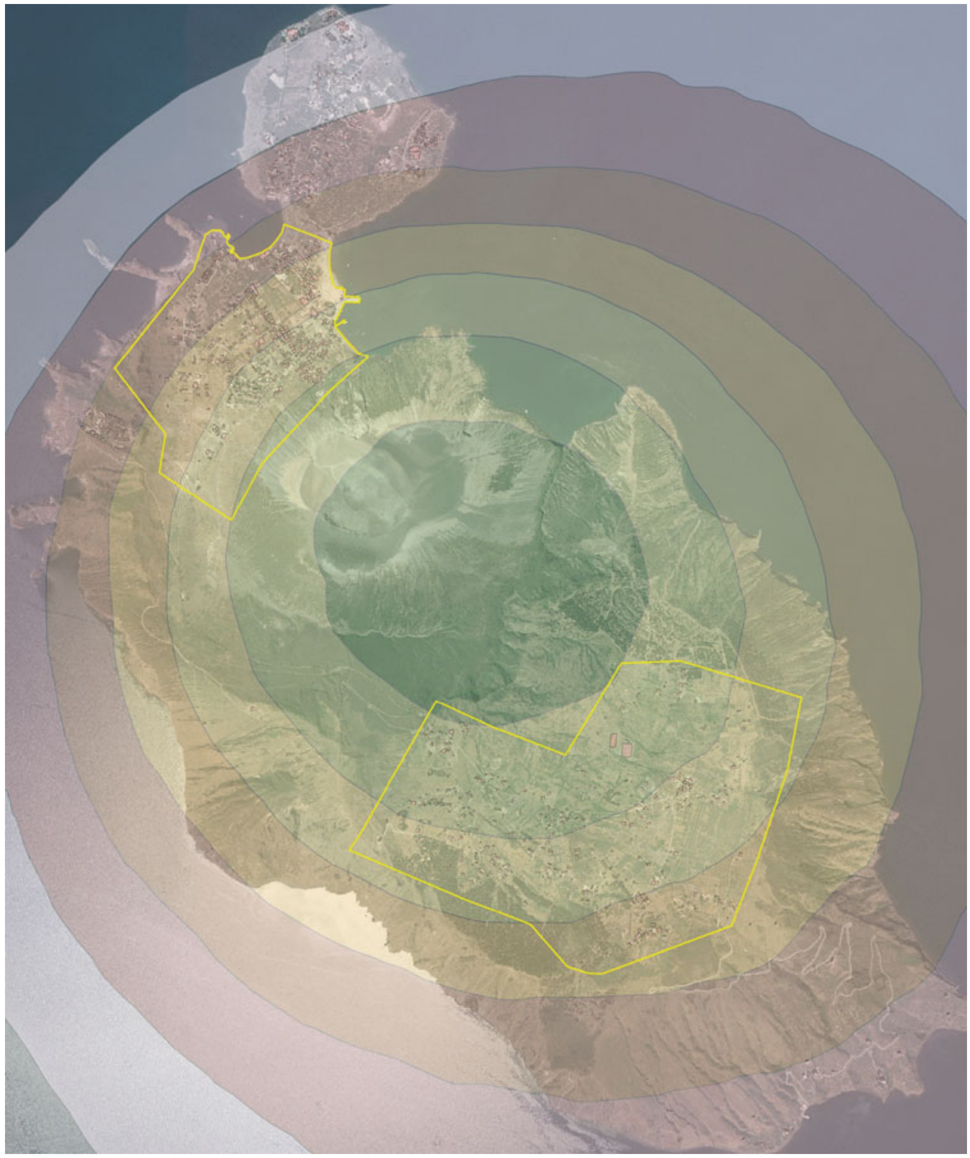

Fig. 10 Area investigated for the tephra hazard and vulnerability assessment (*yellow*) also showing the probability of reaching an accumulation of 300 kg/m^2

has been focused mainly on the impact of tephra on critical infrastructures, in particular in terms of accessibility (internal and external), redundancy and transferability of functions, such as ports and heliports (Fig. 11).

The third set of indicators, focused on mitigation capacities has allowed us to clearly highlight that knowledge and mitigation policies are still mainly focused on hazard. In fact, hazards are very well known and monitored, whereas exposure and vulnerability analyses are still lacking. Consequently, structural defence measures are generally favoured with respect to the non-structural ones.

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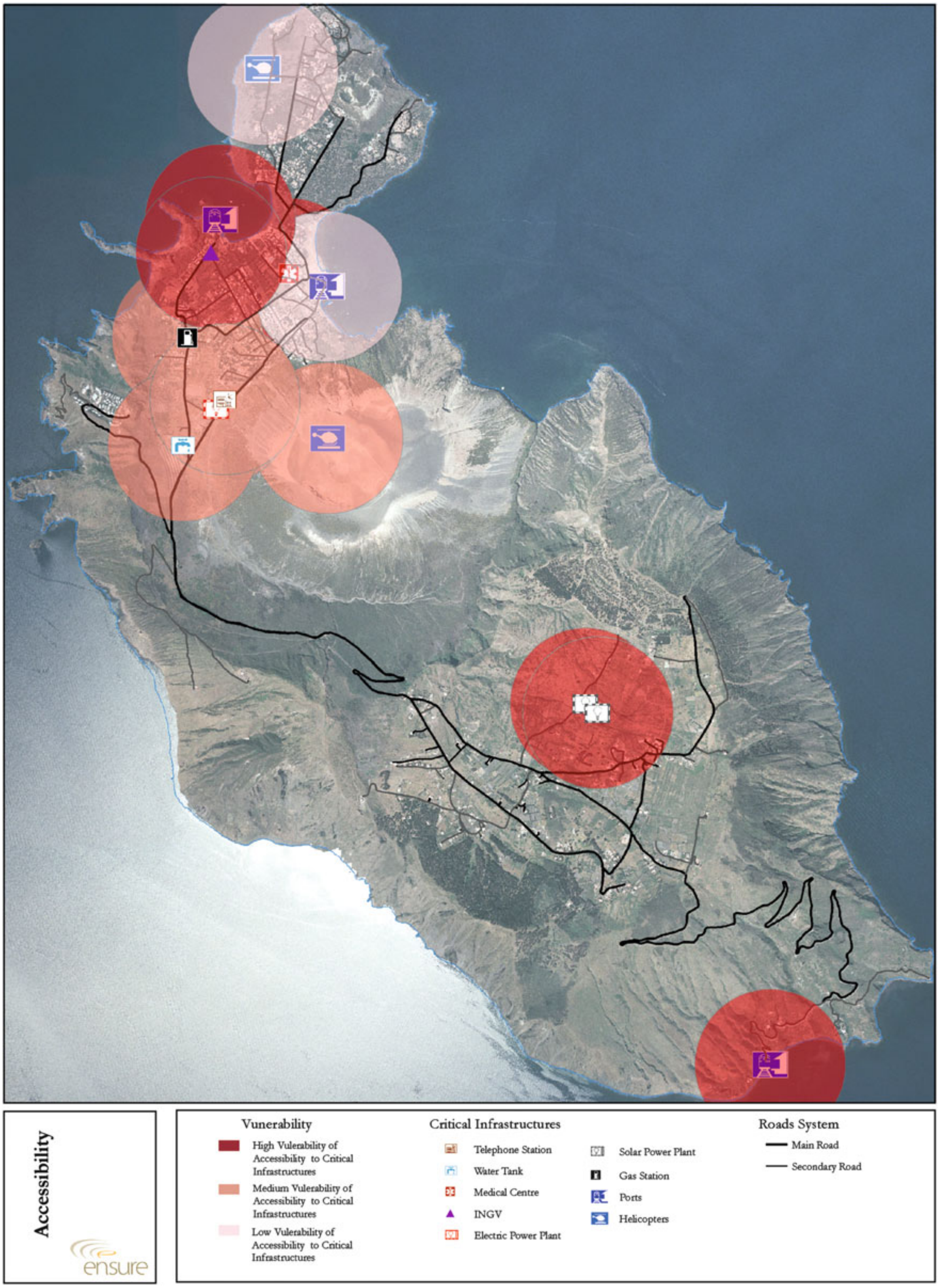

Fig. 11 Systemic vulnerability in terms of accessibility to critical infrastructures

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THE SECOND WORLD LANDSLIDE FORUM

Geomorphologic Evidences of Flank Instabilities in the Eastern Sector of the Tejeda Volcano (Canary Islands, Spain) During the Quaternary

Jorge Yepes Temiño, Martín Jesús Rodríguez-Peces, Nieves Sánchez, Inés Galindo, and Rodrigo del Potro

Abstract

This paper provides both geological and geomorphologic observations that support the existence of flank instabilities in the eastern sector of the Tejeda Volcano (Gran Canaria) during the Quaternary. The observations are focused on the analysis of the drainage system, scarps, erosion surfaces, residual reliefs, field of volcanoes and lithological correlation between the surface geology and data derived from wells and boreholes. We have identified a wide paleo-valley developed in Miocene volcanic materials, which could be related to a large rock slide, as well as a subsequent secondary scarp of Pliocene age developed at the distal area of the slide mass. These observations confirm the occurrence of large insular flank collapses of the Tejeda Volcano during the Miocene to Pliocene. These flank instabilities suggest a NE-SW extensional regime, which could be related to a NW-SE fault zone that divides Gran Canaria Island into two sectors.

Keywords

Canary Islands • Flank collapse • Gran Canaria • Pliocene • Quaternary • Rock slide • Volcanic rock

Introduction

The occurrence of large flank collapses has largely influenced the morphological evolution of volcanic islands and, particularly, the Canary Islands. In fact, a large number of flank instabilities have been described, mainly in the western islands of the archipelago (Tenerife, La Palma and El Hierro) which show the clearest evidence of recent landslide activity (Holcomb and Searle 1991; Teide Group 1997; Carracedo et al. 1999; Masson et al. 2002; Urgeles et al. 2001). Other works have been performed in the eastern islands (Gran Canaria, Lanzarote and Fuerteventura) and in the complete Canary archipelago (Carracedo 1996; Funck and Schmincke 1998; Krastel et al. 2001; Acosta et al. 2003; Lomoschitz et al. 2005). The discovery and identification of deposits of such great slides was based on the interpretation of geomorphologic features derived from bathymetry and seismic reflection data of the marine bottoms. The deposits have been identified as debris avalanches which can cover wide areas of the sea floor (200–2,600 km^2), with estimated

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volumes between 25 and 650 km^3 with more than a hundred of kilometres spanned from the island flank. The risk related to such events is very significant, but the recurrence intervals seem to be very long and, hence, the hazard is considered as extremely low.

The flank collapse deposits have been traditionally linked to the large coastal scarps located at the sub-aerial flank of the islands. However, the efforts to integrate land and marine data have been limited, since sub-aerial erosion attenuates the morphology of the scarps and marine dynamics mask the collapsed deposits with turbidites. In addition, the sub-aerial morphological features observed are difficult to explain following the suggested mechanisms of movement. This fact has been solved inaccurately assuming that the sub-aerial remnants of the mobilized rock masses are totally absent.

Gran Canaria is a volcanic island dating back more than 14.5 Ma developed during four main volcanic stages (Balcells et al. 1992; Ancochea et al. 2004; Guillou et al. 2004). There is evidence of a number of superposed volcanic edifices, developed in the initial two stages: a shield volcano with caldera collapse (Cycle I) of Miocene age (14.5–7.3 Ma) and a stratovolcano (Roque Nublo Cycle) of Pliocene age (5.6–2.9 Ma). The Plio-Quaternary activity of the last two stages is mainly related to fissure eruptions (Post-Roque Nublo Cycle), and small monogenetic edifices and their basaltic lavas (Recent Cycle), which partially cover the previous relief. Several intensive erosive stages have been developed between the main volcanic cycles. The most significant flank collapses and large rock slides of Gran Canaria have been triggered in relation to these periods of erosion, in particular, at the final phases of the Miocene shield volcano (~ 9 Ma) and the end of Roque Nublo Cycle (3.5–2.9 Ma) (Funck and Schmincke 1998; Mehl and Schmincke 1999; Yepes et al. 2011).

This paper provides geological and geomorphologic observations that support the existence of flank instabilities in the eastern sector of Gran Canaria, in a triangular area of about 160 km^2, which could be defined between the Jinámar, Arinaga and Cazadores villages (Fig. 1).

The geomorphological observations are focused on the analysis of the drainage system, scarps, erosion surfaces, residual reliefs and field of volcanoes. The geologic evidence is derived from the lithological relationships between the surface geology and 54 lithological columns that reach depths between 30 and 700 m (Fig. 4 and Table 1). The surface data were derived from geological maps (Balcells and Barrera 1987; Balcells et al. 1989, 1992), whereas the underground data were obtained from the wells and boreholes reported in Galindo et al. (2006). This latter report was developed under the agreement made

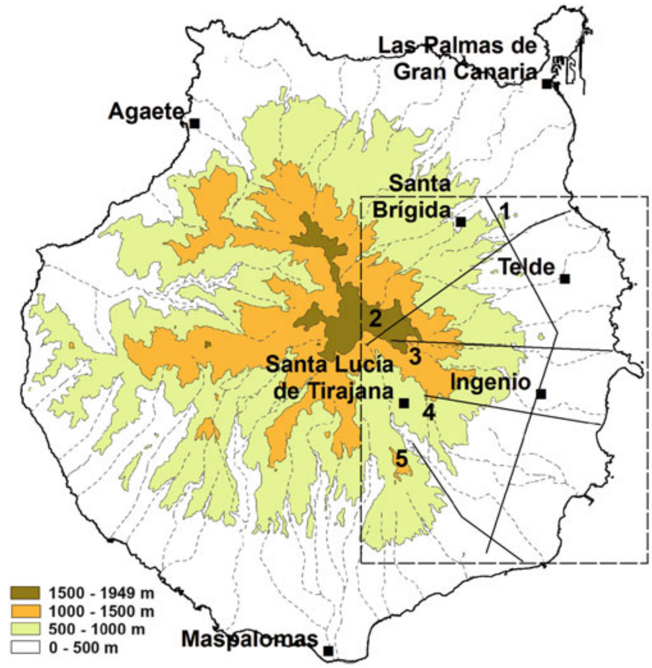

Fig. 1 Topographic map showing the location of the eastern sector of Gran Canaria (Canary Islands, Spain). The *dashed black square* shows the area of Fig. 2

between the Instituto Geológico y Minero de España (IGME) and the Cabildo Insular de Aguas de Gran Canaria for the implementation of a hydrogeological study of the eastern sector of Gran Canaria Island. The descriptions of the lithological columns (Table 1) were obtained from the database of boreholes developed by the IGME during different research projects (cf. Montero Caballero 2010).

Geomorphological Observations

The drainage system is hierarchical in the study area. The centrifugal character observed in the adjacent erosion surface (S_0) has disappeared. The channels have lost their original parallelism and have converged into the main stream (Telde Ravine) by both margins, defining very pronounced curved paths (Fig. 2). The secondary streams have developed deep and narrow incisions in the rocky substratum, whereas the main stream has excavated a wide valley that is partially filled by deposits of recent slope instability, the Tenteniguada debris avalanche (Lomoschitz et al. 2008), and intra-canyon lavas of the Post-Roque Nublo Cycle. The efficient erosional discharge that has undergone at the head of the Telde Ravine has been attenuated by the Tenteniguada debris avalanche deposits and the lava flows that cover it superficially.

Table 1 Wells and boreholes data of the eastern sector of Gran Canaria Canaria (cf. Galindo et al. 2006)

							Thickness of main lithologies (m)						
Cross section	Reference number	IGME Borehole	X (UTM)	Y (UTM)	Z (m)	P (m)	SH	CR	CPRN	FDLP	CRN	C1-FS	C1-FB
1	1	424230035	452083	3102609	360	118	–	–	–	–	118	–	–
	2	424230038	453509	3102106	405	70	–	–	–	–	20	50	–
	3	424230036	453024	3100788	456	108	–	40	30	–	–	38	–
	4	424230048	454757	3099846	270	68	–	–	–	–	–	68	–
	5	424230039	454477	3099018	362	159	–	–	–	–	159	–	–
	6	424230016	454869	3098696	298	148	–	–	51	–	97	–	–
	7	424270082	456517	3095496	240	125	–	–	125	–	–	–	–
	8	424270077	456847	3095017	267	272	–	–	136	–	136	–	–
	9	424270061	457398	3095305	209	191	–	–	81	–	110	–	–
	10	424330145	456434	3087880	307	283	–	–	150	–	133	–	–
	11	424330146	456715	3086939	246	313	–	–	90	–	–	–	223
	12	424330098	455786	3086334	278	304	–	–	304	–	–	–	–
	13	424330002	455397	3085489	174	282	28	–	254	–	–	–	–
	14	424330009	455445	3084740	161	222	–	–	–	–	–	–	222
	15	424330027	455810	3083583	105	164	–	–	–	–	–	–	164
	16	424330028	454696	3083403	127	152	–	–	–	–	–	–	152
	17	424330052	455025	3081132	127	155	–	–	–	–	–	–	155
	18	424330060	453905	3080239	149	187	154	–	–	–		4	29
	19	424330068	453809	3079910	115	82	45	–	–	–	–	37	–
2	20	424260070	444185	3091985	1,150	73	–	–	–	–	73	–	–
	21	424260103	446240	3093615	1,671	696	–	–	–	–	696		–
	22	424260006	448008	3094543	1,028	264	–	–	–	–	194	70	–
	23	424260028	448427	3095287	867	168	20	–	–	–	148	–	–
	24	424260105	448427	3095964	819	158	8	–	–	–	150	–	–
	25	424260117	449410	3096305	713	136	–	–	30	–	106	–	–
	26	424230041	451104	3097764	615	196	–	–	–	–	196	–	–
	27	424230037	451590	3097626	547	144	–	–	–	–	87	57*	–
	28	424230020	453699	3098483	344	152	–	–	–	–	152	–	–
	5	424230039	454477	3099018	362	159	–	–	–	–	159	–	–
	4	424230048	454757	3099846	270	69	–	–	–	–	–	69	–
	31	424230031	455635	3100059	214	31	–	–	31	–	–	–	–
	32	424230022	456312	3100299	186	158	–	–	–	–	158	–	–
	33	424230043	457588	3101150	111	48	–	–	–	22	26	–	–
3	34	424260001	447122	3092109	1,469	180	–	–	60	–	120	–	–
	35	424270075	450730	3092103	1,037	381	–	–	308	–	73	–	–
	36	424270047	452553	3091708	856	382	–	–	352	–	30	–	–
	37	424270057	453926	3091846	611	317	–	–	296	–	27	–	–
	38	424270078	455052	3091474	455	313	–	–	294	–	19	–	–
	39	424270015	456305	3091851	436	283	–	–	283	–	–	–	–
	40	424280017	460553	3091648	74	95	15	–	80	–	–	–	–
4	41	424330168	451432	3087003	535	110	–	–	55	–	–	20	35
	42	424330164	452888	3086950	453	187	–	–	–	–	–	–	187
	43	424330105	454431	3086566	316	264	–	–	–	–	–	–	264
	44	424330160	455042	3086698	310	302	–	–	200	–	–	102	–
	45	424330098	455534	3087207	330	304	–	–	304	–	–	–	–
	12	424330104	455786	3086334	278	385	–	–	220	–	–	165	–
	11	424330146	456715	3086939	246	313	–	–	90	–	–	–	223
	48	424340010	459135	3085517	54	62	–	–	–	62	–	–	–

(*continued*)

Table 1 (continued)

							Thickness of main lithologies (m)						
Cross section	Reference number	IGME Borehole	X (UTM)	Y (UTM)	Z (m)	P (m)	SH	CR	CPRN	FDLP	CRN	C1-FS	C1-FB
5	49	424320048	448412	3083785	363	112	10	0	0	0	0	0	102
	50	424320010	448538	3083408	368	167	0	0	0	0	0	0	167
	51	424320004	449916	3081227	235	273	10	0	0	0	50	110	103
	52	424320005	450180	3081269	228	260	15	0	0	0	55	80	110
	53	424320002	450252	3079627	234	300	0	0	0	0	0	300	0
	54	424320003	450527	3079369	192	253	12	0	0	0	0	241	0

C1-FB Cycle I. Basaltic Formation, *C1-FS* Cycle I. Salic Formation (Phonolitic and Rhyolitic-Trachytic formations), *CPRN* Post-Roque Nublo Cycle, *CR* Recent Cycle, *CRN* Roque Nublo Cycle, *FDLP* Las Palmas Detritic Formation, *SH* Holocene sediments, *P* depth of borehole, *Z* height of the top of the borehole above sea level

The erosion surfaces are presented in a number of steps, fitting into the previous surfaces. The remains of the main surface of the island at the end of Cycle I (S_0) are difficult to notice. The remnants of the surface which defines the top of the Roque Nublo Cycle (S_2) mark the narrow watersheds of the secondary channels. Only the structural surface that defines the lava flows of the Post-Roque Nublo Cycle (S_4) has a significant development. All the geomorphological observations suggest the existence of prolonged erosion in the study area (Fig. 3), which has underwent a number of pulses and that would have resulted in the recent relief with few inherited elements. The fields of volcanoes located along the collapsed flank, comprising about ten cinder cones of the Recent Cycle (e.g. Montaña Las Palmas, Las Huesas, Las Piletillas, El Gamonal, El Draguillo, El Toscal, La Pasadilla), suggests the existence of lithostatic unloading related to the traction that occurs in a landslide scarp (Fig. 4).

Geological Investigations

Lithological cross sections (Fig. 5) show the existence of a wide flat-bottomed paleo-valley that extends with an E-W trend. At present, this relief (S_3) has been filled by lava flows of the Post-Roque Nublo Cycle, exceeding 300 m in thickness at several points. This channel is clearly visible in the transverse cross section between the towns of Telde and Ingenio (Fig. 5). The age of the paleo-relief is implied by a structural surface (S_2) which is defined by the deposits of the Roque Nublo Cycle of Pliocene age.

A sharp change of thickness between the volcanic materials of the Cycle I (Phonolitic Formation) and Roque Nublo Cycle has been found below the paleo-relief described previously. This topographical discontinuity (S_1) suggests the existence of a wider channel, which is older than the one described but located in the same place.

These observations confirm the occurrence of at least two great translational rock slides of Miocene to Pliocene age.

Discussion and Conclusions

Four specific observations indicate that much of the erosion could be attributed to a sequence of fractures. By means of these weak zones, the drainage system would be embedded and at least two great translational rock slides would have been triggered during the Quaternary. The observations are the followings: (1) the superposition of two paleo-relief features elongated in the same trend; (2) the efficient erosional discharge that has undergone at the head of the Telde Ravine, that has been attenuated by the Tenteniguada debris-avalanche deposits and the intra-canyon lava flows that cover it superficially; (3) the arched trace that defines the secondary drainage system; and (4) the existence of a small field of volcanoes along the collapsed flank comprising about ten cinder cones.

The inferred slope instabilities have affected the eastern flank of the Tejeda Volcano, since the edge of the caldera is only recognized in some of the longitudinal cross sections. These large flank instabilities found in the eastern sector of the Gran Canaria Island would be an expression of a decoupling of the Gran Canaria into two parts due to a central NW-SE fault zone, which would have worked with a NE-SW extensional regime.

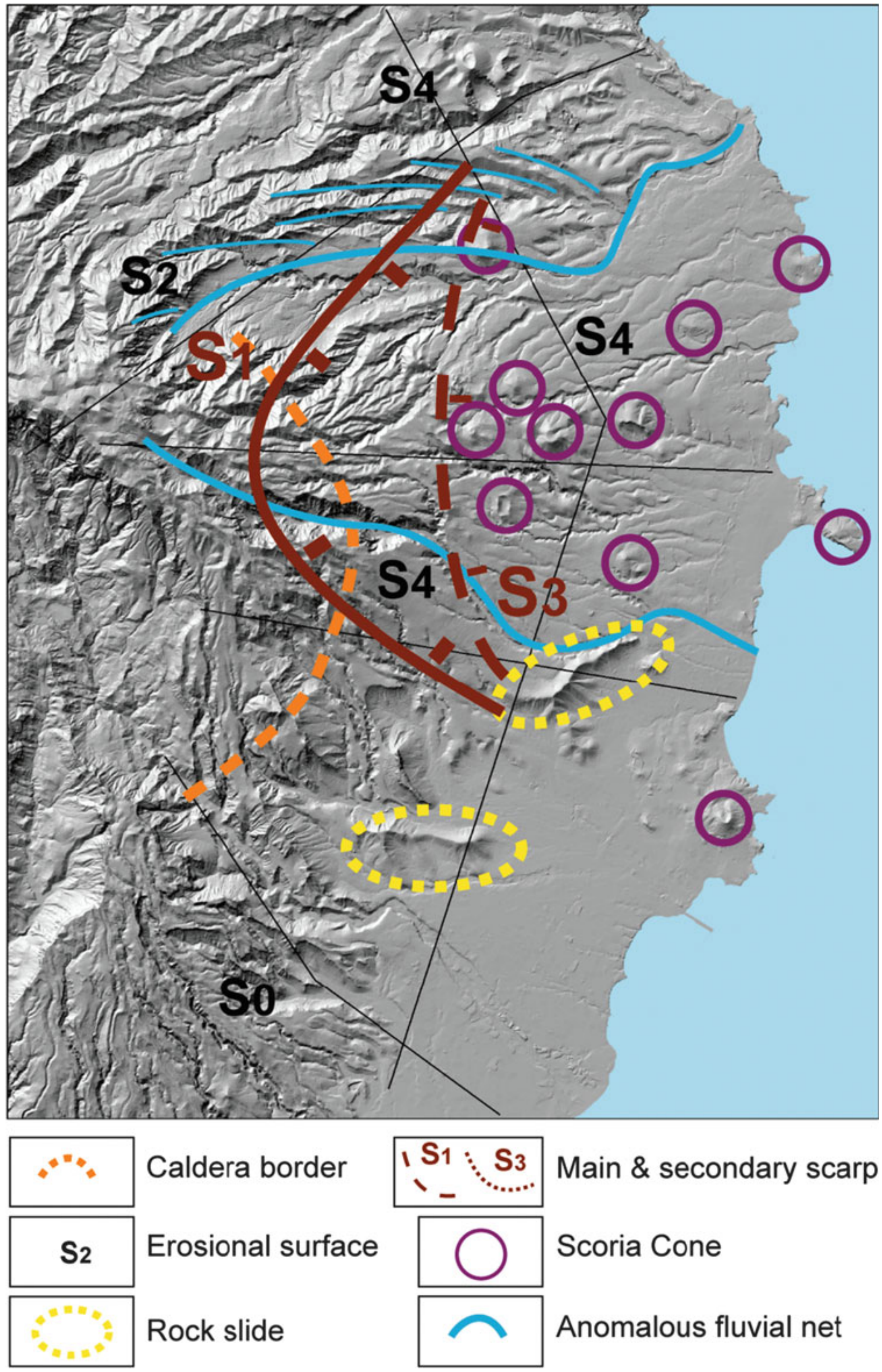

Fig. 2 Shaded relief image showing the main geomorphological features observed at the eastern sector of the Gran Canaria (see text for more details)

Fig. 3 Panoramic view of the eastern sector of Gran Canaria showing the erosional surfaces (S_0 and S_4) and the location of the cinder cones and caldera limit. The photo has been taken from the west in the Telde village

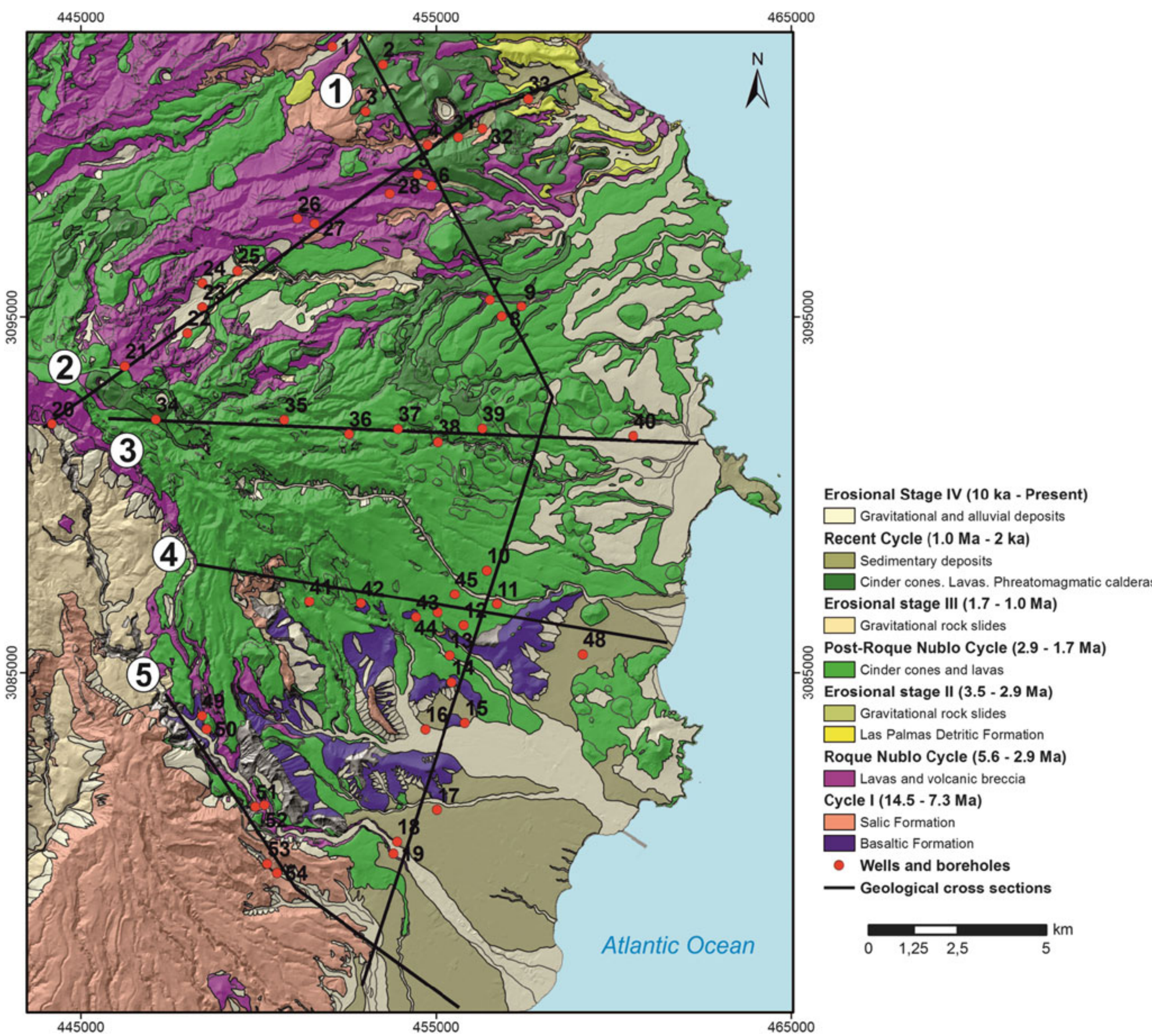

Fig. 4 Map of the superficial geology of the eastern sector of Gran Canaria showing the main volcanic and erosional stages. The location of the five lithological cross sections (*black lines*) and the 54 wells and boreholes (*red dots*) are also depicted

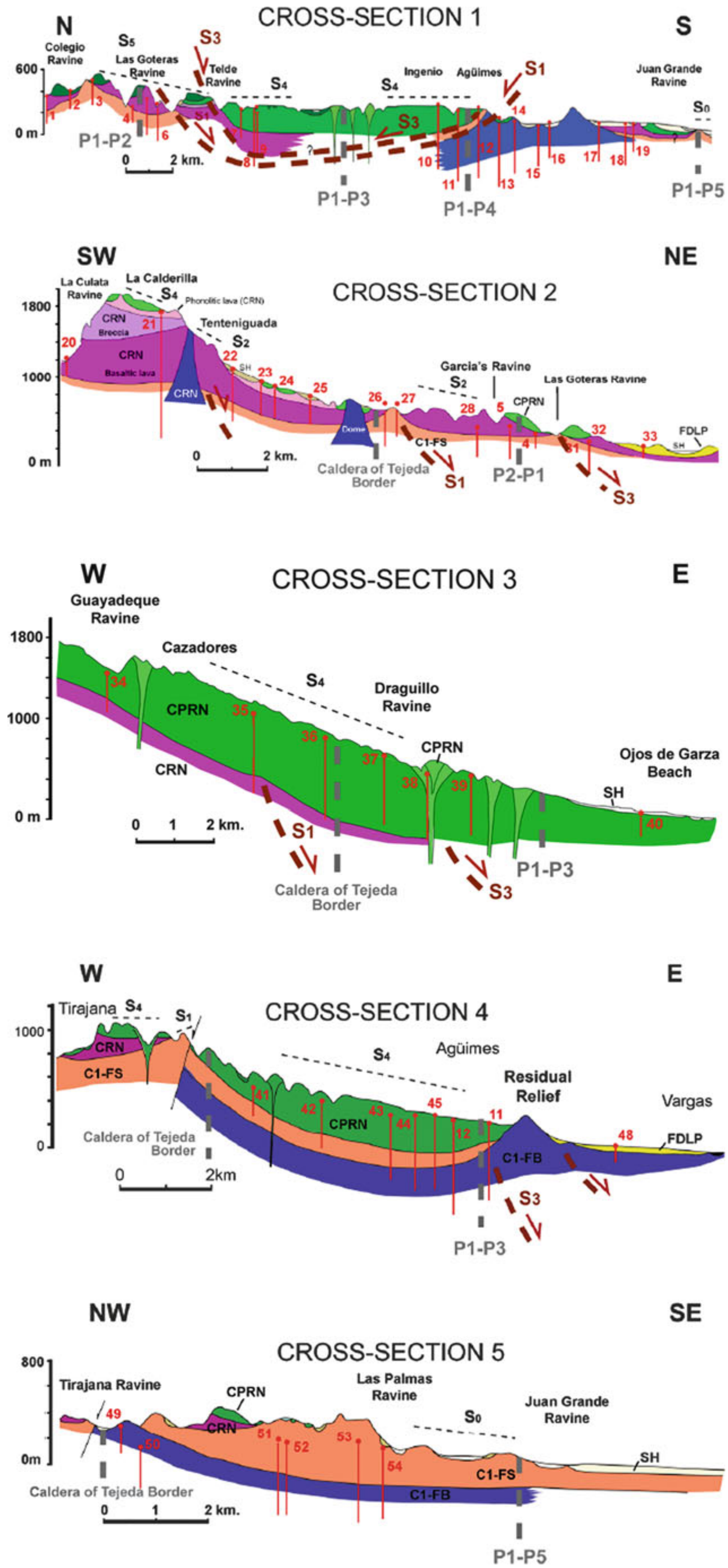

Fig. 5 Transversal (1) and longitudinal (2–5) cross sections derived from the wells and boreholes data (*red lines*). See Fig. 3 for localization

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Geomorphologic Evidences of Great Flank Collapses in the Northwest of Gran Canaria (Canary Islands, Spain)

THE SECOND WORLD LANDSLIDE FORUM

Jorge Yepes Temiño, Nieves Sánchez, Martín Jesús Rodríguez-Peces, Inés Galindo, and Rodrigo del Potro

Abstract

This work provides geological observations that support the existence of several large rock slides in the northwest sector of the Gran Canaria Island, which are now covered by recent lavas. Some erosional forms has been identified: a paleo-relief developed in Pliocene volcanic materials which could be related to a large rock slide, a number of streams with strong incision and sharp diversions which are related to the flanks of the fractured rock mass, a clear topographical unconformity between the oldest erosion surfaces, as well as a prior secondary scarp near de coastal border. Moreover, we have identified some aggradational morphologies: a debris avalanche deposit covering the offshore area of the island, several scoria cones which are developed following the main scarp of the rock slide and a field of volcanoes which covers the foot of the slide in the onshore part of the island. These observations confirm the existence of some large rock slides that affect successively the NW flank of Gran Canaria during the Miocene to Pliocene. These flank instabilities suggest a NE-SW extensional regime, which could be related to a NW-SE fault zone that divides the island into two sectors. This hypothesis is in agreement with the spreading process which has been proposed for other volcanic islands.

Keywords

Canary Islands • Flank collapse • Gran Canaria • Pliocene • Quaternary • Rock slide • Volcanic rock

Introduction

Gran Canaria is a circular volcanic island dating back more than 14.5 Ma, but eruptions have continued until very recent time. The geological evolution of the Gran Canaria comprises four main volcanic stages, alternating with periods of erosion (Balcells et al. 1992; Carracedo et al. 2002; Ancochea et al. 2004; Guillou et al. 2004; Pérez Torrado 2008; Schmincke and Sumita 2010). The first volcanic stage of the island was built during the Miocene (14.5–7.3 Ma) by a shield volcano of basic composition, which developed later a kilometric caldera collapse in the central part of the island. Two generations of superimposed stratovolcanoes were developed inside the caldera: Tejeda and Roque Nublo volcanoes. The Tejeda Volcano was related to the Miocene activity (Cycle I), but had a salic composition (rhyolitic to trachyphonolitic).

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The Roque Nublo Volcano was developed during the Pliocene (5.6–2.9 Ma) forming the basic to salic deposits of the Roque Nublo Cycle. The Plio-Quaternary activity of the last two stages is mainly related to fissure eruptions of basaltic composition (Post-Roque Nublo and Recent Cycles). This last activity developed a number of fields of cinder cones and their lavas, which have been related to a NW-SE rifting.

Several intensive erosive stages have been developed between the main volcanic cycles. The most significant flank collapses and large rock slides of Gran Canaria have been triggered in relation to these periods of erosion, in particular, at the final phases of the Miocene shield volcano (~ 9 Ma) and the end of Roque Nublo Cycle (3.5–2.9 Ma) (Funck and Schmincke 1998; Mehl and Schmincke 1999; Yepes et al. 2011). The oldest evidence of flank instability has been related to breccias levels which are found in discordant contact between the lavas of the Miocene shield volcano, located in the southwestern sector of the island (Schmincke 1993; Schmincke and Sumita 2010). Other evidence of this phenomenon would be the coastal morphology in arc extending between La Aldea and Agaete villages, in the western sector of the island (Coello and Coello 1999). This coast defines a deep coastal cliff that has some collapsed rock masses on his foot (Criado et al. 1998) and seems to involve the volcanic materials that define the western border of the Tejeda caldera (Yepes et al. 2011). Our research has been also motivated by the anomalous distribution of lithologies of the different volcanic cycles in the field, in particular the location of the deposits of the Roque Nublo Cycle in the southern and northern sectors of the island. These observations have been considered as evidence of two large flank collapses: one that took place in the Roque Nublo stratovolcano at the end of the Roque Nublo Cycle (García Cacho et al. 1994; Pérez Torrado et al. 1995), and another that would have occurred in the northeastern sector of the island (Hansen 2009). Finally, additional evidences of flank instabilities have been described in the offshore sector of the island. The anomalous topography found in this sector has been interpreted as submarine deposits of debris avalanches and debris flows, which can cover wide areas of the sea floor, related to large flank collapses (Funck and Schmincke 1998; Krastel et al. 2001; Acosta et al. 2003).

This paper provides geological and geomorphologic observations that support the existence of flank instabilities in the northwest sector of the Gran Canaria, in a circular sector of about 175 km^2, which could be defined between the Agaete, Arucas and Cruz de Tejeda villages (Fig. 1).

The geomorphological observations are focused on the analysis of the drainage system, scarps, erosion surfaces, residual reliefs, cinder cones and offshore debris avalanche deposits. The geologic evidence is derived from the lithological relationships between the surface geology and 71 lithological columns that reach depths between 20 and 460 m (Fig. 4, Table 1). The surface data were derived from geological maps (Balcells et al. 1986; Barrera and Gómez 1986; Balcells and Barrera 1987a, b; Balcells et al. 1992), whereas the underground data were obtained from the wells and boreholes reported in Galindo et al. (2011). The descriptions of the lithological columns (Table 1) were obtained from the database of boreholes developed by the Geological Survey of Spain (Instituto Geológico y Minero de España, IGME) during different research projects.

Geomorphological Observations

The drainage system is centrifugal and it is modified by sharp river diversions with a NW-SE trend. These diversions seem to be related to the main NW-SE trend of the feeding dykes of the Post-Roque Nublo Cycle, conditioning the differential erosion of the substrate. These small anomalies in the drainage system would be a morphological expression of the NW-SE extension that would have undergone on Gran Canaria during the Post-Roque Nublo Cycle. The streams with the steepest slopes are located on the lateral edges of the study area (Agaete and Guía). At least one embedded stream that describes very sharp changes in its path can be recognized in both margins. The Berrazales (or Agaete) Ravine would be the most typical case in the western sector, and the San Andrés and Moya ravines in the eastern sector. These streams increase sharply their relative divergence close to the populations of Fontanales and Fagagesto, defining a wide circular sector of the island with a relief organization which is uncorrelated laterally with the geomorphology observed in the surrounding areas. These observations suggest that these streams with a variable path have been fitted in favour of very penetrative planes of weakness in the rock mass. These planes could be related to the lateral flanks of a large rock slide. This phenomenon is also observed at a small scale in the area between Agaete and Gáldar, coinciding with a morphostructural scarp (S_5). In addition, at the base of this scarp, a number of rock slide deposits have been recognized (Fig. 2).

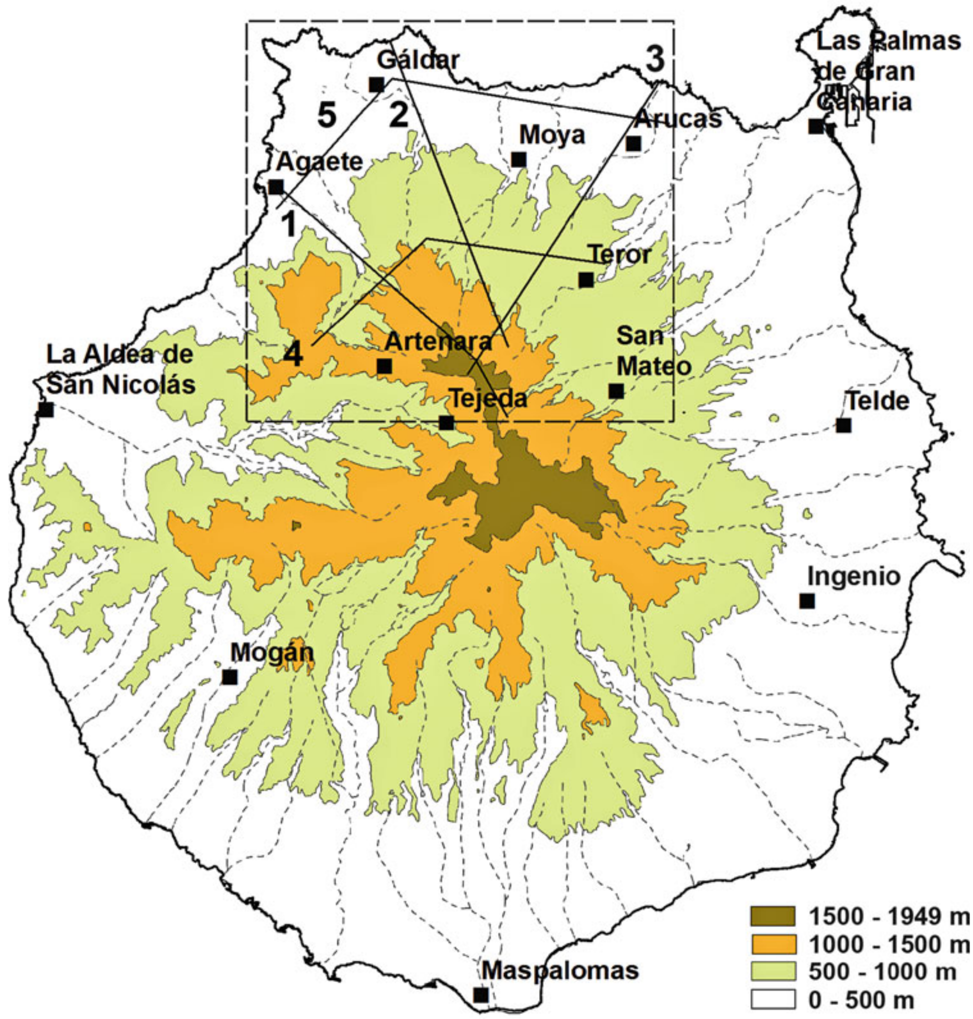

Fig. 1 Topographic map showing the location of the northwest sector of the Gran Canaria (Canary Islands, Spain). The *dashed black square* shows the area of Fig. 3.

In the coastal zone, most of the ravines are interrupted or deviated by a wide flat-bottomed valley with a NW-SE trend and a few isolated cinder cones (Gáldar, Gallinero and Montaña Clavijo) of the Recent Cycle (Fig. 3). The peripheral location of this small volcanic field could be in agreement with lithostatic unloading related to the foot area of a slipped mass. These observations suggest that the occurrence of the flank instabilities in Gran Canaria could be extended during the Post-Roque Nublo Cycle. In addition, the head area is disconnected from the summit of the island by a number of cinder cones of the Recent Cycle (e.g. Pinos de Gáldar, Juncalillo and Montañón Negro). This observation suggests the existence of a lateral spreading due to the intrusion of dykes during the Post-Nublo Roque and Recent cycles, a process that has already been described in other volcanic islands (McGuire et al. 1990; Elsworth and Voight 1995; Voight and Elsworth 1997; Day et al. 1999; Galindo 2005; Cecchi et al. 2005; Del Potro and Hürlimann 2007). The process of intrusion of dykes took place until the end of the Cycle I, a period in which the orientation of the stress field related to volcanism changed: from a radial pattern change to a NW-SE fissural regime (Yepes et al. 2011). In addition, the lateral spreading would be amplified by the age of the island, as it would provide a longer period to increase the weight of the volcano and, subsequently, to produce an unstable condition as other authors has been proposed in similar volcanic areas (Lo Giudice and Rasa 1992; Clague and Denlinger 1994; Van Wyk de Vries and Francis 1997; Borgia et al. 2000; Reid et al. 2001).

The relief inflections allow distinguishing remnants of four different erosional surfaces (S_0, S_2, S_4 and S_6) (Figs. 2 and 3). The older structural surface (S_0), defined by the lava flows of the Phonolitic Formation (Cycle I), can be related to a surface of summits where the lava flows of the subsequent volcanic

Table 1 Wells and boreholes data of the NW sector of Gran Canaria Canaria (cf. Galindo et al. 2011)

							Thickness of main lithologies (m)							
Cross section	Reference number	IGME Borehole	X (UTM)	Y (UTM)	Z (m)	P (m)	SH	CR	CPRN	FDLP	CRN	C1-FF	C1-FRT	C1-FB
1	1	0639 TP	432368	3107372	113	105	–	–	–	–	–	–	–	105
	2	0640 TP	433290	3106562	177	72	–	–	–	–	–	–	–	72
	3	1625 TP	434575	3105432	261	120	–	116	–	–	–	–	–	4
	4	3425 TP	436979	3103318	1,021	300	–	–	220	–	80	–	–	–
	5	2411 TP	437112	3103202	1,076	464	–	–	304	–	160	–	–	–
	6	1487 TP	437247	3103082	1,068	251	–	–	236	–	–	–	–	–
	7	1492 BTP	437504	3102856	1,090	236	–	–	236	–	–	–	–	–
	8	1430 TP	438147	3102291	1,246	336	–	–	111	–	225	–	–	–
	9	3394 TP	438560	3101928	1,271	210	–	–	75	–	135	–	–	–
	10	5363 BTP	441123	3099265	1,596	237	–	–	7	–	230	–	–	–
2	11	0143 CP	437414	3113381	123	107	10	0	90	–	–	7	–	–
	12	0410 TP	437674	3112703	151	126	14	0	112	–	–	–	–	–
	13	0103 TP	437883	3112156	313	81	–	–	0	–	–	73	–	8
	14	4769 TP	438609	3110256	447	298	–	–	200	–	–	98	–	0
	15	2077 TP	438669	3110099	497	320	–	–	70	–	–	80	–	170
	16	0675 TP	438953	3109356	539	369	–	–	40	–	–	150	–	179
	17	2558 TP	439746	3107280	766	452	–	–	212	–	–	240	–	–
	18	2224 TP	439768	3107224	816	401	–	–	401	–	–	–	–	–
	19	3179 TP	440270	3105910	811	314	–	–	314	–	–	–	–	–
	20	3536 TP	440429	3105493	865	250	–	–	235	–	15	–	–	–
	21	5503 TP	440554	3105166	856	250	–	–	80	–	170	–	–	–
	22	3228 TP	440605	3105033	858	302	–	–	69	–	233	–	–	–
	23	0739 TP	440893	3104280	904	331	–	79	252	–	–	–	–	–
	24	3032 TP	441496	3102702	894	155	–	–	–	–	155	–	–	–
	25	1449 TP	441684	3102211	1,032	140	–	–	–	–	140	–	–	–
	26	3078 TP	441712	3102138	893	91	–	–	–	–	91	–	–	–
	27	3177 TP	441891	3101669	980	157	–	–	–	–	157	–	–	–
	28	3098 TP	441998	3101388	1,039	138	–	–	–	–	138	–	–	–
	29	3033 BTP	442064	3101217	1,107	146	–	–	–	–	146	–	–	–
3	30	3033 TP	441409	3100964	1,164	118	–	–	–	–	118	–	–	–
	31	3033BTP	441526	3101143	1,107	146	–	–	–	–	146	–	–	–
	32	3098 TP	441733	3101459	1,039	138	–	–	–	–	138	–	–	–
	33	3177 TP	442027	3101908	980	157	–	–	–	–	157	–	–	–
	34	1449 TP	442033	3101917	1,032	140	–	–	–	–	140	–	–	–
	35	3078 TP	442227	3102214	893	91	–	–	–	–	91	–	–	–
	36	1450 TP	442436	3102534	868	100	–	18	–	–	82	–	–	–
	37	3391 TP	442982	3103369	938	198	–	–	–	–	198	–	–	–
	38	3573 TP	443437	3104063	869	149	–	–	–	–	149	–	–	–
	39	3287 TP	443445	3104076	836	263	–	–	–	–	263	–	–	–
	40	1340 TP	443735	3104518	755	207	–	–	43	–	164	–	–	–
	41	1277 TP	443778	3104585	782	180	–	–	180	–	–	–	–	–
	42	0269 CP	444038	3104982	612	50	–	50	–	–	–	–	–	–
	43	1918 TP	444300	3105382	752	203	–	–	–	–	203	–	–	–
	44	1733 TP	444466	3105635	804	105	–	–	40	–		65	–	–
	45	0755 TP	445256	3106843	633	172	–	–	110	26	20	–	–	16
	46	1485 TP	445496	3107209	587	156	–	–	89	–	67	–	–	–
	47	1993 TP	446018	3108007	461	219	–	–	35	–	74	111	–	–

(*continued*)

Table 1 (continued)

							Thickness of main lithologies (m)							
Cross section	Reference number	IGME Borehole	X (UTM)	Y (UTM)	Z (m)	P (m)	SH	CR	CPRN	FDLP	CRN	C1-FF	C1-FRT	C1-FB
4	48	5247 TP	437124	3104867	974	280	–	–	280	–	–	–	–	–
	49	3515 TP	437399	3105124	1,052	382	–	–	80	–	302	–	–	–
	50	3397 TP	437595	3105308	970	300	–	–	300	–	–	–	–	–
	51	3346 TP	438743	3105925	948	343	–	–	343	–	–	–	–	–
	52	3310 TP	438895	3105904	921	330	–	–	126	–	204	–	–	–
	53	3179 TP	440042	3105746	811	314	–	–	314	–	–	–	–	–
	54	3536 TP	440158	3105730	865	250	–	–	235	–	15	–	–	–
	55	4392 TP	441128	3105595	779	282	–	–	90	–	192	–	–	–
	56	0586 TP	443613	3105252	597	83	–	–	29	–	54	–	–	–
	57	0269 CP	443637	3105248	612	50	–	50	–	–	–	–	–	–
	58	2178 TP	443687	3105241	605	113	–	–	6	39	67	–	–	–
	59	1918 TP	444216	3105168	752	203	–	–	–	–	203	–	–	–
	60	1733 TP	444798	3105088	804	105	–	–	40	–	–	65	–	–
5	61	2196 TP	434952	3111928	111	80	10	–	70	–	–	–	–	–
	62	0833 TP	436025	3113125	87	62	29	–	23	–	11	–	–	–
	63	2037 TP	436283	3113414	101	84	7	–	77	–	–	–	–	–
	64	0830 TP	436333	3113469	110	75	–	–	75	–	–	–	–	–
	65	0213 TP	441649	3113031	17	19	–	–	–	–	–	19	–	–
	66	0395 TP	441978	3112977	10	187	–	–	–	–	–	5	–	182
	67	0044 SI	443811	3112677	48	42	–	–	33	–	9	–	–	–
	68	0913 TP	444346	3112589	99	65	–	–	65	–	–	–	–	–
	69	0021 TP	444748	3112523	36	27	–	–	–	–	27	–	–	–
	70	0010 TP	446388	3112255	112	111	–	–	–	–	78	33	–	–
	71	5899 TP	448486	3111911	143	137	–	97	30	–	10	–	–	–

C1-FB Cycle I. Basaltic Formation, *C1-FF* Cycle I. Phonolitic Formation, *C1-FRT* Cycle I. Rhyolitic-Trachytic Formation, *CPRN* Post-Roque Nublo Cycle, *CR* Recent Cycle, *CRN* Roque Nublo Cycle, *FDLP* Las Palmas Detritic Formation, *SH* Holocene sediments, *P* depth of borehole, *Z* height of the top of the borehole above sea level

Fig. 2 Panoramic view of the NW sector of Gran Canaria between Gáldar and Agaete villages, showing the erosional surfaces (S_0, S_2, S_4 and S_6) and the location of the rock slides deposits. The photo has been taken from Montaña Almagro

stages (Roque Nublo, Post-Roque Nublo and Recent cycles) have been gradually embedded. Hence, the most recent surface (S_6) defines the most embedded reliefs in the NW sector of the island. We have noticed a temporal alternation between these erosion surfaces and the stratigraphic unconformities (S_1, S_3 and S_5), which are recognized later with lithological cross sections and interpreted as the sliding surfaces. This alternation of forms and processes support the hypothesis of large island flank instability along several volcanic cycles. This idea would be compatible with the existence of one or more translational rock slides with a very slow rate of movement. Triggering factors for this type of instability would be very old, reducing their energy. This fact suggests three remarks: (a) the recent processes of erosion could be able to generate new morphologies but not to remove the inherited forms, (b) the lava flows of the most recent cycles

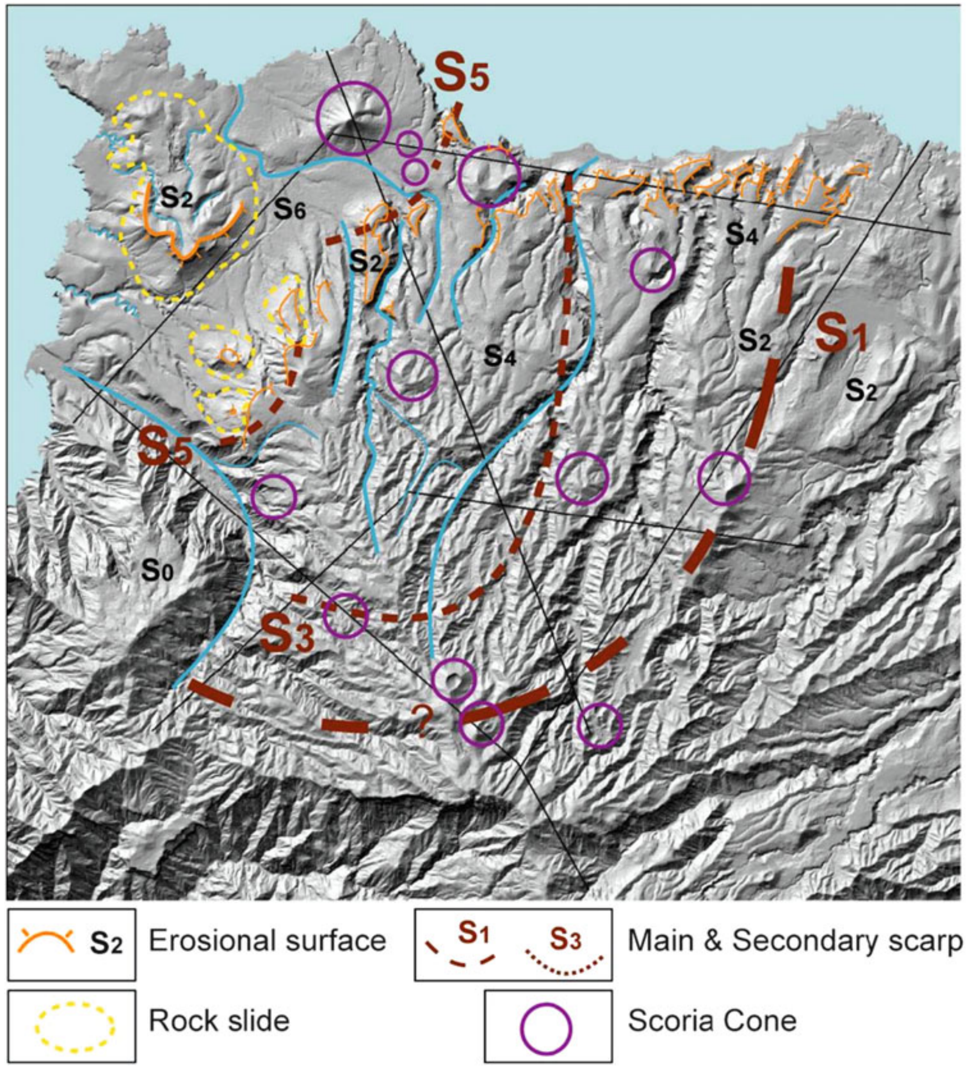

Fig. 3 Shaded relief image showing the main geomorphological features observed at the NW sector of the Gran Canaria (see text for more details)

are embedded in the preexisting reliefs, and (c) the old sliding surfaces cover a greater extent than modern sliding surfaces.

The wide NE-SW valley is flanked by steep scarps, where old materials of the Cycle I outcrop (Figs. 3 and 4). These materials are difficult to correlate topographically with the surface of summits described above (S_0) and, in addition, the southern scarp is covered by recent rock slides. These observations suggest that this valley could be the geomorphologic evidence of a secondary scarp (S_5) that could be developed at the foot of a prior sliding mass (S_3), resulting in a large rocky block (Montaña Almagro) disconnected of the main trend of the topography (Figs. 2 and 3). This hypothesis would be in agreement with the debris-avalanche deposits identified by other authors at the foot of the island shelf, between Agaete and Gáldar (Acosta et al. 2003).

Along the northern coast, there is a very steep escarpment with a height of several hundred meters. This relief has been interpreted as a result of a general tilt of the island to the south (Menéndez et al. 2008). However, the offshore investigations of the island shelf show the existence of several debris avalanche deposits close to Galdar (Acosta et al. 2003). Therefore, the complexity of the vertical movements experienced by the volcanic terrains indicates a polygenic character to the morphogenesis of the relief. The height of these coastal cliffs is compatible with the occurrence of an old flank slide and a later differential rising of a coastal block of the island.

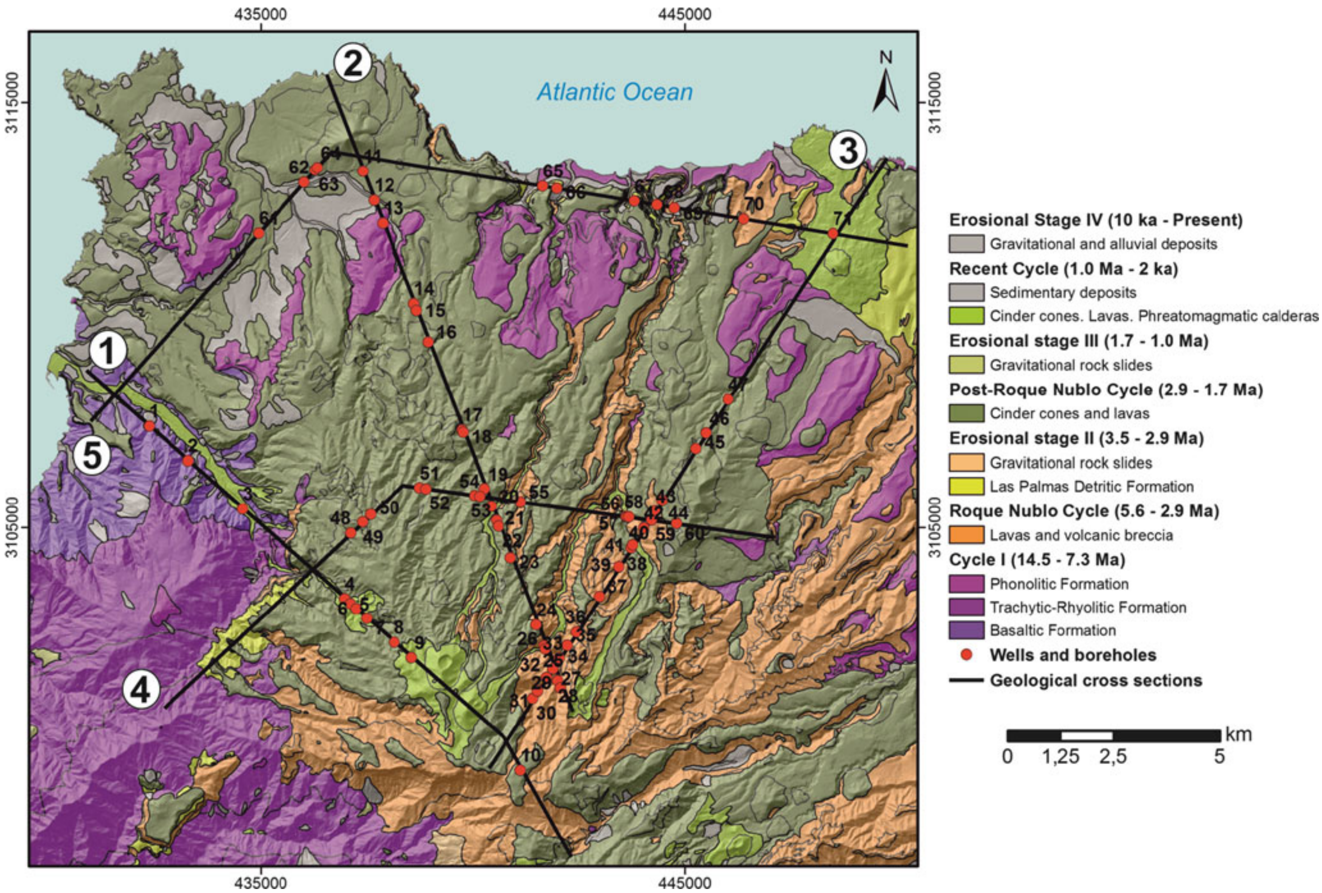

Fig. 4 Map of the superficial geology of the NW sector of Gran Canaria showing the main volcanic and erosional stages. The location of the five lithological cross-sections (*black lines*) and the 71 wells and boreholes (*red dots*) are also depicted

Geological Investigations

Lithological cross-sections (Fig. 5) show sharp changes in the thickness of the formations of the Roque Nublo and Post-Roque Nublo cycles. The contact between the two formations suggests the existence of a paleo-relief compartmentalised in wide flat-bottomed valleys, separated by residual reliefs. This paleo-relief defines an erosion surface (S_3) embedded between the remains of two previous structural surfaces: the top of the Roque Nublo Cycle (S_2) and the surface of summits (S_0).

The age of the paleorelief is implied by a recent structural surface (S_4) which is defined by the lava flows of the Post-Roque Nublo Cycle of Pleistocene age. A thinning of the prior substratum, defined by the most recent materials of the Cycle I (Trachytic-Rhyolitic and Phonolitic formations), has been found below the paleo-relief described above (S_3). This discontinuity (S_1) confirms the occurrence of previous translational rock slides of Miocene to Pliocene age.

Discussion and Conclusions

The large flank instability found in the northwest sector of the Gran Canaria Island would be related to the intrusion of dykes during the end of the Cycle I and suggests a NE-SW extensional regime, which could be related to a central NW-SE fault zone that divides the island in two sectors: northeast and southwest. This stress regime seems to be established for an extended period of time, suggesting the coexistence of other triggering factors such as the lateral spreading of the volcanic edifice due to the combined effect of the weight of the volcano and the time. Moreover, the existences of two different lahar deposits (Las Palmas Detritic Formation) in the stratigraphic sequence of the island (Balcells et al. 1992) suggest the occurrence of highly explosive eruptions. The earthquakes related to these explosive periods could also be considered as a triggering factor of the large flank instabilities in Gran Canaria Island.

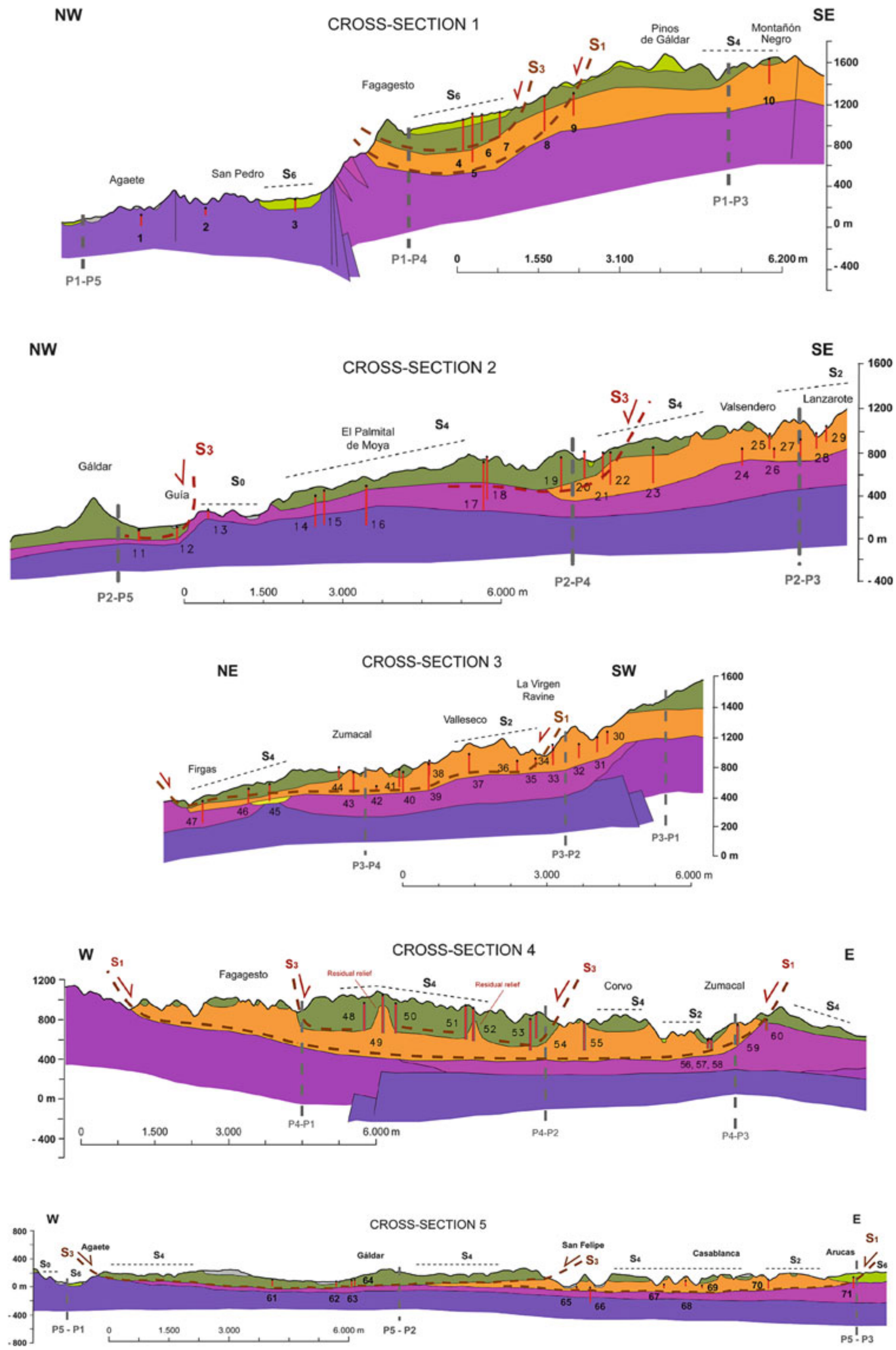

Fig. 5 Longitudinal (1–3) and transversal (4–5) cross-sections derived from the wells and boreholes data (*red lines*). See Fig. 4 for localization

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Landslides in a Multi-Hazard Context

Melanie S. Kappes and Thomas Glade

Abstract

Landslides and other hazards are components of natural systems and thus are often related to each other. Since these relationships may result in unexpected effects, an approach to account for these relationships in a regional multi-hazard study is proposed. Subdivided into relations concerning disposition alteration and hazard chains in which one process triggers another process, the hazard links are identified and studied by means of GIS-based methods. Two techniques are used for the implementation of relations into the analysis procedure, the establishment of feedback loops and the overlay of hazard areas to determine overlaps. Such a regional analysis enables in the first place the definition of those areas possibly affected by unexpected effects due to hazard relations and indicates the spots to be studied in detail by local and detailed methods to quantify the potential consequences.

Keywords

Multi-hazard • Interaction • Hazard chains • Disposition and triggering

Introduction

For many years "system theory" has attempted to account for the continuous nature of the world and the complex relations between components (Chorley and Kennedy 1971). One prime example of the implementation of a systems approach in geomorphology is the concept of debris or sediment cascades (Chorley and Kennedy 1971). In these cascading systems "the output of one subsystem forms the input of another" (Schneevoigt and Schrott 2006, p. 182). Processes as rock falls, debris flows or shallow landslides form part of these systems. Due to "certain characteristics which possibly pose a threat to elements at risk" these, primarily natural, processes may convert to natural hazards (Kappes et al. 2010, p. 351). Although this does not change anything concerning their affiliation to geomorphic systems, natural hazards and among them also the previously mentioned processes are still commonly regarded, analyzed and managed separately. However, interactions cause consequences, lead to modifications, for example of hazard levels and result in unexpected incidences. Thus, a reductionist approach is not able to account for such effects and thus not advisable. An example for hazard relations is the Jubaguerra event: a debris slide blocked the Arroyo de Jubaguerra gorge resulting in a damming of the stream. As a consequence of the subsequent dam break a flood wave rushed down the river and reached the mouth of the watershed (Carrasco et al. 2003). Costa and Schuster (1988) present a range of examples on formation and dam failure events of which several resulted in unexpected incidences with high numbers of fatalities.

The consideration of multiple hazards jointly and the inclusion of cascade and interaction effects is still an emerging research field. One pioneer project which addressed the topic from a geomorphic and system theoretic approach rather than from a hazard approach is SEDAG (SEDiment cascades in Alpine Geosystems). One main objective of SEDAG was to better understand the sediment pathways (Wichmann et al. 2009). However, Wichmann and Becht (2003) mentioned that

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the applied models might also be used for hazard assessments. By investigating source, transport and deposition areas of each process and the identification where these zones overlap the sediment routing can be determined (e.g. rock fall deposition in locations of debris flow erosion leads to cascading propagation of the sediment).

A practical approach coming from a hazard assessment background is proposed by Kappes et al. (2010). According to this concept, two types of influences between hazards can be distinguished: (1) the alteration of hazard dispositions by a hazardous event, e.g. the accumulation of material by rock falls and the subsequent availability of this material for debris flows or an increase of the load on a slope which destabilizes the slope and the disposition to a failure, and (2) the triggering of one or more hazards by another hazard, e.g. the triggering of rock falls by an earthquake or of lahars by a volcanic eruption hitting a glacier. Likewise, the triggering of at least two hazards by a process which does not classify as hazard, e.g. the triggering of debris flows and landslides by heavy rainfall, falls into this category.

In this study, the practical consideration and implementation of interactions in a regional study are presented, subdivided into disposition alteration and triggering (according to Kappes et al. 2010). For the performance of the hazard modelling, the multi-hazard risk analysis tool MultiRISK Kappes et al. (in prep) was used and the case study is carried out in the Barcelonnette valley, located in the South-eastern French Alps.

Consideration of Interactions in a Regional Context

Multi-hazard analyses suffer several limitations. The extended requirements of soil, infiltration, geology, precipitation, discharge data and further information are often limiting factors. Inventories of past events are of particular relevance for the calibration and validation of hazard models. However, high quality multi-hazard inventories are extremely scarce. A second challenge in a multi-hazard setting is the multidisciplinarity of the topic. Seldom is one expert proficient with all processes. Thus a first evaluation of the multi-hazard situation, including areas of potential overlay and the occurrence of relations and interactions between them is much more difficult than the determination in a single-hazard environment. Both issues call for a top-down approach in multi-hazard investigations. As a first step, an approximation of the patterns is obtained. This is done by simple methods with low data requirements to ensure its applicability as approximation and avoid extensive and time-consuming data acquisition. On this basis, the resources can then be applied specifically to detailed local analyses in the areas identified as potentially prone to hazard interactions and risk.

The Medium-Scale Analysis Scheme

Kappes et al. (in prep) present a simple, GIS-based analysis scheme based on low data requirements (Fig. 1). It is designed as the first step of a top-down approach for multi-hazard exposure analyses. From a digital elevation model (DEM), land use/cover and lithological information (dark grey boxes at the left side of Fig. 1) multiple derivatives are deduced (medium grey boxes). These serve as input for the models and GIS operations (light grey boxes with rounded edges). With this input the areas of potential rock fall, shallow landslide, debris flow and avalanche sources and areas affected by the run out as well as the zone susceptible to river flooding are modelled. The analysis scheme has been automated in the software tool MultiRISK. Herein, the intermediate steps such as the computation of derivatives, required format changes etc. are automatically computed. The software interface guides the user through the modelling process and guarantees user-friendly, faster, less error-prone and reproducible multi-hazard modelling (for further details concerning the analysis scheme and MultiRISK refer to Kappes et al. in prep). The consideration of hazard relations is still not automated in MultiRISK. However, the joint analysis of multiple hazards and the option of a fast re-calculation form a solid basis for *external* examinations of hazard cascades, feedback loops and other effects.

To illustrate the application of the concept of dealing with hazard interactions, a case study has been carried out in the Barcelonnette basin. This high mountain valley is prone to a multitude of landslide types and other natural hazards. In Kappes et al. (in prep) a worst-case analysis of shallow landslides, rock falls, debris flows, snow avalanches and river floods has been carried out and the obtained susceptibility zones form the basis for the hazard relation analysis which is presented in this study.

The Barcelonnette Valley

The Barcelonnette valley is situated in the "Département Alpes des Haute Provence" in the South-eastern French Alps. The altitude ranges between 1,100 and over 3,000 m a.s.l. Autochtonous black marls underlie allochtonous flysch in a geological window (Maquaire et al. 2003) and a multitude of torrents at the north- and south-facing mountain sides is drained by the Ubaye River. For more detail on the area refer to Kappes et al. (in prep).

The environmental characteristics give rise to several landslide types such as rock falls (e.g. RTM 2000), rotational and translational landslides (Thiery et al. 2004), mud flows (Malet et al. 2004) and debris flows (Remaître 2006). Other hazards comprise flash floods (Remaître 2006), river floods

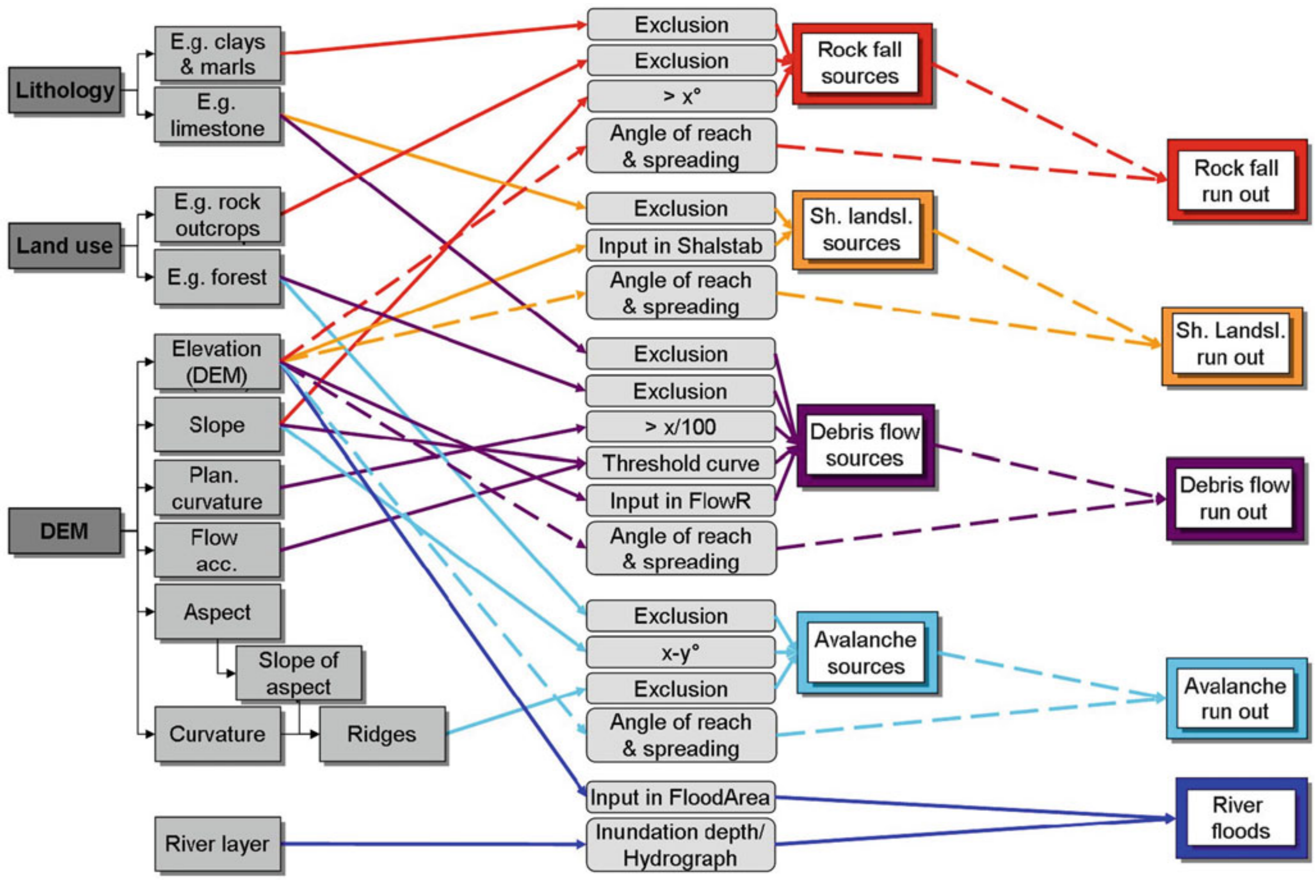

Fig. 1 Analysis scheme for medium-scale multi-hazard analyses according to (Kappes et al. 2012)

Table 1 Matrix for the identification of disposition alterations between hazards. The hazard in the line causes and the hazard in the column receives the influence (Modified after Kappes et al. 2010)

Avalances	Land cover	Land cover		
	Debris flows			River bed morphology
Slope roughness	Material supply	Rock falls		River bed morphology
Surface roughness	Material supply		Landslides	River course
	Material supply		Erosion/saturation	River floods

(Le Carpentier 1963; Sivan 2000), earthquakes (CETE 1987) and snow avalanches (MEDD).

Consideration of Disposition Alteration

An option to account for an alteration of the disposition has already been presented in Kappes et al. (2010). The potential influences are identified in a matrix (Table 1). Those influences relevant at the respective scale are determined and the implementation in the modelling procedure is designed.

In the case of a medium-scale analysis and with the input parameters proposed in Fig. 1, the alteration of the land

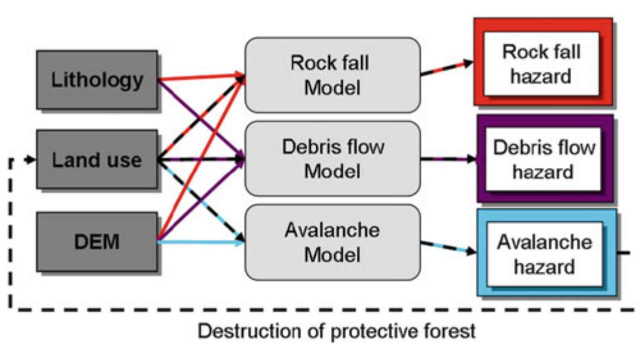

Fig. 2 Feedback loop (indicated by *dashed lines*) implemented in the (simplified) modelling procedure (Modified after Kappes et al. 2010)

Fig. 3 Identification of zones of potential slope undercutting. The area marked with the *red ellipse* is shown in photograph of Fig. 4

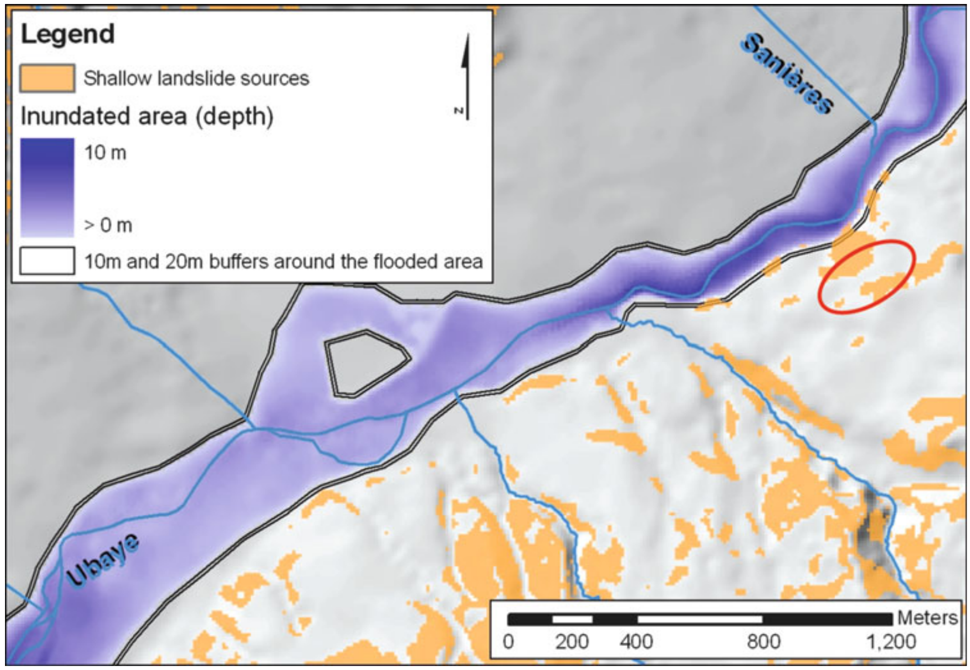

Fig. 4 Area of potential undercutting of the slope, situated at the Ubaye river close to the confluence of the Sanières torrent with the Ubaye (area located in the *red ellipse* of Fig. 3)

cover by snow avalanches, e.g. the destruction of forest which protects from rock falls and debris flows but also from further avalanches, is the only type of disposition alteration which can be considered. River bed morphology, erosion processes or material supply are parameters which are not represented in the input information of this rather generalised modelling approach. By means of a feedback loop the influence of avalanches on the land cover can be accounted for as shown in Fig. 2.

After having modified the land use, the three processes depending on this input (rock falls, debris flows and snow avalanches – refer to Fig. 2) are re-calculated. This is a fast and user-friendly procedure with the MultiRISK software although the feedback loop itself is not automated.

Consideration of Triggering

Within the set of hazards under consideration in this study only two major hazard cascades have been identified: (1) landslides damming rivers or torrents with the potential to cause upstream flooding and dam break with downstream flooding (e.g. Costa and Schuster 1988), and (2) torrent and river floods undercutting slopes and leading to a slope failure. If this leads to a damming of the river or torrent, the same potential consequences as previously described can also be expected.

The study of Carrasco et al. (2003) is very instructive concerning a method to identify spots where such cascading events could take place: based on a landslide susceptibility analysis, Carrasco et al. (2003, p. 361) determined those slopes that are “connected to streams and torrents (gorges)” as *restrictedly susceptible*, i.e. susceptible to a relation between slope and stream processes. This approach is broadly adopted with modifications. In the following, the adjusted method and the GIS operations used for this study are presented and applied to the Barcelonnette basin:

1. Undercutting of a slope:

By using the flood hazard analysis result and overlying it with the potential source areas of shallow landslides, zones potentially destabilized by high water can be identified. However, influences cannot only be expected in the overlap of both processes but also interferences due to for instance water saturation of the slope toe and consequently changes are likely in the slope hydrology. This means, the influence may reach beyond the area of actual overlap. Simply, this effect can be accounted for by introducing a buffer around the flooded area.

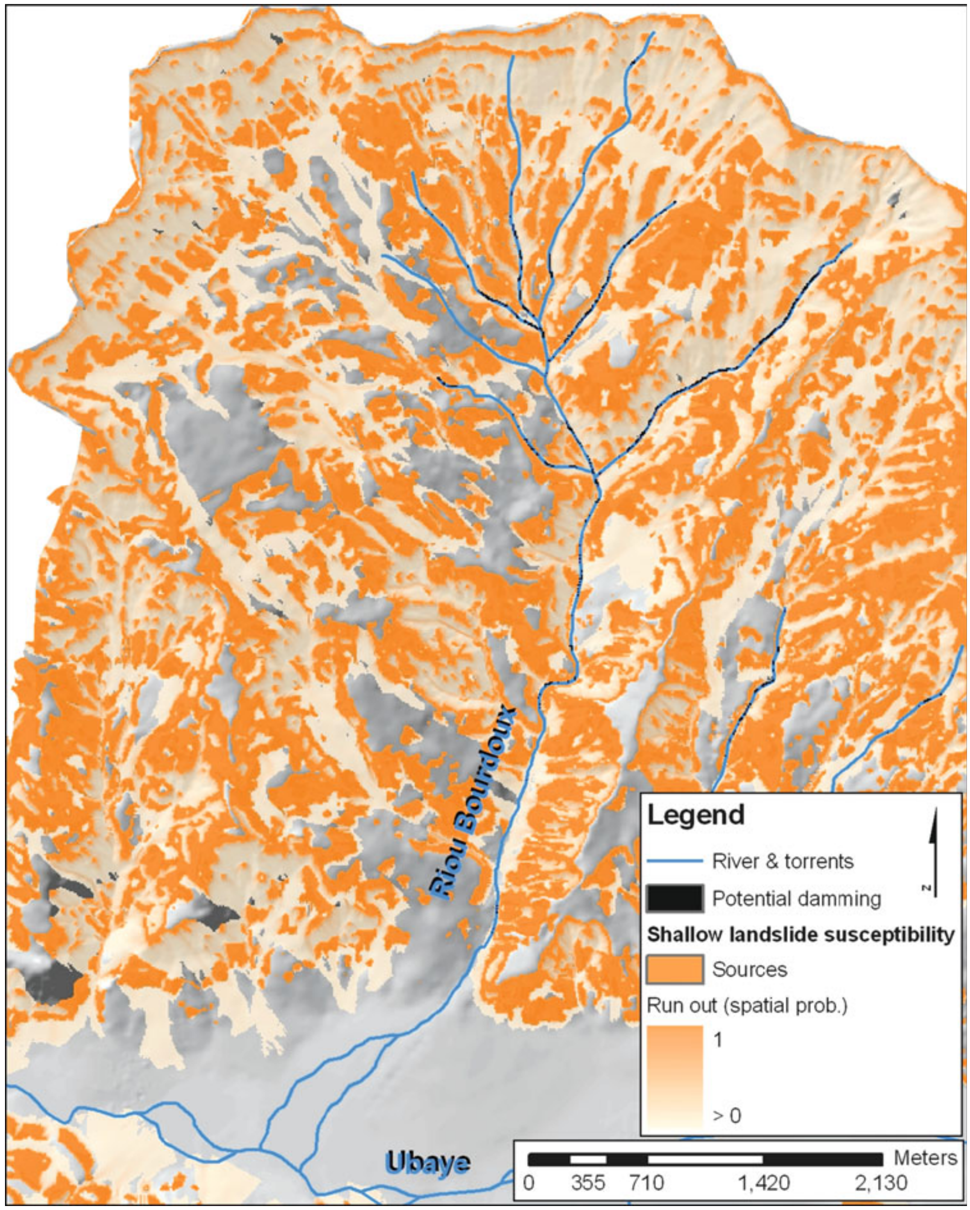

Fig. 5 Areas of potential damming of the torrent by landslide masses, example of the Riou Bourdoux

The main challenge is the definition of the buffer width, especially the scale, resolution of the DEM and specific characteristics of the area are of importance in this decision.

Example from Barcelonnette

For the Barcelonnette study a digital elevation model of 10 m was available thus a buffer of 10 and 20 m was applied to the flooded area (Fig. 3). However, a definite decision about the buffer width can only be made after observations in the field.

As shown in Fig. 3 several locations were identified as susceptible to undercutting. In a field survey multiple spots were examined and proved to be prone to undercutting. An example is given in Fig. 4 depicting the area situated in the red ellipse of Fig. 3.

2. Damming of a torrent/river by a landslide:

To identify those torrent and river sections which could possibly be dammed by landslide material the river and torrent network is overlaid with the landslide run out. However, only in "gorge-type" valleys can a damming be expected (at least for moderate debris volumes) whereas in wide valleys the sliding material is most probably not sufficient to block the whole riverbed (Carrasco et al. 2003). In Carrasco et al. (2003) gorge-type valleys are valleys with a bottom not wider than 25 m and identified with a neighbourhood analysis. Since Carrasco et al. (2003) do not provide sufficient detail to reproduce the presented methodology, the landform classification after Jenness (2006) has been applied in this study. The landform classification is based on the topographic position index (TPI) proposed by Guisan et al. (1999) and Weiss (2001). The TPI operates by "calculating the difference

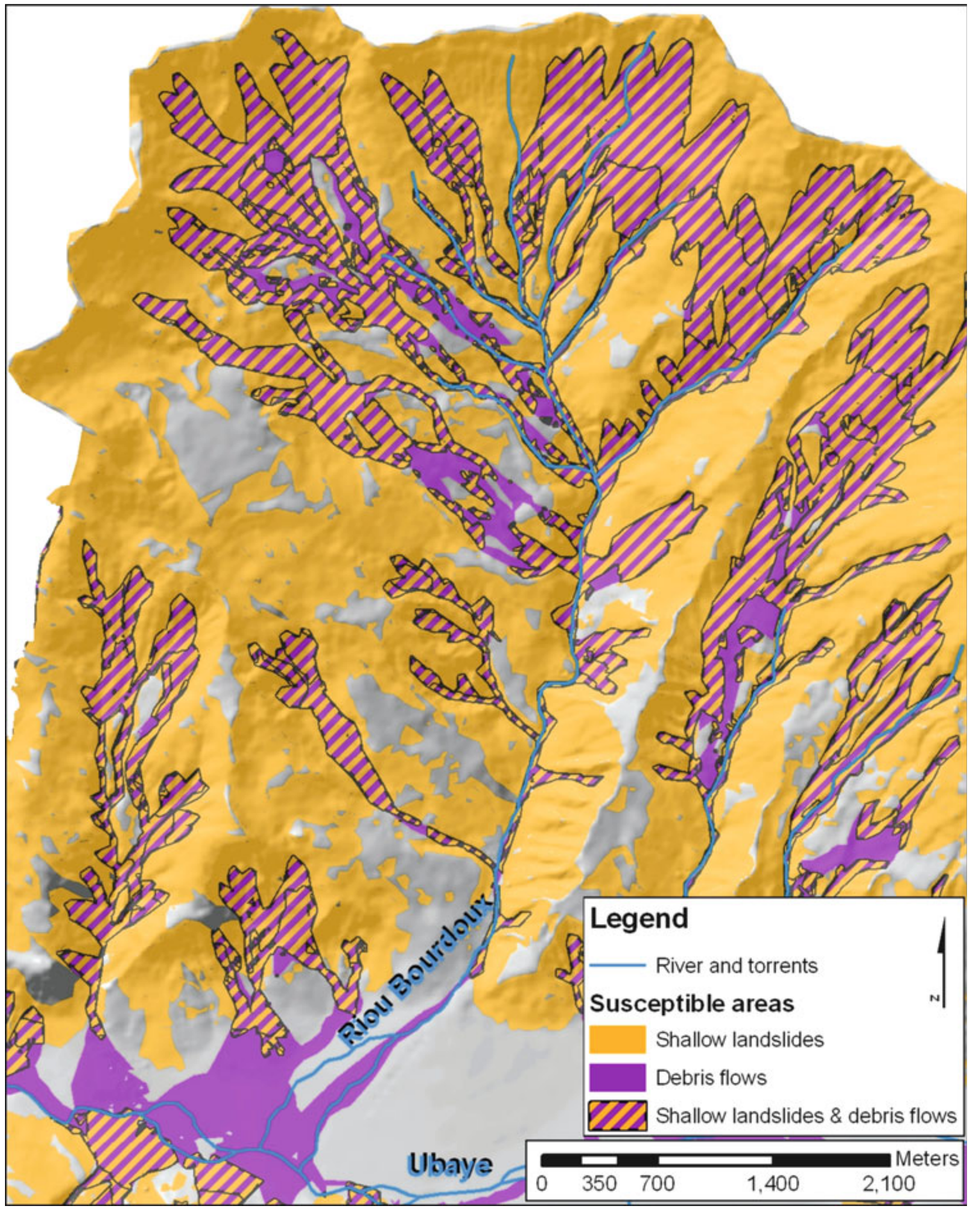

Fig. 6 Identification of the area susceptible to being affected shallow landslides and/or debris flows triggered by heavy rainfalls in the Riou Bourdoux catchment

between the elevation of the cell and the mean elevation calculated for all cells of a moving circular window centered in the cell of interest" (Guisan et al. 1999, p. 110). The application of thresholds for the TPI values allows the identification of different topographic positions such as ridge, slope, valley, etc. The TPI depends strongly on the size of the neighbourhood taken into account: the larger the considered neighbourhood, the larger are the classified forms. In contrast, small neighbourhoods lead to small-scale classification. For the identification of certain landforms Jenness (2006) combines two TPIs which differ in the size of the neighbourhoods considered for the TPI calculation and defines thresholds at both scales for the different landforms.

When defining the parameters for the landform classification, an important aspect is that the size of the valleys potentially blocked by landslide masses depends on the volume of the slide. This means, large slides can block wider valleys whereas the material from small slides may not fill the full width of the riverbed. Thus, the definition of the TPI neighbourhoods already implies to a certain degree an assumption on the volume of the sliding mass.

The gorge-like torrent partitions are determined by overlay of the valleys with the water courses. By a further overlay of these partitions with the area susceptible to be hit by shallow landslides the areas of potential river/torrent damming are identified.

Example from Barcelonnette

Based on expert judgement, the landform classification of Jenness (2006) was carried out with a smaller neighbourhood of 3 × 3 and a larger neighbourhood of 6 × 6 pixels. With this combination, areas known by the authors as valleys with steep slopes and small bottoms were determined as best. Figure 5 shows the result for one catchment, the Riou Bourdoux, situated in the western part of the Barcelonnette basin.

Apart from the explicit cascades also the triggering of multiple hazards by one event which is not necessarily a hazard (e.g. prolonged rainfall) or a process not included in the multi-hazard analysis should be considered. In this study, this would primarily include floods, debris flows and shallow landslides as a consequence of precipitation or rock falls and shallow landslides triggered by an earthquake.

Example from Barcelonnette

Concerning the triggering by precipitation the rainfall patterns have to be considered. For the Barcelonnette Basin Remaître et al. (2010) identified heavy daily rainfall as trigger for debris flows whereas cumulative rainfall, i.e. rainy periods of about 30 days, may rather lead to shallow landslide events. However, heavy rainfall after antecedent precipitation could lead to a combination of landsliding and debris flows. In contrast, river floods of the Ubaye, are the result of prolonged rainfall in autumn or related to very rapid snow melts in spring (Sivan 2000). Consequently, the creation of one map with all three rainfall triggered hazards would not be realistic but a splitting into short heavy and long cumulative rainfalls is advisable. In Fig. 6 an example is given for the case of heavy rainfall with the potential to trigger shallow landslides and debris flows. The areas susceptible to the effect of one or both are identified.

Conclusions

The integration of hazard relations into hazard analyses is necessary to avoid facing unexpected effects in the aftermaths arising from cascades or feedbacks. The way this can be done depends on the scale level, the methods and models chosen and the hazards combined. However, by means of general identification techniques as matrices a general overview over potential effects can be gained. On this basis, methods suitable to account for relations relevant at the respective scale can be chosen. In this study an example is given for the regional scale at which primarily an identification of spots of potential relations can be performed. However, this is an important starting point for subsequent detailed and time- and data-intensive analyses of the full cascades and effects possibly resulting at these points.

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A Performance-Based Approach to Landslide Risk Analysis and Management

Roberto W. Romeo, Milena Mari, and Giulio Pappafico

Abstract

A performance-based approach for the assessment of landslide risk and management is shown and discussed. The implemented method is based on a probabilistic model which takes into account all the uncertainties of the involved variables and allows following a performance approach based on given loss or damage thresholds. Given the landslide area-extent and type as the only deterministic input, all other properties to derive landslide severity and frequency are statistically inferred from actual landslides and probabilistically managed to derive probability density functions of the demand of resistance. In turn, the capacity of resistance (i.e., fragility functions) is derived via damage surveys and cards compilation for each investigated asset group (structures, roads and lifelines) and for each limit state (aesthetic, functional and structural). Finally, convolution of landslide hazard, asset fragility and exposure (as the amount of potentially damaged goods) allows the computation of the risk for each limit state condition.

Keywords

Landslide hazard • Fragility functions • Performance • Exposed assets • Loss probability

Introduction

The risk is a possible loss that an asset may undergo due to the occurrence of a threat, whose, in turn, is a potentially damaging event of a given severity (or intensity) within a reference time (Glade et al. 2005). For the risk assessment is therefore necessary to set: (1) the characteristic of the event, as a timely frequency of occurrence of given intensities (namely, the hazard or demand); (2) the capacity of the asset to withstand the demand in terms of damage probabilities (namely the fragility); (3) the nature and amount of assets that may be lost (namely the exposure). Adopting a suitable probability model to convert frequencies, we can mathematically express the risk as:

$\text{Risk} = p(L \geq l|\text{hazard, fragility, exposure})$ with:

$\text{Hazard} = p(S \geq s|t)$

$\text{Fragility} = p(D \geq d|I)$

$\text{Exposure} = \Sigma(\$,N,T)$

where L is a randomly distributed variable which represents the loss of a given asset, S is the landslide severity, D the asset damage, and $-N-T are, respectively, the costs, casualties and function interruptions depending on the nature of the exposed asset and the measure of the loss chosen to represent the risk. The inequalities set loss, damage or intensity thresholds beyond which the system's performance is no longer met (e.g., a landslide occurrence over a given dimension, a structural damage to a lifeline, the interruption of a public service, and so on).

According to the above definition a proper methodology for the risk assessment requires accounting for the uncertainties of the involved variables and a performance approach to set significant thresholds (i.e., limit states) beyond which losses may be of social or economic concern.

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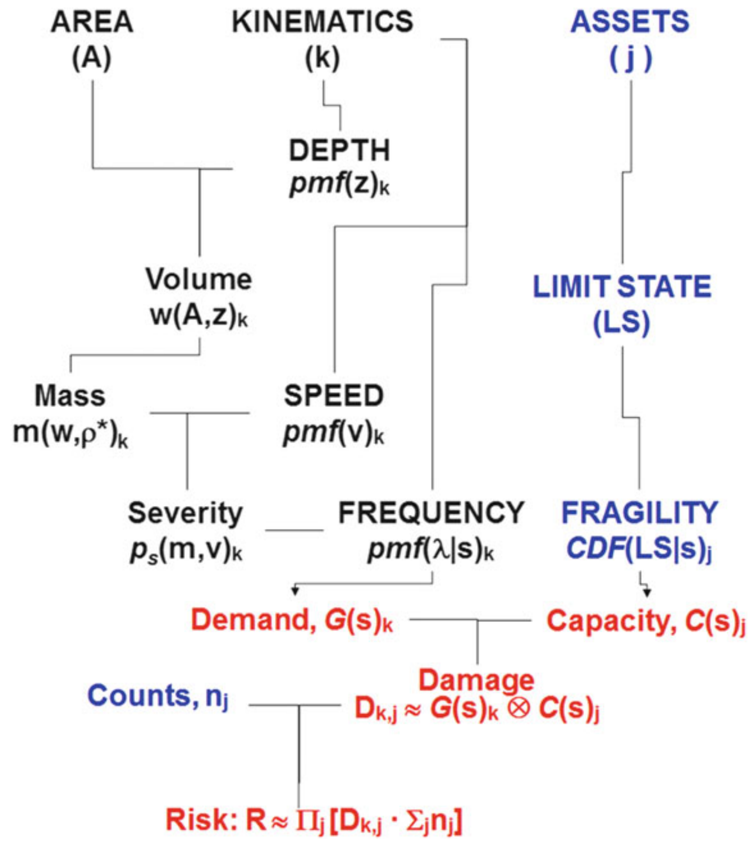

Fig. 1 Landslide risk model

Methodology

The Model

The risk model used in this work is shown in Fig. 1. In the first row the three basic information to be acquired are reported: from the left, the area-extent and kinematics of each landslide, and the exposed assets. They represent the only data to be gathered in a deterministic way.

Then, following the first two columns in black style the procedure adopted to assess the landslide hazard (i.e., the demand of resistance) is shown: in capital letters the variables determined through specific surveys and data acquisition (depth, speed and frequency of occurrence) with their own probability mass function (pmf) for each kinematic type of landslide (the subscript k for, respectively, falls, slides and flows). In lower case the data computed through the gathered variables, e.g. the landslide volume from the area-extent and depth or the landslide severity from the mass and speed (i.e., a parameter related to the kinetic energy). Finally, in red, the landslide hazard (here termed as Demand) is the [yearly] frequency of exceedance of a given severity for a given kinematic type of landslide.

The third column, in blue style, refers to the assets for which the landslide risk is assessed (the subscript j for, respectively, buildings, industrial facilities, lifelines and roads).

Then, for each asset the limit states for which the risk is computed have to be selected. In this work three limit states are considered: aesthetic, of nominal value only, for which no significant damage or service interruption can arise; functional, for which a service interruption may incur; structural, for which the partial or total loss of the asset can occur. Fragility functions for each asset and limit state are then empirically derived on the basis of a damage survey carried out through the compilation of data-cards where the nature and extent of the damage suffered by an asset due to the occurrence of a landslide are assessed. Finally, for each asset the capacity of resistance, in red, is the probability that a limit state is not-exceeded given a landslide severity.

Damage is therefore the probabilistic convolution of the capacity and demand and the risk, in turn, the arithmetic product of damage and exposure, where the exposure is simply the count of assets that may suffer a damage given the occurrence of a landslide.

Maths and Functions

Landslide hazard formally incorporates the concept of landslide severity (or intensity, Hungr et al. 2005) which is,

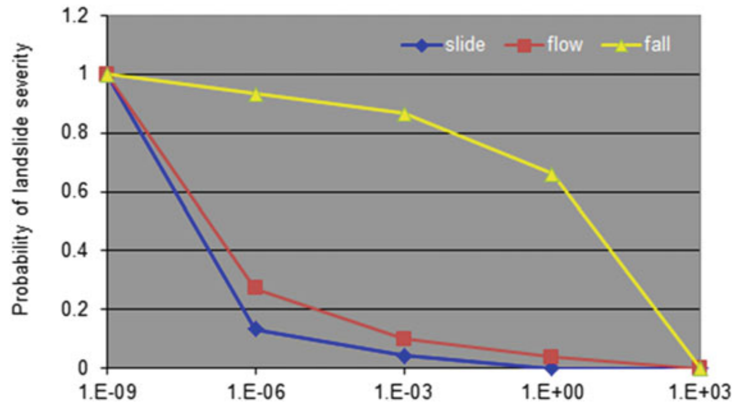

Fig. 2 Landlide severity probability

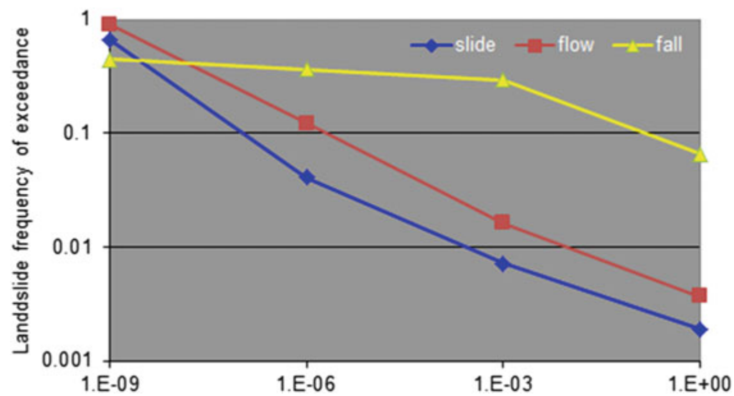

Fig. 3 Landlide hazard (note that the landslide severity is truncated at the lower range of 1.E + 00 since the graph represents the frequency of exceedance of each severity class)

in turn, a function of the landslide mass, speed and travel distance. In this work we computed the probability of a landslide severity as a function of mass and speed alone for each kinematic type, discarding the travel distance owing to the lack of information about. Thus, with reference to Fig. 1:

$$P(s)_k = \int_S \int_M \int_V f_{S|M,V}(s|m,v)_k f_M(m)_k f_V(v)_k \, ds\, dm\, dv \qquad (1)$$

The probability of a landslide severity is shown in Fig. 2 for the three kinematic types.

The severity is highest for falls because the speed of rock and debris falls is infinitely higher than that of slides and flows. Severity is computed in terms of kinetic energy (units is joule), but its discontinuous values doen't allow to represent it as a continuous variable. Therefore, the observed severities have been grouped into four classes each one spanned by three orders of magnitude.

When taking into account the landslide frequency of occurrence, too, the demand of resistance, namely the landslide hazard (Aleotti and Chowdhury 1999), is given by:

$$G(s)_k = 1 - \int_S p(\lambda|s)_k \, p(s)_k \, ds \qquad (2)$$

whose distributions are shown in Fig. 3.

The [yearly] frequency of occurrence for falls is almost the same above a wide range of landslide severity and then drops abruptly since the highest severity is reached only if a joint probability of high speed and huge mass are reached.

The fragility functions of the exposed assets (namely, the probability that a limit state is reached) are derived from a damage survey through a data card compilation and their distributions are displayed in Fig. 4 as a function of landslide severity.

Fragility is higher for lifelines, as may naturally be inferred, and lower for industrial facilities, which are usually founded on piles and thus less susceptible to fail.

Damage is then computed through the convolution:

$$D(LS)_{k,j} = \int G(s)_k p(LS|\, s)_j \, ds \qquad (3)$$

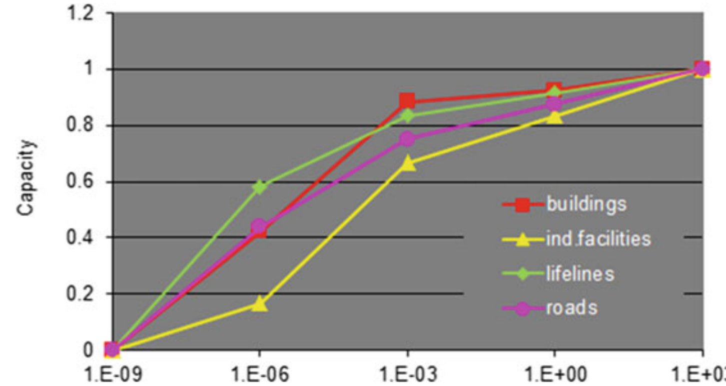

Fig. 4 Fragility functions of the exposed assets

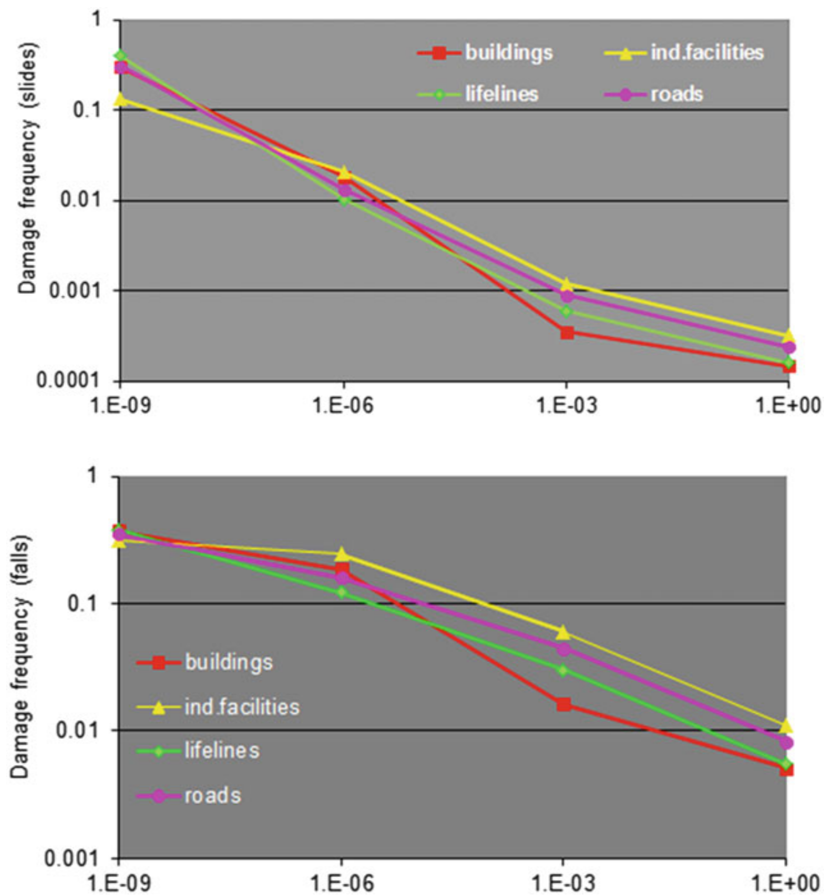

Fig. 5 Yearly frequency of exceedance of structural damage (limit state) for the exposed assets and the kinematic types of slides (*top*) and falls (*bottom*)

Since the hazard, $G(S)_k$, is in the form of a probability of exceedance (a complementary cumulative distribution function, statistically speaking), fragility functions must be converted in probability mass functions (the first derivative of the $C(s)_j$ in Fig. 1).

Damage functions of the exposed assets have then the shapes shown in Fig. 5 due to the occurrence of slides and falls (up to down, respectively).

The damage frequency of flows is not shown since it is similar to that of slides because of their similar frequency of exceedance (see Fig. 3).

Damage frequency is finally converted into a damage probability by assuming a probabilistic model of occurrence: for landslides the models usually adopted are Poisson or Binomial, whose formulations are respectively:

$$P\left[D_{k,j}\middle| t\right] = 1 - e^{\left(-D_{k,j}t\right)} \tag{4a}$$

$$P\left[D_{k,j}\middle| t\right] = 1 - \left(1 - D_{k,j}\right)^{t} \tag{4b}$$

The last step prior to compute the risk as a whole, is the counting of the exposed assets. Owing to the nature of the

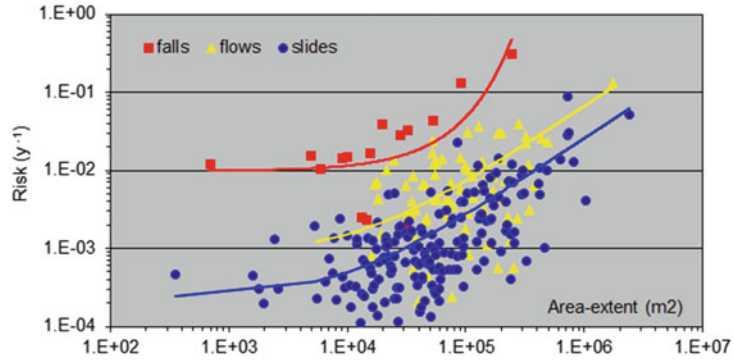

Fig. 6 Landslide risk

assets, the quantification of losses would require to express them in terms of monetary losses. Anyway, due to the lack of a parametric cost of restoration for each type of asset, we calculated a relative risk rather than an absolute one. It consists, for each i-th landslide belonging to a kinematic type k, in computing the percentage of assets of each j-th class respect to the whole assets of the same class threaten by the landslides of the k-type:

$$E_{i_{k,j}} = \frac{n_{i_{k,j}}}{\sum_i n_{i_{k,j}}} \quad (5)$$

Finally, the risk is computed for each i-th landslide of the k-th kinematic type. Then, since each landslide may threaten more than one asset-type (buildings and roads rather than lifelines and industrial facilities, and any combination of that), the overall risk is the mathematical product of the damage probability (4a), (4b) by the exposure (5):

$$R_{i_k} = 1 - \prod_j \left(1 - P\lfloor D_{i_{k,j}} | t \rfloor \cdot E_{i_{k,j}}\right) \quad (6)$$

Risk is expressed as an yearly frquency of exceeding a certain limit state; units is therefore year^{-1}, because exposure is not expressed in terms of monetary losses, casualties or service interruption, but it is adimensional.

Figure 6 shows the risk computed for each of the 325 landslides censed by a National Basin Authority in Italy as potentially damaging landslides, for which this procedure has been applied. Landslides are grouped by kinematic type and the risk (in the form of an yearly exceedance probability) is plotted versus the area-extent of the landslides, which represents, along with the kinematics, the basic data entry for this kind of analysis. Despite the damage frequency is naturally decreasing as the severity of the landslides increases (see Fig. 5), risk has an opposite trend (assumed the area-extent to be a proxy of the landslide severity); this is due to the large proportion of exposed assets that are thretened by large landslides. In other words, the high exposure of assets to large landslides compensates their low frequency.

Conclusions

This work has concerned the assessment of the landslide risk following a performance-based approach well established in the structural engineering but still far from to be applied in other fields of non-structural failures.

Risk was evaluated on the basis of the capacity-demand model, where the capacity of exposed assets to withstand different limit states has been determined by observing and reporting their actual behaviour against the landslide threat. In the same manner, the landslide hazard has been empirically determined through an in-depth census and data card compilation of actual landslides inducing damages, assessing their frequency of occurrence as the more.

The landslide risk has been computed via a probabilistic convolution of the demand (i.e., the landslide hazard) and capacity (i.e., the assets fragility functions), taking into account the amount and nature of the threatened assets (i.e., their exposure). Since the exposure is still dimensionless, risk has the units of a yearly frequency, even if the amount of losses is implicitly considered in the exposure.

The methodology, though apparently cumbersome, is a tentative to provide a more rational approach to the landslide risk assessment respect to the qualitative and subjective methods commonly used.

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Part II

Landslides and Socio-Economic Impact: Basic Data and Loss Modeling

Introduction by Lynn Highland[1], Dave Petley[2], and Dahlia Kirschbaum[3]

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Socioeconomic impacts of landslides are diverse and varied as evidenced by the fine papers and presentations in this session. Although each is different in nature, they outline the universal problems and challenges that occur for areas exposed to landslide hazard. The papers touched on various case histories of land-use management, and ranged from micro-zoning of sites for landslide hazard and characterized the effectiveness of using various tools such as aerial and observations and other data-collecting methods. Various mitigation approaches were characterized and especially interesting was the actual relocation of a village in Romania. The landslides experienced by countries such as Nepal and India are especially poignant as these countries have a large percentage of their terrain designated as landslide-prone—also there are a large number of people exposed to the hazard. Many of the papers emphasize the importance and impacts of indirect losses for example, tourism in Majorca Spain, indicating that these indirect losses can in many cases, be a great deal larger than the direct impacts of landslides. Some of the papers dealt with loss-models being applied in various areas (for example a large region of the Mediterranean) and our discussions touched upon the fact that loss models are a new and burgeoning area of landslide hazard mitigation and we were fortunate to hear and talk about their value to characterizing losses to communities and the political realm in which those communities exist. The ever-present and critical effects of landslides on highways and transportation corridors were discussed and the fact that there might be a larger inventory of landslides that affect highways, which omit other landslides elsewhere that might be just as significant for susceptibility maps, but that are not otherwise as damaging as highway landslides. These other landslides may not be detailed, evaluated or taken into account or given proper weight in assessing the recurrence rate of landslides in a given area.

We again wish to thank all of the participants for their valuable insights, papers, posters, and presentations, which are critical additions in rounding out the very complex aspects of landslide science.

We hope that the knowledge shared in these proceedings will help others in their approaches and experiences in mitigating landslides.

Landslide Monitoring in the Himalayan Region, India

S.K. Sharma and S. Singh

Abstract

In Uttarakhand, the northern most state of India, comprising the sub and lesser Himalayan region, natural as well as human induced hazards casts a wide shadow over human life. The landslide occurrence is more frequent and is considered to be a major geological hazard. Every year valuable top soil cover erodes and washes away, several places experience massive landslides and debris flow, which results in damage to human life as well as to property. In recent years the intensity of natural hazards has increased surprisingly as a result of increase urbanization, hill slopes are being disturbed due to various construction activities particularly the road construction. It is difficult to stop the debris flow due to natural hazards like earthquake and landslides or weather related or by man made activities like dam and road construction. Number of Eco-task force have been created to conserve the forests. One of the major mitigation strategies could be through micro zonation approach. Satellite imagery can help both the monitoring and measuring of soil erosion.

Keywords

India • Debrisflow • Himalayan • Satellite imagery • Soil erosion

Introduction

According to the United Nations Environment Program (UNEP), natural disasters have become a common occurrence. Moreover, most of disasters happen in developing nations like in India and it is always the poorest who are most at risk like the hilly region habitants of Uttarakhand. These are getting both frequent and more serious. Since 1990, their number increased threefold and their cost, in real terms, rose ninefold culminating into economic losses from weather-related disasters exceeding those for the previous decade. As the population and poverty is increasing in the hilly regions of Uttarakhand, more and more people are having to live on vulnerable land of hill slopes. The earth's natural defenses against disaster are becoming even more eroded due to deforestation. Even, the global warming is playing an important role in controlling the weather conditions of this area.

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Geological Setting of the Uttarakhand Area

The focus is on the Sub-Himalaya and Lesser Himalayan terrain. From south to north, the following sub-divisions of the Himalaya are generally recognized:

1. Sub-Himalaya – refers to southern most part of Himalaya and is demarcated to the south by the alluvial piedmont. To the north, the Sub-Himalaya is delineated by a tectonic Main Boundary Thrust (MBT). The Sub- Himalayan belt consists predominantly of fluvial sequences which have been deposited in the Neogene.
2. Lesser – Himalaya – refers to the litho-tectonic province which is demarcated to the south by the MBT and is separated to the north by the Main Central Thrust (MCT).

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It predominantly consists of Proterozoic – Cambrian shelf to shallow marine sequences deposited in two main belts viz; the inner carbonate belt and the outer Krol belt.
3. Higher Himalaya
4. Tibetan Tethys Himalaya
5. Indus Suture Zone.

Of these, the first two are of relevance to present investigations. The following Fig. 1 shows five seismic zones divisions (I to V) and the area of Sub and Lesser - Himalaya in Uttarakhand lying in the northern part of India which is falling under Zone IV indicated by the green color (The Time of India 2004).

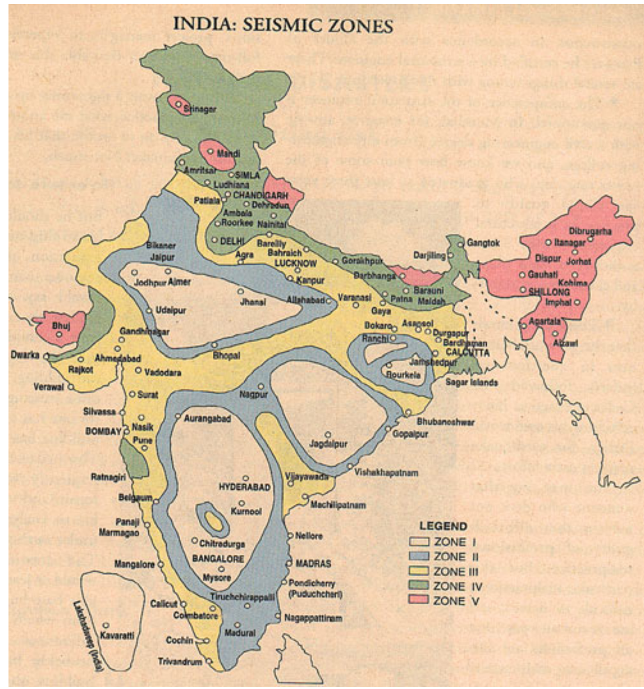

Fig. 1 Seismic Zones of India (*Green color* shows the highest seismic activity zone – Utaarakhand lies in this zone)

Reasons and Consequences of Soil Erosion and Debris Flow in the Area

The area lies in the seismically active Himalayan region where high intensity earthquake are not very uncommon. Uttarkashi (1991 measuring 6.6 on Richter scale) and Chamoli (measuring 6.8 on Richter scale) earthquakes in last one decade are only a few to mention. The two fault lines passing across the Himalayan region – MBT and MCT. Uttarkashi and Chamoli fall on the MCT. The movement gives rise to accumulation of stress and as it exceeds the bearing capacity of the rocks, earthquake occurs due to rock slippage. This loosen the soil and soil erosion in the form of landslide and debris flow is prevalent during monsoon period (July to October). In these rain-fed areas, usually only one single crop is gown, leaving the land unused for almost eighth months a year. This reduces moisture and organic content of the soil, leading to soil erosion. Water percolates down through the cracks and pores. While going down it encounters with slippery layers of shale and clay which are inclined to the valley. Water softens the upper layer which loses its support with the underlying slippery layer and slides down causing disastrous landslides, like Vaunavrat (Fig. 2) which took place 3 years back in the region causing destruction of settlement, uprooting the trees and animals, blocking the local rover flow that posed the danger of flood. Similar danger was posed by Parchu river of Tibet. A landslide blocked the flow of Parchu which is a tributary of Sutlej river that enters Himachal Pradesh in India from Tibet (Down to Earth 2005).

Under the patronage of hill development, number of roads are being constructed to link the remote hilly villages. According to an estimate for the Himalaya, construction of 1 km of road creates 40,000–80,000 m^3 of debris which flows down the hill slopes during monsoon times (Fig. 3).

Fig. 2 Debris flow in the Uttarakhand region

Massive destruction being caused to a dozen villages below Badrinath, Joshimath town due to deforestation for the construction of hydel power projects like Vishnuprayag hydropower project and the recent mega Tehri hydro power project etc.. Cracks have appeared in walls of every house in Chayin village which sits on the slope of the mountain through which tunnels are created by using explosives to divert the Alaknanda Ganga water. This has resulted in landslides

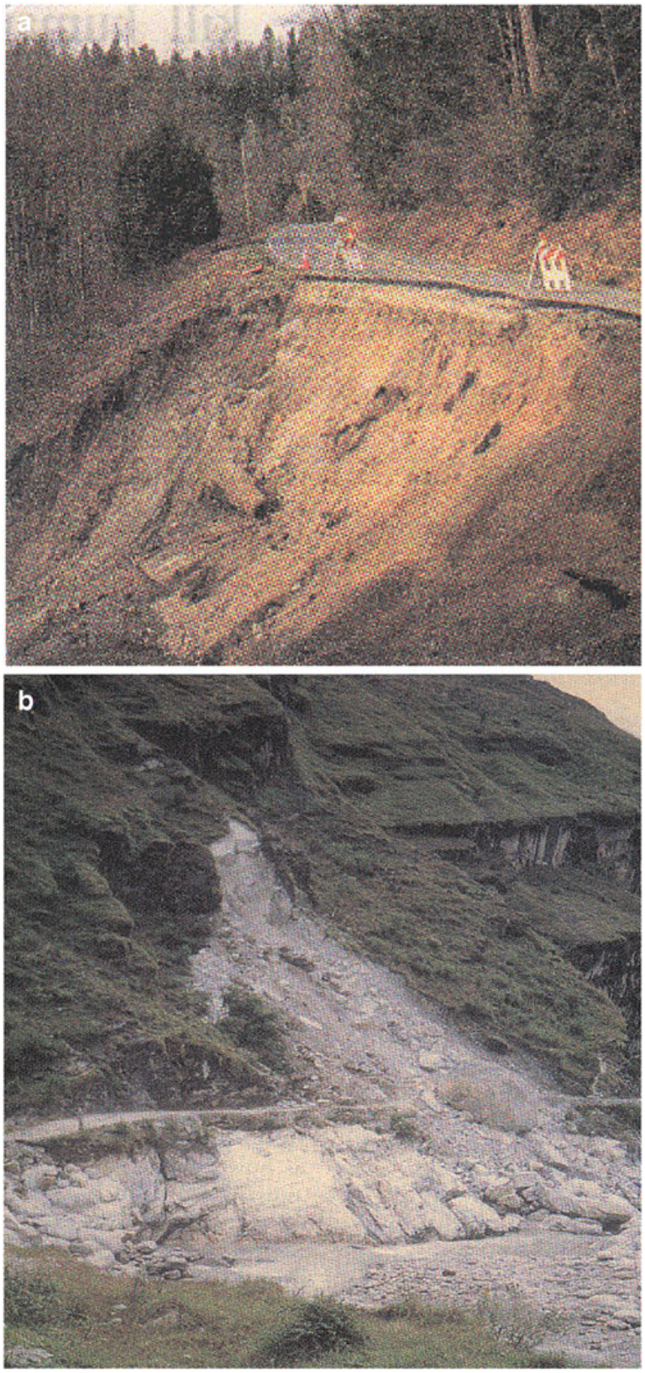

Fig. 3 Debris flow due to road construction (**a**) and due to deforestation (**b**) in the Uttarakhand region

Fig. 4 Debris blocking and changing the flow of Alaknanda Ganga water in the Uttarakhand region

Fig. 5 Debris flow in Tehri village in Uttarakhand

around Joshimath town blocking National Highway 58. The thin layer of soil on rocky slopes, on which the town itself sits and other villages and their terrace fields are built, is sliding down, threatening their existence. The earth all round trembles like in an earthquake, every time the explosive chain is set off. Thousands of tons of rock is being dumped into Alaknanda Ganga, blocking and changing its flow in Tehri village, leading to erosion of its left bank and posing threat to habitants right down to over 300 km way (Figs. 4 and 5).

Mitigation Efforts

In Uttarakhand, the northern most states of India in Himalayas, forests meet nearly 40 % of the energy needs in the form of fuel wood which is of the order of about 235 million m^3 annually and the green fodder for livestock which is also of the order of 882 million tons per year making it 50 % of the

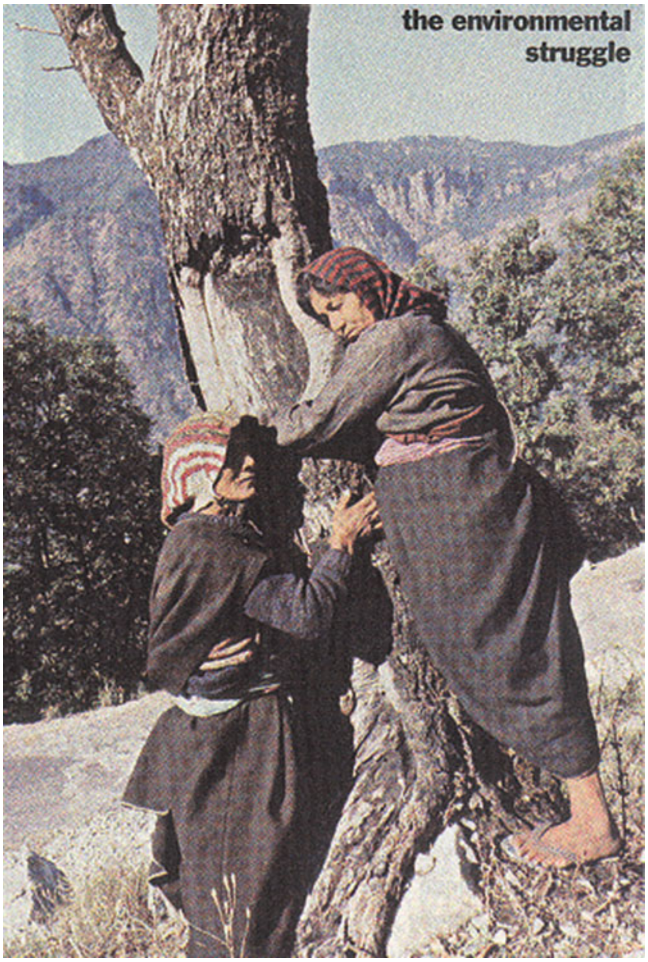

Fig. 6 Chipko (stick to the tree) movement in India

requirement while remaining is met by destructive overgrazing within forests (The Hindustan Times 2006). This has lead to massive deforestation In this regard, However, It is also not possible to maintain absolute conservation in the Himalayas, where the people are dependent on the forests for their basic requirements of water, fuel and fodder. But the landslides can be effectively controlled by putting ban on deforestation. In this regards, Chipko movement initiated by Sunderlal Bahuguna in 1973, in which a human chain around the tree was made by the local people, thus, saving the trees from cutting by the traders plays an important role in restoring ecosystem in the region.

Figure 6 shows the local women clunging to the trees and dared to say the loggers to kill them first before cutting the tree. Their determination compelled the loggers to leave.

The top soil did not lose its contact with underlying layer when the area remained forested. The roots of the plants held the soil from sliding down. A few years later the news of this movement crossed the international boundaries and 'Chipko-Day' was observed at New York in USA on the 29th April, 1983.

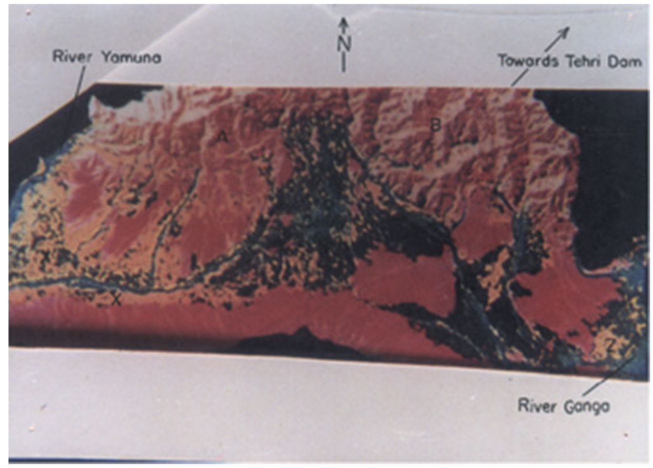

Fig. 7 Showing the present land cover

Monitoring the Damage by Space-Based Satellite

In a bid to quantify the extensive damage due to deforestation and incessant rain, the Uttarakhand state government is now forced to seek help of state-of-the-art space based satellite technology. Such a sophisticated technology is being used for the first time in the Central Himalayan region to assess the natural as well as the human induced damages. The monitoring and assessing the damage of Central Himalayan region through satellite imagery is more relevant than physical land verification because most of the areas are inaccessible due to poor communication. The state government has acquired a Canadian Satellite Radar Sat-II, which is a high resolution satellite fitted with the highly sensitive cameras, that can easily take high resolution physical pictures of the damages caused to the roads, properties, agricultural lands etc. by landslides and flash floods etc. The satellite is being used to provide data pertaining to the rising water levels in all the big dams dotting the Uttarakhand Himalaya including the Tehri dam (260 m high Large Tehri Dam on one of the tributaries of the river Ganges in Central Himalayan Region, is the highest in this part of world) as well as the damages the landslides triggered by these overflowing reservoirs have caused in villages in their vicinity. Besides, there is one more major advantage of carrying out this type of scientific assessment that relates to getting a correct picture of the extent of the damage that would be done by the construction of medium and big dams to the region's fragile hills. Once that is known, it would be easy to take necessary measures required to build such hydropower projects without causing damage to the environment. One of the major monitoring strategies could be through micro zonation approach. Satellite imagery can help both the monitoring and measuring of soil erosion.

Figure 7 showing the Satellite imagery of the present land cover has helped in diving the region into micro zonation

(Geological Society of India 1998). The red color covering an area of about 1,500 Km^2 shows the forest envelope at higher altitudes(more than 2,300 m above sea level, marked with A and B in figure) which is vital for men, plant and animals, fulfilling the basic needs of fuel fodder, manure, medicines and raw materials for industries. The yellow color depicts the agricultural area of about 700 Km^2 where the soil is very fertile having moderate organic content. This region requires special attention as it a high Hazard Risk Zone for probable landslides in future and requires extensive field surveys to prepare management plans.

The green and orange colors together show the plantation of various kind covering an area of about 350 Km^2. The urban area is very less and the area covered by the water is about 20 Km^2 shown in blue color. Thus, he recently acquired satellite images on 1: 50,000 scale have been used to prepare thematic maps depicting the vegetation, soil cover, geo- morphological features, drainage pattern and water shed areas which helped in depicting the land use, in an otherwise, difficult and unapproachable terrain.

In addition to it, number of eco-task force have been created by the Government of India by enacting "The Forest Conservation Act, 1980" to conserve the forests for protecting the valuable soil cover, acquiring fresh water and air, shelter, and a clean and healthy environment in which we live.

Conclusions

We cannot stop natural disasters to occur but we can mitigate the damage caused by them. Landslides and consequently the debris flow can be controlled by effectively controlling deforestation. Thus, a balance is required between development and protection of natural resources in the Himalayan region.

The conservation efforts through pubic participation, namely, the Chipko Movement, enacting various laws and acts by the Central Government and various task forces has mitigated the instability of slopes making them susceptible to potential degradation by deforestation and run-off through flash floods erosion, slide etc. Further monitoring through Canadian Satellite Radar Sat-II which is being used in the Central Himalayan region for the first time has helped in taking appropriate steps, as some of the human activities had an impact on increasingly instability of slopes, making them susceptible to potential degradation by run off through flash floods, sheet erosion and massive landslides/slips.

Acknowledgements The authors are thankful to the officers of the Himalayan Institute of Action Research and Development, Dehradun with whom he had very useful discussions. They are also thankful to their colleagues in the Geological Research Institute who helped them in preparing the paper.

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Losses Caused by Recent Mass-Movements in Majorca (Spain)

Rosa María Mateos, Inmaculada García-Moreno, Gerardo Herrera, and Joaquín Mulas

Abstract

The main income of the island of Majorca (Balearic Islands, Spain) comes from tourism (83 % of its GDP), as it welcomes over nine million visitors each year. During the years 2008–2010, Majorca experienced one of the coldest and wettest winters in living memory. The result was that 34 mass movements were triggered, distributed along the Tramuntana Range, in the northwest sector of the island, namely 14 rockfalls, one rock avalanche, 15 landslides and 4 karstic collapses. Fortunately, there were no deaths but there were numerous cases of damage to dwellings, holiday apartment blocks, barns and power stations, and especially the road network in the range, most significantly the numerous blockages on the Ma-10 road, which caused significant economic losses in the different tourist resorts. On the southern coast of the range, 17 holiday homes have been evacuated recently due to the impending risk of a large rockfall. Total economic losses are valued at approximately 11M Euro, which represents 0.042 % of the Balearic Autonomous Region GDP.

Keywords

Landslides • Rockfalls • Damage • Losses • Resort • Majorca

Introduction

Since the early 1950s, the economy of Majorca has gone through many changes with the tourist trade leading the way. Nowadays, the tourism business has become the main source of revenue for the island (83 % of its GDP). The population of Majorca is approximately 800,000, most of whom work in the tourism sector, attending to over nine million visitors every year.

The Tramuntana mountain range is the main mountainous alignment of the island of Majorca. This region encompasses 16 municipal districts with a total population of 115,000 inhabitants, with the northern face much more heavily populated and urbanised. The economy of the Tramuntana region revolves exclusively around tourism, which accounts for 95 % of its GDP.

The steep topography of this chain, which is linked to its geological complexity and Mediterranean climate, determines intense slope dynamics with the consequent movements of all categories (Mateos 2002; Mateos and Azañón 2005; Mateos et al. 2007). The vast urban development that the Tramuntana region has undergone in the past 30 years has considerably increased the risk originating from mass movements.

During the hydrological years 2008–2010, Majorca experienced one of the coldest and wettest winters in living memory. Not only did the accumulated rainfall show twice the average recorded values, this period also witnessed the highest rates of intense rainfall (up to 296 mm/24 h) since instrumental records have been available (1944). These rainy episodes have also coincided with cold periods in which several days elapsed with temperatures ranging from 0 °C to −6.8 °C, which are anomalous values in the mild Mediterranean climate. The result was that 34 mass movements were triggered,

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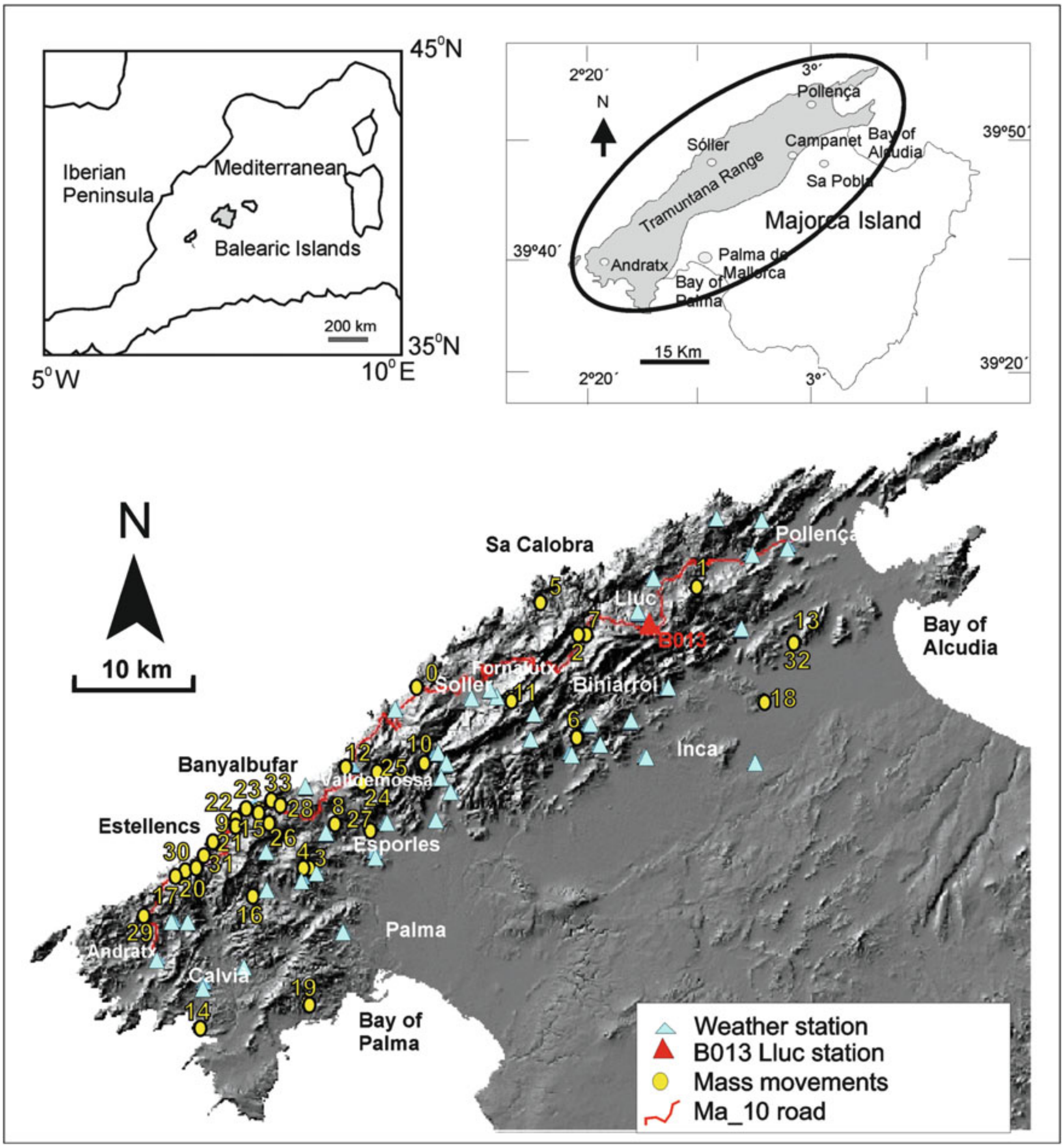

Fig. 1 Location of Majorca in the Western Mediterranean and the Tramuntana Range on the Northwest extreme of the island. The 34 mass movements registered, the weather stations locations, as well as the road network on the range (Ma-10 in *red*), are shown over the digital elevation model

distributed along the Tramuntana Range (Fig. 1). There were 14 rockfalls, one rock avalanche, 15 earth slides- earth flows and 4 karstic collapses.

Fortunately, there were no deaths but there were numerous cases of damage to dwellings, holiday apartment blocks, barns and power stations, and especially the road network in the range, most significantly the numerous blockages on the Ma-10 road, which caused significant economic losses in the different tourist resorts.

This study aims to contribute to the evaluation of the damage and costs caused by these mass movements, in order to get real data that contribute to having a greater awareness of risk in this region.

Recent Mass Movements

During the period spanning from October 2008 to May 2010, the island of Majorca experienced two of the coldest and rainiest winters in living memory, standing out as the wettest years in the past 40 years. On the 15th of December 2008, the highest precipitation was registered in the central sector of the Tramuntana Range since instrumental data has been available (1944). A total of 296 mm of rain fell in 24 h near Soller, and the accumulated rainfall during hydrological years 2008–2010 was almost twice the average value. However, the 2008–2010 period was not only exceptionally rainy on the island but also anomalously cold, with abundant snowfall as well as freezing in the highest zones in the range. This is an unusual occurrence in the mild Mediterranean climate, where extreme temperatures are attenuated by the proximity of the sea. Additionally, the high precipitation and the low temperatures coincided, as the rainfall took place mainly during the winter months, and were linked to cold fronts coming in from northern Europe.

As a result of this climatic episode, 34 mass movements were triggered in the Tramuntana Range, distributed along the entire mountain chain and on both sides of its faces. The inventory of these movements is shown in Fig. 1, where the movements were grouped into three main categories:

- Rockfalls – rock avalanches (15)
- Landslides and mud flows (15)
- Karstic collapses (4)

The structural layout of the materials that outcrop on the Tramuntana Range affected the distribution of the movements. The northern face, where 23 of the 34 movements took place (68 %), is more hazardous due to the existence of steeper slopes and a higher density of outcroppings of soft materials (Gelabert et al. 1992).

The Road Network

13 of the 34 mass movements seriously affected the road network of the range: 7 landslides, 3 rockfalls and 3 karstic collapses caused numerous blockages with significant economic losses in the different tourist resorts.

Ma-10 Road

The Ma-10 road, located on the northern face of the mountain range, has heavy traffic estimated at 7,200 vehicles per day on average, and constitutes the main road of this region. During 2008–2010 eight mass movements (five landslides and three rockfalls) seriously affected the road. Figure 2 shows some photographs of the most important movements, being noted the Gorg Blau rockfall (Fig. 2-2), on 31st December 2008 and Estellencs 2 landslide (Fig. 2-4), on 8th March 2010, which blocked the Ma-10 road for 3½ months, cutting off the access to several locations and villages.

Other Roads in the Range

Secondary roads through the range have also been affected by land movements, especially by karstic collapses. In Majorca, the predominance of a carbonated rocky substrate, mainly limestone and dolomite from the Lower Jurassic, determines the occurrence of common processes in karstic areas, like sinkholes and shallow subsidence depressions. During the past 2 years, pre-existing holes have increased considerably in size. This is mainly due to the increase of the recharge prompted by the intense and continuous rainfall on the island. This additional recharge has not only led to an elevation in the piezometric level of the aquifers, but also (1) a rise in the load due to soil saturation, (2) a loss in internal resistance of the surface materials, (3) the increase in the dissolution processes which affect the rocky substrate, (4) the migration of the cavities and cracks formed in the rock towards the surface (Hyatt and Jacobs 1996; Benito et al. 1995). The results are some karstic collapses which are clearly visible on roads.

Figure 3 shows some karstic collapses affecting the road network (Fig. 3-4, 5, 6) as well as the Cala Tuent landslide (Fig. 3-1, 2) which blocked the road and cut off the tourist resort of Cala Tuent for a couple of months.

Buildings, Dwellings and Others

Rockfalls and landslides during 2008–2010 have also caused serious damage to buildings, holiday houses, dwellings and a power station in several places throughout the range. The area of Costa d´en Blanes, in the southern sector of the Tramuntana Range, should be noted, where 17 holiday houses haven been evacuated due to the impending risk of a large rockfall. This urban area was built in the 1990s surrounding a former gypsum quarry (Fig. 4-6). The geology determines the movement characteristics. Highly karstified carbonatic rocks (limestone) outcrop on the surface with a thickness of up to 10 m. At the base of the quarry, and below the limestone, we can see the marls within the gypsum which were exploited during the mining activity. Large blocks of limestone are sliding over the soft materials, and large cracks have recently appeared at the top of the quarry, affecting some of the houses.

Small rockfalls have also affected houses (Fig. 4-2, 3, 5) and apartment blocks (Fig. 4-4) causing a great alarm in the population. Damages to barns and a power station (Fig. 4-1) have also been registered. Fortunately, there were no deaths.

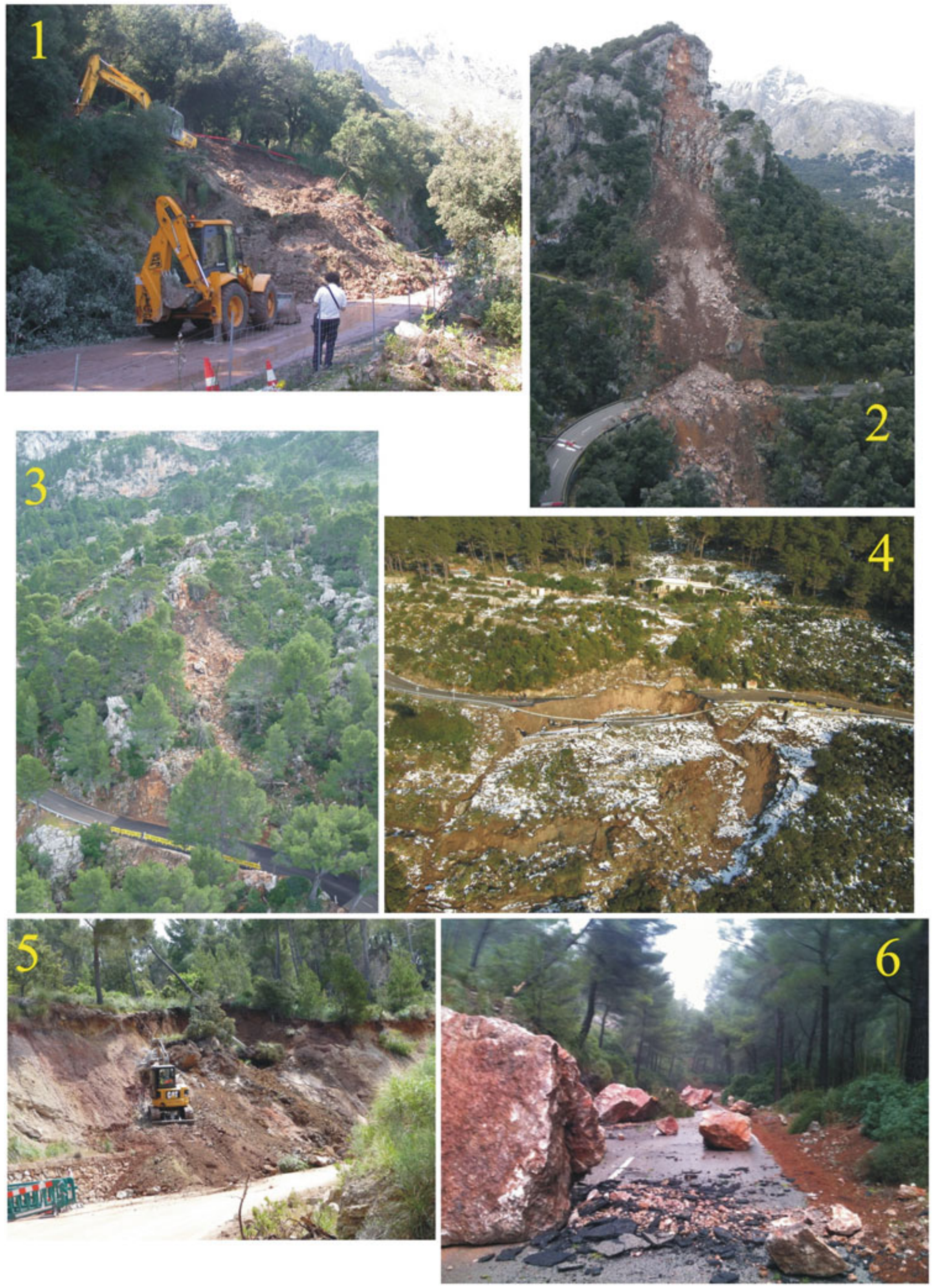

Fig. 2 Photographs of the most important movements affecting the Ma-10 road. *1* Sa Calobra (3/12/2008), *2* Gorg Blau (31/12/2008), *3* Estellencs 1 (15/01/2010), *4* Estellencs 2(8/03/2010), *5* Banyalbufar (09/05/2010) and *6* Pilar (12/10/2010)

Economic Repercussions

Aiming to evaluate the economic losses caused by the mass movements, the authors have contacted various local and regional departments of the Government of Majorca. Road damage was evaluated in accordance with information from the Road Maintenance Services, and included: debris removal from road, adequacy of banking, research and stability projects, as well as those relating to the repair of the road. Indirect costs have also been calculated referring to the economic losses of the different municipal districts affected by the cutting off of the road, such as Banyalbufar, Estellencs and Cala Tuent.

The interruption in tourist arrivals at these localities for several months led to the closure of restaurants, hotels and snack bars, with the consequent loss of jobs and profits. These councils have provided information concerning these indirect economic losses, evaluated by those affected in order to seek compensation from the State and insurance companies.

Referring to repair costs of houses, buildings and others, information was reported by private individuals. In the case of the Costa d´en Blanes development, all economic data relating to ground studies and repair projects, the indirect cost of

Fig. 3 Photographs of secondary roads on the range affected by landslides and karstic collapses (sinkholes). *1* and *2* Cala Tuent landslide (15/12/2008), *3* Es Verger landslide (15/12/2008), *4* Búger sinkhole (Jan 2010), *5* Es Verger sinkhole (15/12/2008) and *6* Crestatx sinkhole (3/5/2010)

houses evacuation, repair cost, etc., have been provided by the Calvià council.

Tables 1 and 2 show all the costs related to each event. Total economic losses are valued at approximately €11 M, which represents 0.042 % of the Balearic Autonomous Region GDP.

Discussion and Conclusions

Mass movements are a serious problem in many parts of the world; they cause casualties, damage to property, and loss of services, and they use significant resources to prevent and mitigate (Roberds et al. 2002). Statistics of fatalities and damage from these processes are not systematically recorded; therefore estimating economic losses is difficult (Ghayoumian et al. 1998). A landslide risk analysis usually considers direct costs, mainly the reconstruction of and repair to exposed elements (Zezere et al. 2008), but it is not usual to include indirect costs, as a large quantity of not readily-available information must be acquired and evaluated.

In the present study, an analysis of the damage caused by numerous mass movements (34) in the Tramuntana range (Majorca) during a rainy and cold period (2008–2010) has been carried out. Not only was the road network seriously

Fig. 4 Damage caused to buildings, dwellings and others by rockfalls and landslides during 2008–2010 in several places on the range. *1* Deià power station (29/10/2008), *2* Biniaraix (6/01/2009), *3* Puigpunyent (14/09/2009), *4* Siesta (8/01/2009), *5* Son Albertí (Jan 2010) and *6* Costa d´en Blanes (Jan 2010)

affected, but also several buildings, dwellings, houses etc., causing great alarm in the population. The repair and reconstruction costs have been calculated based on the information reported by the local authorities, Road Maintenance Services as well as private individuals. These direct costs have been estimated at approximately €6.4 M.

Taking into account that the economy of this region depends mainly on tourism, indirect costs have also been noted, valued at approximately €4.5 M. Road blockages have caused the interruption of tourist arrivals at some localities, which have triggered the closure of restaurants, hotels, snack-bars etc., for several months, with the consequent loss of jobs and profits. The evacuation of 17 holiday houses due to the impending risk of a large rockfall has also caused indirect costs.

In the Balearic Islands, the awareness of risk from landslides, rockfalls and other mass movements was insignificant. The population and authorities were unaware of the damage and economic impact that these processes may involve. The 34 movements recently recorded have completely changed this perception. An area such as Majorca, which lives from and for tourism, cannot underestimate this kind of natural

Table 1 Direct and indirect costs (€) caused by mass movements in the road network of the Tramuntana range, during the rainy and cold period 2008–2010

Movement		Cost (€)	
Inventory No. and date	Damage	Direct	Indirect
Sa Calobra (Nº 2) 03 Dec 2008	Ma-10	100,000	
Es Verger (Nº 3) 15 Dec 2008	Es Verger road	10,000	
Es Verger (Nº 3) 15 Dec 2008	Es Verger road	10,000	
Cala Tuent (Nº 5) 15 Dec 2008	Cala Tuent road	200,000	300,000
Gorg Blau (Nº 7) 31 Dec 2008	Ma-10	15,000,000	1,000,000
Banyalbufar (Nº 9) Jan 2009	Ma-10	6,000	
Crestatx (Nº 13) Jan 09, 03 May 10	Housing development road	200,000	
Búger (Nº18) Jan 2010	Búger road	120,000	20,000
Estellencs (Nº 17) 15 Jan 2010	Ma-10	150,000	
Estellencs (Nº 29) 08 Mar 2010	Ma-10	2,000,000	1,500,000
Petrol station (Nº 31) 09 Apr 2010	Ma-10	20,000	
Banyalbufar (Nº 33) 09 May 2010	Ma-10	300,000	

Table 2 Direct and indirect costs (€) caused by mass movements in several buildings, dwellings, houses and others located in the Tramuntana range, during the rainy and cold period 2008–2010

		Cost (€)	
Movements	Damage	Direct	Indirect
Costa Deià (Nº 0) 29 Oct 2008	Power station	72,000	
Biniaraix (Nº 11) 06 Jan 2009	Small building	12,000	
Crestatx (Nº 13) Jan 09, 03 May 10	Housing develpment street	120,000	
Edificio Siesta (Nº 14) 09 Jan 2009	Building	30,000	
Son Albertí (Nº 15) 23 Jan 09, Jan 10	Small building	20,000	
Casa Puigpunyent (Nº 16) 14 Sept 09	Dwelling	30,000	
Costa d'en Blanes (Nº 19) Jan 2010	Dwellings	1,500,000	1,700,000
Son Antic (Nº 27) 17 Feb 2010	Barn and terraces	30,000	

risk, the safety of the island's population and its visitors must be the priority of all concerned.

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Deep Seated Landslides of Seciurile (Getic Piedmont, Romania) and Its Implication for the Settlement

Sandu Boengiu, Marcel Torok-Oance, and Cristiana Vîlcea

Abstract

The Seciuri settlement in Romania emerged and developed on a corrugated terrain, fragmented by numerous small valleys cut by sheet wash and the Amaradia springs. In the west, north and east, it neighbours two lignite quarries – Seciuri Vest and Seciuri-Ruget, lying at the contact between the Getic Piedmont and Getic Subcarpathians. In the spring of 2006, the settlement was destroyed almost completely by a landslide that perfectly overlaps the heartland of the village. Due to the risks incurred, the local authorities decided to evacuate the village and move it to Campu Mare Depression, where a new settlement was built.

Changes in the slope stability are the results of cumulated effects of various factors, such as: lithology and strata slope, overloading of the slope, water excess on the slopes, artificial mechanical shocks, and changes in the terrain land use. The rainfalls in 2004 and 2005, as well as the sudden melting of snow in the spring of 2006 are the main factors that triggered the landslide. The vibrations induced by coal conveyors and the heavy traffic on the industrial road, both of which are on the upper side of the slope, where the detachment scarp emerged, also contributed to the landslide.

The analysis of the landslide mass indicates that it slid in a series of steps that formed sliding prisms inside this mass, most of the time having a local character. This activity explains the appearance of some local compression of the water logged sand, leading to deepening and local detachment steps.

Keywords

Landslide • Impact • Remote sensing

Introduction

The areas affected by mining activities are mainly characterized by the modification of geomorphologic systems, landscape changes and impact on human settlements. The areas modified by opencast mining had been studied a long time in Oltenia (Cioacă and Dinu 1996, 1998; Boengiu 2007; Anghel and Surdeanu 2007; Boengiu et al. 2008a, b, 2010; Braghină et al. 2010) and internationally (Evans and Willgoose 2000; Goudie and Viles 1997; Hancock et al. 2003). All these evident negative processes cause: deep modifications of the water courses, partial modification or destruction of the water-bearing layers, effects on the biotic and pedological environment, the triggering or the acceleration of present geomorphologic processes, changes of the topoclimate, inundation on inhabited spaces, and impacts on human health.

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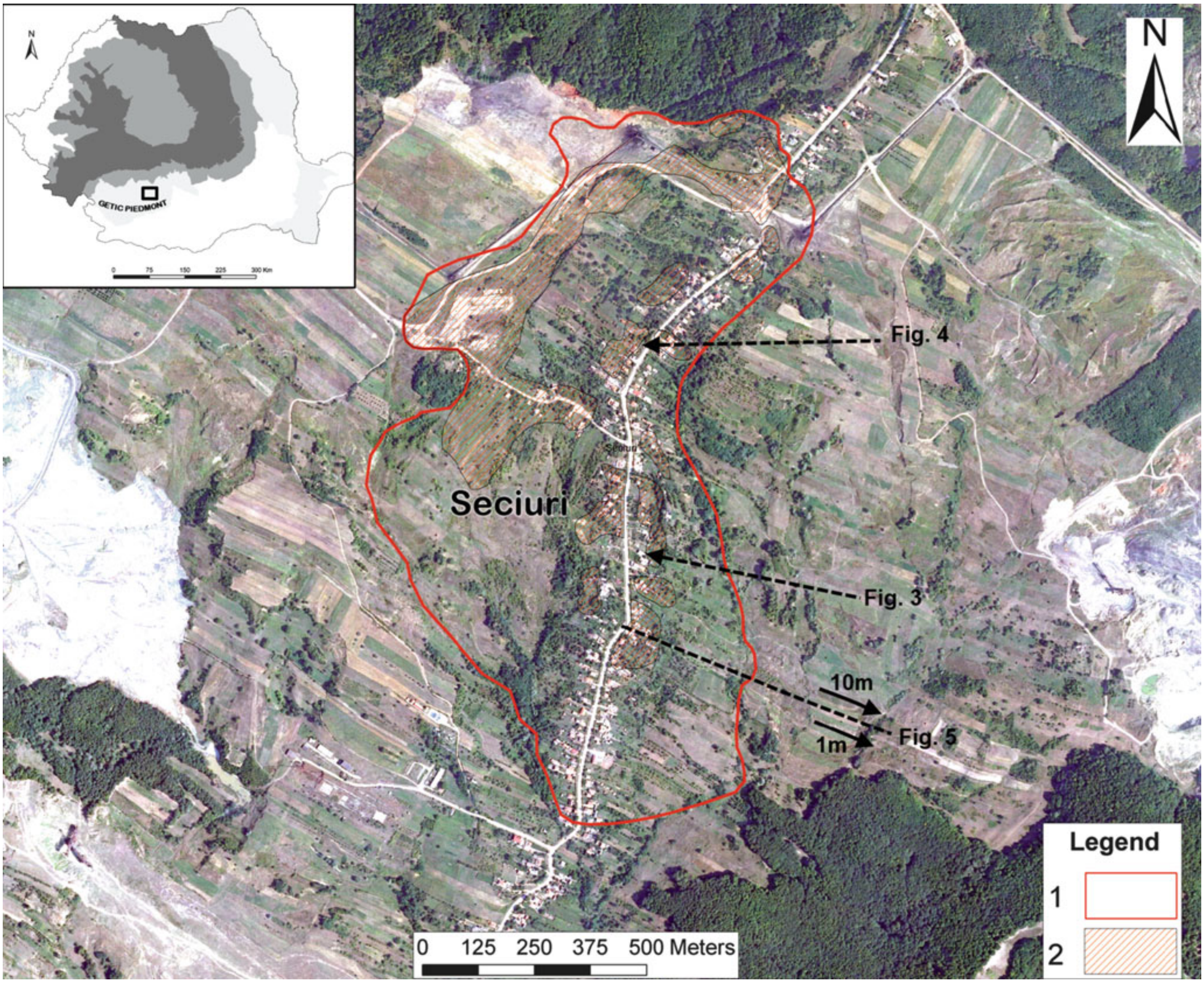

Fig. 1 The location of Seciuri settlement: *1* the area affected by the landslide; *2* subsidence areas

Study Area

The area affected by the landslide is located in the perimeter of Seciurile settlement, Gorj county, along the county road 675 C, Roşia de Amaradia – Poiana Seciuri, in the northern extremity of the Getic Piedmont, Romania (Fig. 1).

From the geological point of view, the area consists of Pliocene and Quaternary formations (Pontian, Dacian and Romanian deposits) belonging to the Getic Depression. In the Dacian and Romanian deposits, in the Seciurile and Ruget open pits nearby, the coal was mined from "layer I of lignite" that crops out, and which also exists in the area of the Seciuri settlement. The Pliocene and Quaternary formations have a monocline structure inclining from north to south with an average value of 5–6° (Boengiu and Enache 2002; Enache 2008).

From the geomorphologic point of view, the area belongs to the hilly region extending southwards to the Târgu Jiu-Râmnicu Vâlcea depression. The configuration of the relief is influenced by the lithological constitution and the structure of the Pliocene deposits. These deposits with high lithological monotony (alternation of sands and clays) having a weak resistance to external factors, generated a monocline relief represented by extended structural surfaces with cuesta escarpments and slopes of 35–40°. The altitude ranges between 350 and 548 m and the hydrographical network is tributary to the Amaradia river (Badea 1967; Aur 1996).

The degree of land cover with vegetation varies depending on the land use. Generally, the slopes corresponding to the structural surfaces are partially covered with forests, fruit bearing trees or pastures. In the perimeter of the settlement, the agricultural lands are predominant,

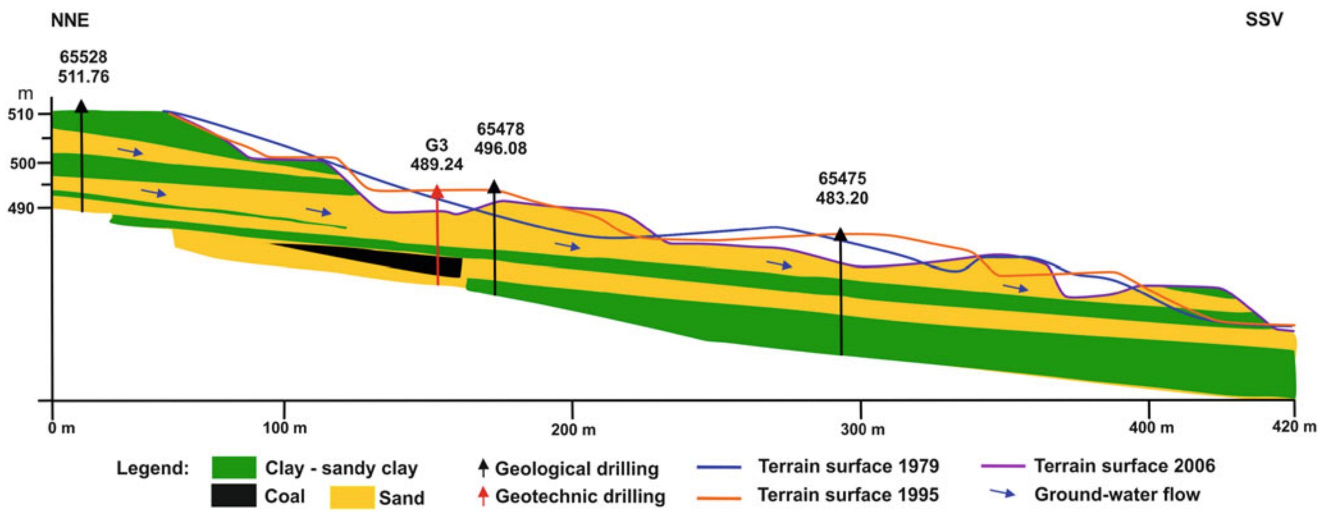

Fig. 2 Cross sectional profile (according to drillings made by I.C.S.I.T.P.M.L. S.A. Craiova)

while the soil with no vegetation layer and the outcrop rocks appear in the areas affected both by mining and erosion.

The landslide occurred in the spring of 2006 in the perimeter of Seciuri settlement and it was triggered by rainfalls, on the background of favourable petrographic and structural conditions and within an area subjected to severe human pressure. The effect of the landslide on the community living in Seciuri was devastating: over 500 buildings needed repairs or had to be reconstructed in other areas that were not endangered. Until now, out of 253 houses, 182 had been already evacuated, and subsequently during the next period the entire village had to be evacuated.

Data and Methods

Because the landslide from Seciuri is not a typical one a complex investigation of the study area was needed. We used the geological, hydrological and climatic data, as well as the topographical surveys, geomorphological mapping and the assessment of the transformations based on the aerophotogrammes taken in different periods of time.

Geological and Hydrogeological Data

The geological and hydrogeological data has been obtained, and was, obtained, in 2006 (I.C.S.I.T.P.M.L. S.A. Craiova), seven geotechnical drill holes were dug in the area of the landslide with depths between 9.50 and 17 m. The drillings, shown in Fig. 2, had been located as follows: G1 and G3 in the northern sector, along the route of the conveyors TMC 4, where the deepest subsidence movements were registered, with depths up to 8 m; G2, G5, G6 and G7 drillings are performed along the county road 675C, Roşia de Amaradia-Poiana Seciuri, where subsidence and landslides occurred and G4 drilling located westward into an area affected by subsidence movements. In all drillings we identified sandy layers, sandy-fine dust layers, liquefiable with thickness of 0.5–10 m that are located under a clayey, clayey-sandy layer of approximate 0.5–2 m. In the G1, G3 and G6 drillings was intersected a layer of hard wood coal with thicknesses ranging between 0.8 m northwards and 5–9 m southwards, being a layer without continuity. In G5, G6 and G7 drillings was intersected a sandy and dusty layer with water up to 10 m thick where there are intercalated two layers of plastic clay of 1–3 m thick and in the depth there is a grey plastic clay layer. In the G1 drilling, the layer of fine sand was intersected with approximate 5 m deeper than in a drilling performed in 1997, which demonstrates that the subsidence phenomenon was triggered in the northern sector. From the laboratory analysis, fine dusty sand intersected in most of the drillings has the following grain composition: sand 56–80 %, dust 14–32 % and clay 6–12 %. The lab analysis obtained for the samples collected from G1 and G3 drillings proved that the sand found in these drillings is identical with the one in the south, on the Cotului Valley, in the section where the subsidence phenomenon occurred.

In the depth, the water was found in the form of springs, the hydrostatic level being established at values ranging between 1.50 m (G3) and 7.50 m (G5). The springs are evidenced especially in the north sector of the landslide, where the subsidence process is more evident (G1, G2, G3, G4). The G4 drilling intersected two springs with high flows, which raised the hydrostatic level at 1.90 m. The flowing direction in natural conditions is NNW-SSE, with a hydraulic gradient < 0.05, calculated on the basis of the piezometric levels measured in the performed drillings. The existing hydrostatic pressure is still extremely high, as there is no proper drainage of the upper water-bearing layer.

Climatic Data

After analysing the pluviometric regime for 2005 and 2006, we noticed that the entire year of 2005 was characterized by rainfalls (Boengiu et al. 2009; Fábián et al. 2010), which fell as snow (January and February) or as long-lasting rainfalls (the interval between March and September, with a peak during April and May). 2006 started with heavy snow, with quantities up to 15 l/sqm in 12 h followed by rainfalls during the March-May interval. According to the National Meteorology Agency, in March 2006, the quantity of precipitations was twice as much than the normal values for this time of year. The monthly quantities of precipitations registered at the closest meteorological station, the Polovragi station, for the first part of 2006, were the following (l/sqm): January 62.6; February 30.7; March **115,6**; April **107,6**; May 74.1.

Topographic Surveys

The topographic surveys performed along the county road starting with the route of the conveyors TMC3-TMC4-TMC4', on the western and eastern side outlined land subsidence processes of high amplitudes up to 8 m, affecting the houses in different stages of collapse (Fig. 2). In the micro-depressions of subsidence that are formed there are found water accumulations of extended surfaces. Eastward, toward the end of the stock-pile at the Poiana Seciuri small pit, there are subsidence processes on extended surfaces, with swampy areas, and surface humping processes downstream, on the N-S direction, including the deviation of the county road. Lateral movements, with smaller deviations, had also been observed.

Geomorphological Mapping

The field investigations showed the presence of numerous cracks, fractures and micro-depressions, where water accumulated creating swamps with variable extensions, especially in the north sector of the landscape. It was noticed that there are several alignments of scarps, being outlined on the western and the eastern one. In the slope sector there are numerous stairsteps, their configuration at the level of microforms being completely modified. The households in the settlement are the most affected, presenting cracks, and fractures and some of them are partially or entirely collapsed (Fig. 3). There are also households that were not affected, but they entirely isolated. There were three torrential valleys identified with an intensive erosional effect (on the right side of the road, the Cotului Stream with two tributaries, and on the left side, the Ferigilor Valley and Pârâul Amaradia spring), which are tributary to the Amaradia river. Also identified were areas strongly affected by erosion along the Cotului Valley, with ravine formation of steep slopes of 3–5 m. The ravines caused local landslides downstream, opening the sandy layers and allowing the dynamic evacuation of water from the intersected layer of sand.

Fig. 3 Photograph of a household (2006), located on a stairstep, which was moved 8 m towards east (see Fig. 1)

Remote Sensing Data

In order to assess the modifications that took place pursuant the landslide occurred 2006 and in order to estimate the geomorphological evolution of the study area, there were used aerophotogrammes from different periods of time: 1979, 1995, 2005 and 2008. The aerophotogrammes from 2005 (an year before the occurrence of the event) and from 2008 are digital coloured aerophotogrammes, georeferrenced in the national system Stereo 1970, with a spatial resolution of 0.5 m and which permitted the accurate assessment of the transformations occurred from the geomorphological point of view and from the point of view of buildings and roads. There could be made a statistic assessment of the displacement degree horizontally for the buildings and roads, as well as the disappearance of some households or road sections S.

Results and Discussions

The petrography and geological structure of the area determines a high potential to landslide; the region is on the list of areas with major risk to landslides occurrence. On the slopes had been noticed since 1978 signs of old landslides (scarps, stairsteps) both in the mining area and outside it. The geological structure is characterized by the alternation of layers with contrasting physical-mechanical properties, a situation which favours the occurrence of displacement phenomena. The inclination of the layers coincides with the inclination of the slope and with the groundwater flow direction, NNW-SSE. The dynamics of the undergroundwater plays an important role in the occurrence of landslides through the significant fluctuations in the pressure of the multilayer water-bearing strata present in the region. The fine grading of the sand layers correlated with the excessive hydrostatic pressure owing to the infiltrations coming from precipitations makes the potential risk to hydrodynamic phenomena like suffusion, running ground or even liquefactions to be extremely high. The safety factor resulted pursuant to the analysis evidences the fact that the slope is relatively stable, but with the values for the safety factor close to the stability limit (1.19–1.22, source Search Corporation). The rise of the hydrostatic level and the slope saturation (due to rainfalls) will cause the loss of its stability by reaching the critical safety factor, without considering other destabilizing factors. In this case, the safety factors vary between 1.03 and 1.06 (I.C.S.I.T.P.M.L. S.A. Craiova).

The rainfalls from 2005 to 2006 cause a considerable rise of the groundwater layer from the layers of sand and to an intensification of the erosion by the Amaradia river and its tributaries.

The rise of the groundwater layer was possible, in the north sector, due to the presence of a feeding area for the water-bearing layer from precipitations, an area of about 10 sq km where fine, friable sands outcrops with thicknesses over 10 m. Between the feeding area in the north and the thalweg of the Amaradia brook there is a difference level over 100 m, which allows the accumulation of a static pressure of 1–5 bars (source Search Corporation) depending on the quantity of water accumulated. In addition, the existence of some lakes and puddles with important water accumulations in the depressions located upstream of the Valea Ferigilor and Valea Cotului springs favoured the feeding with water of the sand layers and contributed to the variation, in time, of the hydrodynamic pressures causing high variations of the flows drained in the underground.

The intense rivers erosion lead to local landslides which opened the ends of the sand lens, causing their hydrodynamic release driving the fine particles of sand. The landslides occurred closer and closer, from downstream to upstream. At a certain moment, due to maximum water accumulations and because the landslides cut the ends of the layers, revealing the water-bearing strata, the fine, liquefiable sands under high pressure outburst through these breaches and caused the siphoning off of the water-bearing (release from under the pressure), when the areas above the fine sands to sink. The hydrodynamic convey of the sands was made on the line of the highest layers slope.

Deforestation, road construction and heavy traffic, mining exploitations, the increase of the number of houses in the Seciuri village from about 60 in 1979 to approximate 200 houses in the present, most of them built without geotechnical permits, represents important factors which favoured the occurrence of mass movements in this region.

By comparing the information from the aerophotogrammes taken in 1979 and 1995 with the result of the topographical survey made in 2006 we noticed a continuous descend with 3–10 m of the levels in the north and a level increase in the south. On the aerophotogrammes taken in 1979, in the north-western part of the landslide were lakes located upstream of the springheads of Ferigilor and Cotului valleys.

After 1979, the date of the first flights and until 1995, when the following flights were made, the surface of the analysed area evolved as follows:

– From N to S there can be observed a vertical movement of the land with lateral displacement of the material, causing level decreases in the N and level increases in the south.
– The vertical movements ranges between 0 and 8 m.
– These phenomena had been noticed since the construction of the conveyors TMC 3 and TMC 4 (1981), when we find in the execution designs observations regarding vertical movements.

The comparison of the aerophotogrammes from 2005 to 2008 outlines the occurrence of major changes in the area of the landslide: the presence of numerous catsteps and scarps, intensive active erosion, total destruction or strong displacement of certain road sectors. Based on the aerophotogramme taken in 2008 and the field data we delimited the area affected by the landslide (95.2 ha) as well as the areas which undergone subsidence movements (0.22 ha). By the digitization of the road network and the buildings perimeter from both photogrammes we determined the amplitude of their horizontal displacements in different sections of the landslide. Therefore, we determined displacements ranging between 1.19 m in the western part and 74.57 m east of the settlement, with an average value of 15.76 m for the displacements (SD $\pm$ 15.66). For the central part of the landslide, along the road crossing the settlement, the average values for the displacements were 22 m. We identified five directions of movement among which three are predominant. Most of the movements are directed southward, followed by the marginal sectors with south-east and south-west movements.

From the observations made after a few years since the occurrence of the landslide, we notice that the instable processes tend to attenuate, but as the hydrostatic level and pressure recuperate due to excessive precipitations it is possible for the phenomenon to be reactivated. Generally, the existence of dead waters accumulated into the micro-depressions contribute to the maintenance of a high potential of landsliding, the permanent source of humidity being one of the most important factors in triggering the landslides. The immediate solutions used to stabilize the slopes in these type of cases is to drain the dead waters into the slope.

Conclusions

The phenomena that occurred in May of 2006, in Seciuri village are complex subsidence and landslide phenomena that occurred on the background of important unbalances accumulated in time due to unfavourable natural factors of geological, hydrological and hydro-meteorological nature and to human factors (deforestations, mining exploitations, road construction for exploitations and heavy traffic, etc). There must be noted the fact that these phenomena occurred along with the occurrence of long-lasting rainfalls which extended from the spring of 2005 until the spring of 2006. The phenomenon is not singular, during the period April-May, in 2006, in the entire Subcarpathian region were numerous landslides which affected the settlements and the infrastructure.

From the structural point of view, the alternation of clays and sands, which crop out in the northern part of the settlement and on the slope, facilitated the formation of ground and captive waters, and the ones located under the local base of erosion have an uplifting character. The water-bearing layers are mainly fed from precipitations in the outcropping areas. The existence of the water-bearing layers led to the formation of numerous springs and swampy areas into the micro-depressions and to the construction of wells with the water table at shallow depths (1–7 m). The inclination of the strata is according to the topography and the deviations of level between the north and the south part of the Seciuri village is about 100 m, which causes the accumulation of important hydrostatic pressures.

An important role was played by the lakes and the puddles formed in the micro-depressions on the slope which contributed to the variation, in time, of the hydrodynamic pressures and which caused high variations in the groundwater flows producing the destabilization of the slopes.

The intense deep erosion of the rivers, with accompanying rainfalls and in the presence of high friable petrographic formations, permitted the cutting of the water-bearing sand layers in the southern part of the region which triggered the landslide. The change in the consistence of clays and the liquefaction of sands due to the groundwater activity allowed the phenomenon to spread regressively. The sudden evacuation of fine sands caused the subsidence of the areas above these layers up to 10 m. Most of the sunken surfaces are located in the northern and central part of the settlement and totalled 0.22 ha.

Fig. 4 Photograph of a banded household (2007), located in a sinking area of 2–4 m (see Fig. 1)

Fig. 5 County road fold-out on 9 m length (see Fig. 1)

In the area affected by the landslide, an area of approximately 95.2 ha, we noticed a big transformation of the landscape with the occurrence of stairsteps, depression areas and scarps. In most of the areas we notice an intensification of the erosion with ravine formation. The average movement rate determined by photogrammetric measurements is of 15.76 m (SD ± 15.66). In the area where most of the constructions are located, along the county road, the average values of the movement were 22 m. The different inclination of the damaged constructions, different collapsing directions, as well as the maintenance of some stable areas in the heart of the village, proves the complexity of the phenomenon (Fig. 4).

The Seciuri settlement had 852 inhabitants and 253 houses of which 189 households were damaged (75 %). In most of the cases they needed to be reconstructed somewhere else, in safer areas, talking actually about a transposition of the entire settlement.

In the areas with average vulnerability we calculated the annual rates of material and human damages in terms of costs. The calculation was made for the households, the road and the population resulting in a population vulnerability of 0.6 (source Search Corporation, 2007), damages of 86,750 € due to the destruction of 4,975 km of county road (Fig. 5) and rural roads, and 2,162,500 € in losses to the households and the outbuildings.

Presently, the region has a high geomorphological-based potential regarding the mass movement, torrential erosion and the erosion of the hydrographic network. The increase of the flows and the ensuing speeds of the rivers after rainfalls can cause the undercutting of the slopes and to the reactivation of the phenomenon. The solution to prevent these types of phenomena is to take complex geotechnical and hydrotechnical measures and to reduce the human-induced factors in the region.

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Landslide Damages: An Econometric Model for Estimating Potential Losses

Kevin M. Simmons

Abstract

Loss estimation for landslides has largely relied on historical slides to serve as a guide for what may be expected in future events. Little has been done to evaluate the role socio-economic factors may play. This paper uses data from the U.S. on landslide events combined with demographic data from the U.S. decennial census to create an econometric loss estimation model. The model shows how a similar event may differ in the amount of damage depending on changes in population, income and other variables and provides a proto-type for the development of future damage functions on landslides.

Keywords

Landslide damages • Loss estimation

Introduction

Social scientists have been interested in natural hazards for many years. But it has only been in recent years that the systematic study of natural hazards has been undertaken by economists, while geographers and sociologists have made it a major topic of their discipline for several decades as Gilbert White and Dennis Mileti[1], are notable examples.

Interest by economists increased after Hurricane Andrew hit South Florida. This event caused over 16 billion dollars worth of insured damages and perhaps twice that amount in uninsured damage. Such a large dollar event was the spark necessary to attract the attention of economists but also the funding agencies which provide the support for university research.

The most comprehensive attempt to judge a community's risk to natural hazards is perhaps the HAZUS program managed by FEMA[2] in the U.S. Wind and flood events are the most common natural hazard in the U.S. and both of these hazards are incorporated into HAZUS. The only geological hazard included is earthquakes. What makes HAZUS so powerful is the incorporation of social and economic profiles of communities to estimate how a future hazard may impact an individual locale. In this way, it goes beyond just examining the direct damage from an event and tries to anticipate the overall cost of an event on a particular community.

Wind events such as hurricanes and tornadoes are common in the U.S. and provide enough annual observations to give researchers the necessary data to perform robust analyses. Geological hazards occur less frequently than wind storms and thus creating socio-economic profiles of these events is more challenging. But the events can be catastrophic and therefore would greatly benefit from this type of analysis. Attempts have been made to categorize the costs associated with landslides (Wang et al 2002; Highland 2006), but the approaches do not attempt to use econometric techniques. An econometric approach attempts to examine how damages vary as certain explanatory variables change while holding others constant (Greene 2003; Heckman 1976). In other words, how would damages from a landslide in California, in a densely populated county compare to a similar landslide in a more rural part of the country?

[1] Natural Hazards Center, Boulder CO.

[2] Information about the HAZAUS program can be found at: http://www.fema.gov/plan/prevent/hazus/index.shtm

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To conduct a meaningful cost/benefit analysis, it is necessary to have a tool to estimate the potential damage that may occur from a future landslide event. This paper does not propose to provide parameters that could be used in definitive estimates of potential damage from landslides. Rather, it provides a prototype methodology for estimating damages that can be expanded and enhanced as data sources and techniques improve. This project is, to my knowledge, the first attempt at creating a socio-economic profile of landslides in much the same way as what has been done for wind storms, floods and earthquakes.

Landslide Losses

In the U.S., landslides cause average annual damages in one to two billion dollars per year (given in 2000 dollars, National Research Council 1985). Additionally, approximately 25 U.S. fatalities are attributed annually to landslides.[3] As a comparison, tornadoes, a much more common and publicized event cause average annual property damage of one billion per year and 80 fatalities.[4] While the economic damage from landslides is similar to that caused by tornadoes, landslides receive much less attention in the media. Indeed a cottage industry has sprung up around chasing tornadoes, during the late spring and early summer. Landslides do not receive the same public attention or fascination and consequently are often overlooked. The exception is when a large event occurs, particularly if casualties are involved. The mudslides in Uganda, during the month of February 2010, are a notable example as well as the tragic mudslide in Zhonqu China later that same year which claimed more than 1,700 fatalities.[5]

While landslides occur in every U.S. state, most of the activity occurs in the western U.S. with most of the attention focused on Southern California. Its vulnerability was recognized early on (Putnam and Sharp 1940). This part of California has experienced dramatic population growth in the 70 years since that study. The exposure provided by the growth is made worse as one of the most appealing locations for a home is on the side of a mountain or hill. Unfortunately, many of these homes are then located on soils prone to landslides and this type of urban development, while aesthetically pleasing, only increases the potential for future damage. Losses from landslides can be avoided or minimized, but it takes knowledge on the part of developers to recognize areas that should be avoided and pay careful attention to how slopes are graded before structures are built (USGS 2005).

[3] http://landslides.usgs.gov/

[4] http://www.economics.noaa.gov/?goal=weather&file=events/tornado&view=costs

[5] http://edition.cnn.com/2010/WORLD/africa/03/02/uganda.landslide/index.html?iref=allsearch

Damage Functions

An econometric approach would attempt to create a damage or loss function for landslides. Loss functions are common in other events and a simple illustration would be a model that attempts to explain the monetary damage to a home by regressing it against a vector of contributing factors. In the case of a hurricane, for instance, the damage to a particular home depends upon the wind speed at that location, structural characteristics of the home and other factors such as the age of the home, type of roof geometry, etc. When damages are examined in the aggregate, rather than at a specific address, the overall damages may depend upon factors such as the population density of the area, average income of the area and factors which either mitigate or increase damage from the event.

Data

The data used for this study comes from two sources. First, the landslide event file was obtained from the natural hazard database (Hazards and Vulnerability Research Institute 2009) maintained by the University of South Carolina called SHELDUS.[6] This database provides the date of the event, location at the county level, type of landslide, property damage and casualty information.

Demographic variables for all events include population density and income gleaned from the U.S. Decennial Census. Intuitively, a denser population should increase damage, other things remaining equal, and economic theory suggests that safety is a normal good, meaning that damage may be inversely related to income. On the other hand, as income increases, the value of property increases as well. As a result, there is no strong expectation on the effect of income on damages. Years between censuses are estimated using linear interpolation. It should be noted that many more landslides are contained in the file from recent years. This is a common problem in studying natural hazards. Events that occurred 40 or 50 years ago were less likely to be documented than more recent events. As a result, two levels of analysis were conducted. The first level uses the full dataset, which goes back to 1960, and the second level focuses on the last 6 years, 2003–2008, which contain 94 or over two thirds of the observations.

[6] http://webra.cas.sc.edu/hvri/products/sheldus.aspx

The more recent data is merged with additional demographic data at the county level obtained from the 2000 U.S. Decennial Census. Years after 2000 were estimated by linear interpolation based on changes between the 1990 and 2000 Census. Census data is available at the county level, which is not as desirable as more finely tuned data but the landslide event file provides only the state and county fips code for the event and not more specific location information. Demographic variables for the more recent analysis included percent of the county that is rural, age, educational attainment and ethnic variables as well as information on the county's housing stock. Also, information about the poverty level and income distribution, the GINI coefficient[7], for each county is included.

Finally, data on possible precipitating events, wildfires and thunderstorms are again taken from the SHELDUS database. For wildfires, the study used any wildfire that occurred in the 24 months prior to the landslide event and for thunderstorms, the number of rain days in the 30 days prior to the landslide event.

Analysis

Descriptive Analysis

The initial analysis was conducted by examining descriptive statistics for several groupings of the data. Damages, in 2007 dollars, are compared against the type of landslide, state, decade, population and income, groupings. Results are shown in Tables 1, 2, 3, 4 and 5. The event file provides both property and agricultural damage but the study focused on total damage which is simply the sum of property and agricultural damage.

In Table 1 through Table 3 average damage is examined by type of slide (Table 1), region (Table 2) and decade of occurrence (Table 3). Beginning with Table 1 a great deal of variability is apparent on damages sustained from one type of slide versus another. The first three types illustrated are large slides triggered by another event. As shown in Table 1, the leading categories for average damages are slides triggered by an earthquake and a lahar. Also, two landslides in the sample were a direct consequence of large weather phenomenon, Hurricane Jerry and a second by El Nino storms. These are rare events and the sample has only one occurrence for each so little can be generalized from these damage figures. However, three categories do have sufficient observations to make comparisons, rock slides, mud slides and landslides. Damages from Rock Slides are far and away the leader with average damages of over 300 million (USD)

Table 1 Average damage by type of event

Type	Events	Average damage
Lahar	1	1,090,000,000
Earthquake	1	700,000,000
Weather	2	10,800,000
Rockslide	8	300,000,000
Landslide	109	16,400,000
Mudslide	17	2,000,000

Table 2 Average damage by decade

Decade	Events	Average damage
Pre 1980	15	140,000,000
1980	16	158,000,000
1990	13	86,000,000
2000	94	3,100,000

Table 3 Average damage by region

Region	Events	Average damage
West Coast	67	83,000,000
Rocky Mountains	34	13,000,000
Plains	3	2,800,000
Appalachia	16	2,100,000
Alaska	5	895,000
New England	13	308,000

and are an order of magnitude larger than the next category, landslides at 16.4 million. Mudslides cause average damages of 2.1 million.

When average damages are examined across time (Table 2), a declining trend is apparent. Part of this trend can be explained by the earthquake and lahar slides which occurred in 1971 and 1980 respectively. It should also be noted, however, that older time periods tend to report only the very large events. As can be seen in Table 2, two-third of the landslides across the entire period occurred before 2000. Thus, average damages would decline when calculated using both larger and smaller events.

Damages by region are illustrated in Table 3 and paint a picture that matches closely with expectations. Average damages for landslides on the West Coast of the U.S., are 83 million, almost seven times larger than the next category, Rocky Mountain states which have average damages of 13 million. The next region is landslides which occur in the Plains states but there are only three observations so the average may not be a good estimate to use as a guide for the typical event. Landslides in the Appalachian Mountains have average damages of a little more than two million followed by Alaska, 895,000 and New England, 308,000.

Tables 4 and 5 show average damage by income level (Table 4) and population density (Table 5). For these tables the observations are limited to the more recent landslides to avoid the bias that may occur from older data that is heavily

[7] GINI coefficient is a measure of income inequality.

Table 4 Average damage by income range (2003–2008)

Income range	Average damage
0–35,000	1,800,000
35,001–48,000	1,296,000
48,001–61,000	639,000
61,001+	3,243,000

Table 5 Average damage by Pop. density (2003–2008)

Pop. Den. per sq mile	Average damage
0–15	563,000
15–72	1,715,000
72–293	772,000
293+	3,051,000

weighted by the large historical events. Table 4 shows the change in damage as income increases. As mentioned previously, economists consider safety a normal good and expect damage to decrease as income increases. This is evident as income increases but when we reach the highest level of income, damage increases dramatically, perhaps reflecting the other role that income plays; that of having property that is worth more and thus more costly to replace. In Table 5, damage is examined by the density of population. There is no apparent trend in this table which highlights the limitation of only using descriptive statistics to evaluate potential trends.

Regression Analysis

The limitation of relying solely on descriptive statistics is that subtle relationships among the variables may be difficult to see. Regression analysis was conducted on the data to try and uncover some of the effects that changes in one independent variable may have on the dependent variable. Results are used to illustrate how econometric models can provide estimates for potential damages in future events. Since damage should increase as the population in a landslide prone area increases, regression results are used to illustrate how two variables related to increased population, population density and the urban/rural mix of the county, affect damage.

The data on landslides is much more consistent after 2002 so regression analysis is limited to observations in the years 2003–2008. This represents two-third of the data but does lose some of the larger events, such as landslides affiliated with an earthquake and severe weather phenomenon as well as the one lahar.

For the damage functions the regression specification is a semi-log equation where the natural log of damages is regressed against the vector of independent variables. The independent variables can be described in categories that may affect damages. First, the model used a set of binary variables for each of the various regions where landslides occurred using the Rocky Mountains as the omitted category. Second, the model used data on precipitating events, the number of days of rain in the month preceding the event and whether or not a wildfire has occurred. Additionally, the number of rain days is combined with whether a wildfire occurred to test the interaction of these two precipitating events. Socio-economic data on population, income, percent of the county that lives in poverty and the GINI coefficient are included. Next, demographic data describing the makeup of the local population is included as controls. Finally a binary variable for each year is included with 2003 as the omitted category. The use of a time trend is a common way to capture any variability in damages that may not be covered by the other variables. For instance the role played by enhanced communication technology is one example.

Regression Results

Results from the model indicate that the model does provide a reasonable prediction of damages but is not as strong as hoped. One weakness of having the data at the county level rather than at a more specific GIS location is that counties can be large units and the average demographic data may not be representative of the actual location of the landslide. Unfortunately, this is the level available for this study so interpretations of the regressions should be made with that noted caveat. The F statistic for the regression model does exceed the critical value so the hypothesis that the coefficients of the independent variables equal zero is rejected.

However, some trends are apparent. Population density and the amount of the county that is rural are both highly significant predictors of damage, as expected. Additionally, both have the expected signs, positive for population density and negative for the percent of the county that is rural. The strong performance of population density illustrates the potential that an econometric damage function can provide. If descriptive statistics alone were used, the contribution of increased population density would be possibly overlooked. These two variables will be used to illustrate how point estimates can be derived to estimate potential damage scenarios.

Damage Analysis

Using the coefficients from the regression model, analysis can be conducted on the damages by comparing various point estimates. A point estimate is an estimated level of damages given certain values of the independent variables.

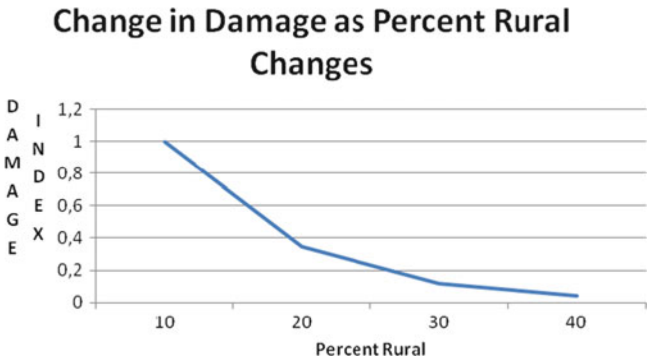

Fig. 1 Illustrates how damage would change as the urban rural mix changes

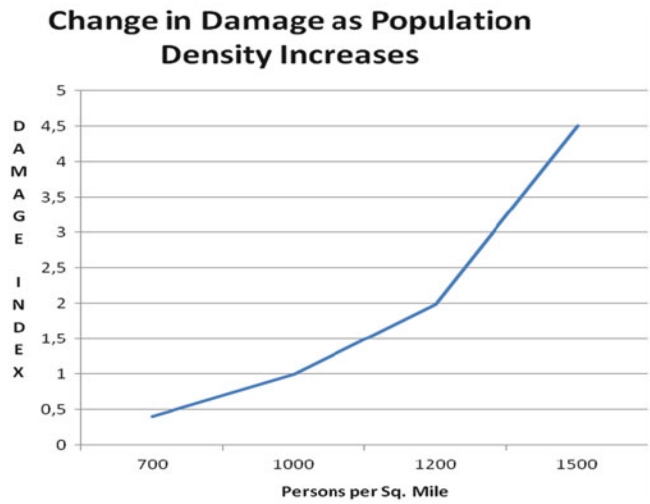

Fig. 2 Illustrates how damage may change as population density increases

This allows for running "what if" scenarios. It gives policy makers a powerful tool in estimating how a landslide may affect one location versus another or how one type of landslide may be more damaging than another in this location. Also, the planner would use socio-economic/demographic data in the model that is specific to that location.

As an example of the power of this tool, results from the regression are used to illustrate how changes in two of our variables could affect estimated damages. The two variables are the urban/rural mix and the population density. For the sample regression, both of these variables were highly significant in estimating damage. Additionally, they both had the expected signs, positive for population density and negative for percent rural.

Figure 1 shows the percent change in estimated damages by different levels of the percentage of a county that qualifies as being rural versus urban, holding all other variables constant. Four levels of rural percentage are shown from 10 %, which is the base of the index, to 40 %. It becomes obvious that as the county's rural area expands, damage declines. Also, it is apparent that the damage does not decline in a linear manner. This suggests that it is more than simply the portion of the county that qualifies as rural. As suburbs expand, they must also make investments in infrastructure, roads, sewers, water systems, that are costly to repair as well as the dwellings that may be affected by the landslide.

Figure 2 shows how damages may vary as the population density of an area changes. Population density is related to the percent rural but may also differ from one community to another based on the type of housing. A community with single family homes on large lots may be urban but will have a lower density of population than an area composed of multi-family housing such as duplexes or apartment complexes. The graph illustrates how damages can rise dramatically as population density increases. A destroyed apartment complex will create more damage, first because of the construction cost to replace it compared to a single family home. But, damages also rise due to the increased content damage from more families living in the building compared to a single family home. Additionally, residents demand more services which the commercial sector will provide. The merchants may not live in the area but have investments in their business which may be affected by a landslide event.

The degree to which this tool can be used depends greatly on the amount and quality of the data available for the regression model. For instance, if good information on precipitating events such as rainfall and wildfires are available, an estimate can be calibrated to see how damage would increase as rainfall increases or if the area experienced a wildfire prior to the landslide. Also, by knowing the profile of the resident population, estimates can be altered to reflect a community of young families as opposed to a retirement community, for instance.

Conclusion

Annual damages from U.S. landslides can run into the billions of dollars yet few planning tools are available for policy makers to use as they consider their strategy in dealing with this hazard. Planners who attempt to anticipate how a landslide may affect their community need data that will allow them to construct studies on how to minimize those effects. To properly conduct benefit/cost analyses, they need a tool that will give them estimates of damage tailored to their community rather than anecdotal estimates from damages which occurred at other locations and that may not reflect the profile of the local area.

This paper uses data from the U.S. on landslides to construct an econometric damage function. The data on landslides was merged with demographic and socio-economic data from the U.S. Decennial Census to create a dataset that is used to create profiles of potential damage from these costly events. Damage functions allow policy-makers to estimate potential damage from events that have not yet occurred by evaluating the relationships between variables that influence damage from previous events. While the results of this project do not provide estimates that should be used reliably by planners, it does illustrate the benefit of having this approach in the toolkit of planners as they consider various “what if” scenarios as well as undertake the cost reasonableness of potential landslide mitigation. Trade-offs are inevitable with any approach but to intelligently choose among the options available, planners need to know the potential damage from the hazards they may face in their particular community. An econometric damage model can provide them with this valuable tool when planning for the next and often inevitable landslide.

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Evaluation of Landslide Inventory Information: Extreme Precipitation and Global Patterns

Dalia Kirschbaum and Robert Adler

Abstract

This study has identified an increase in the number of reported rainfall-triggered landslides in 2010 based on a global database of reports compiled since 2007. Three test areas are identified as having an increased number of landslide reports, including Central America, the Himalayan Arc, and central eastern China, and are compared with precipitation signatures from Tropical Rainfall Measuring Mission (TRMM) data at monthly and daily time scales for a record from 1998 to 2010. Several test statistics confirm that the monthly and daily rainfall patterns were anomalous for 2010 and closely mirror the occurrence of landslide reports over each region. Findings suggest that with additional landslide information and rainfall data, we may be able to better define relationships between extreme precipitation and landslide activity at regional and global scales.

Keywords

Global rainfall-triggered landslide catalog • Precipitation extremes • TRMM

Introduction

Over large areas, landslide initiation processes are often difficult to quantify due to the complex interaction between rainfall infiltration and surface materials as well as the dearth of accurate landslide validation data. Studies have worked to characterize landslide triggering over large spatial scales using empirically or statistically-derived rainfall relationships to approximate the potential for slope failure (e.g. Caine 1980; Guzzetti et al. 2008; Larsen and Simon 1993). However, characterizing the spatiotemporal distribution of landslide occurrence and rainfall triggering characteristics is challenging when these evaluations are extended over larger areas.

Several recent studies have sought to catalog landslide occurrence worldwide using specific indicators. EM-DAT (http://www.emdat.be/) keeps a record of wet and dry mass movement events that cause fatalities, economic damage, or affect populations. Petley et al. (2005) has developed a global database of landslides causing fatalities from 2003 to the present. Kirschbaum et al. (2009) has been developing a rainfall-triggered Global Landslide Catalog (GLC) to identify the occurrence of rapidly-moving landslides events worldwide from 2007 to the present. Upon completion of the rainfall-triggered GLC[1] for 2010, the authors found that the database had a considerably larger number of reported rainfall-triggered landslides across the globe, as well as more reported landslides with fatalities for 2010, as compared to previous years in the catalog. The question is: Is this seemingly anomalous year for landslide activity in the catalog associated with anomalous behavior in global or regional precipitation patterns as well, or is it merely an artefact of the cataloging effort? Understanding if or how changes in precipitation intensity and accumulations impact reported landslide activity may shed new light on

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[1] GLC information and documentation is available at http://trmm.gsfc.nasa.gov/publications_dir/potential_landslide.html

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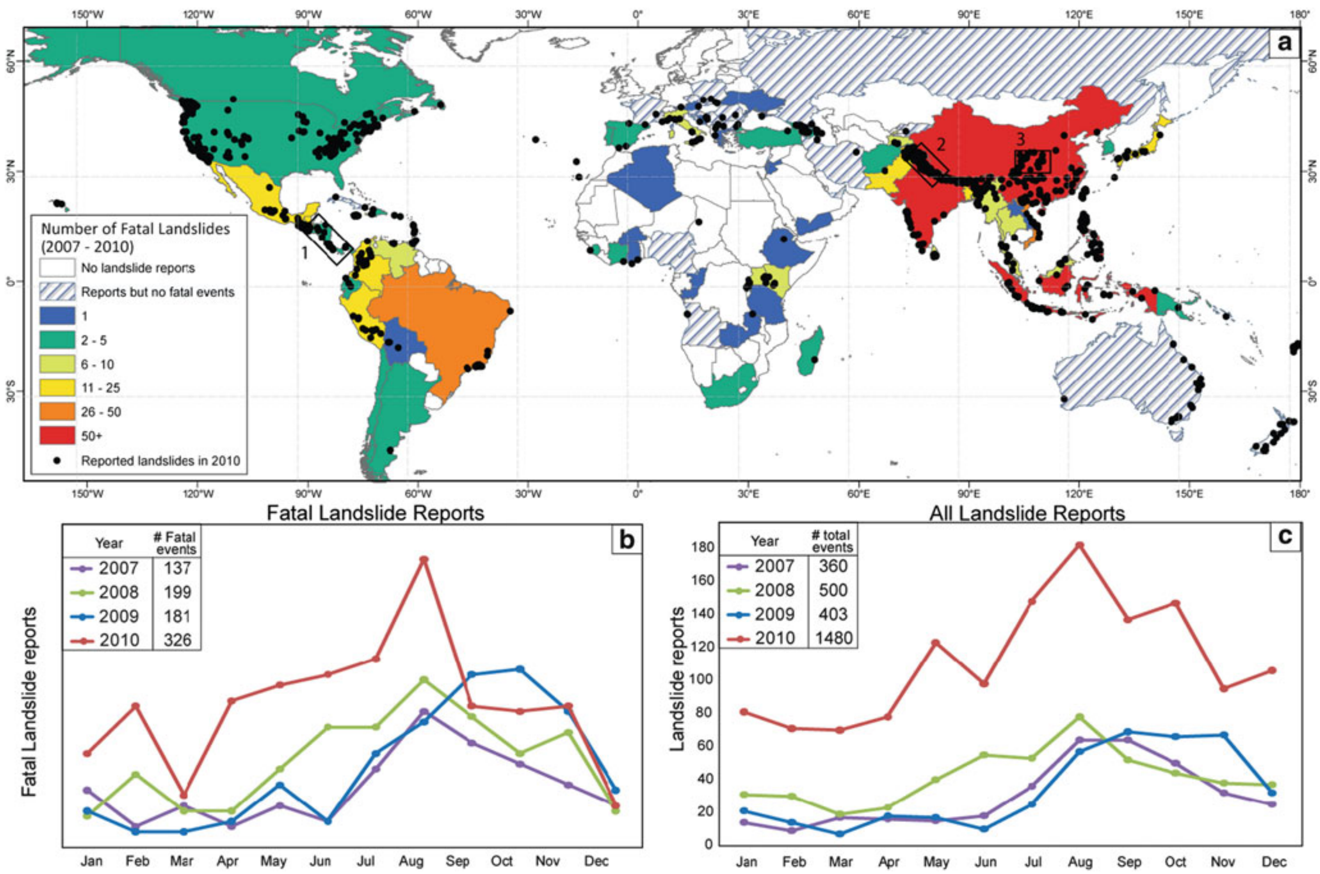

Fig. 1 Distribution of GLC for 2007–2010, showing (**a**) distribution of total landslides with associated fatalities by country over the GLC with reported landslide locations for 2010 (*dots*) and *boxes* showing the test areas evaluated in this study, *1*. Central America, *2*. Himalayan Arc, and *3*. China; and monthly distribution of (**b**) landslides with fatalities and (**c**) all reported landslides by year

quantifying and forecasting landslide activity based on rainfall variability at seasonal, annual and decadal scales.

This study first considers if there is an observable increase in rainfall-triggered landslide reports during 2010 by plotting the global distribution of landslide events and monthly totals for both reported and fatal events. The study then evaluates how the number of reported landslides relate to cumulative monthly and daily extreme rainfall for 2010 over three test areas with particularly high landslide activity. Lastly, the study presents a discussion of the identified relationships between landslide reports and rainfall signatures for each region, providing some possible explanations for the observed increases in monthly and daily extreme rainfall during 2010.

Data and Methods

Global Landslide Catalog (GLC)

The rainfall-triggered GLC considers all rapid mass movements (e.g. debris flows, mudslides, landslides) directly triggered by intense or prolonged rainfall. Landslide reports are obtained from online media reports, disaster databases, and governmental and non-governmental organizations. The landslide entries include information on the date of occurrence, location, type of movement (if available), and impacts (e.g. fatalities, injuries or affected persons, and additional information). The catalog has been compiled since 2007 and provides a retrospective assessment for 2003 (Kirschbaum et al. 2009).

This inventory provides a global picture of rainfall-triggered landslide reports; however, the catalog only represents a fraction of the total number of rainfall-triggered landslides occurring around the world. The GLC is limited by the availability and accuracy of report information, which can lead to large regional reporting biases and difficulties in identifying the precise location and triggers of landslide events. Figure 1a plots the number of landslides with one or more fatalities per country over the GLC record and Fig. 1b, c plot the monthly fatal and total landslide reports by month for each year, respectively. Despite the short record and limitations of the catalog, we observe a peak in both fatal and reported landslides for 2010. We also observed an increase in the number of landslides with fatalities over the span of the GLC, which is consistent with Petley et al.'s worldwide landslide fatality database from 2003 to the present [http://blogs.agu.org/landslideblog].

Rainfall Information

One of the motivations for this study is to determine if globally reported landslide activity, scales with regional or global meteorological forcings, considering either extreme daily precipitation or monthly totals. Tropical Rainfall Measuring Mission (TRMM) Multi-Satellite Precipitation Analysis (TMPA) product is used, which provides a 13-year record of merged satellite-based precipitation estimates from 50 N to 50 S at 0.25° × 0.25° resolution every 3-h (Huffman et al. 2007). This study uses daily precipitation values for this analysis.

Evaluation Metrics

Figure 1a illustrates the spatial distribution of 2010 landslide reports, which are often distributed within a range of clusters. We identify three such cluster regions which have landslide reports throughout the years covered by the GLC. We test the extent to which landslide activity increased in 2010 and evaluate the connection between increased reporting and anomalous rainfall activity within three study areas: Central America, the Himalayan arc, and central eastern China, shown as boxes in Fig. 1a.

Within the three areas, landslides reports and TMPA pixels were extracted and three metrics were evaluated for daily rainfall and monthly anomalies.

Monthly Rainfall Anomalies

2010 monthly rainfall totals were compared to a month climatology calculated from TMPA daily values from 1998 to 2009. Daily values were averaged over each study area and the 2010 values are plotted with the monthly climatology as well as individual years to provide an indication of the range in monthly accumulation over each study area.

Daily Threshold Exceedance

To determine how frequently ‘extreme’ rainfall occurred over the test areas, a 1-day rainfall intensity threshold value is assigned to each region based on previously calculated intensity-duration (I-D) thresholds. The Central America study area uses a value of 39 mm/day, proposed by Guzzetti et al. (2008) and the Himalayan Arc and China regions use a value of 79 mm/day based on an I-D threshold calculated by Hong et al. (2006). Any time the daily rainfall for a given pixel exceeds the threshold value, it is considered as a “hit.” The number of “hits” are summed over the test area by month and divided by the number of total pixels in the test area to provide a relative threshold exceedance rate. Results of exceedance rates are computed monthly for 2010 and averaged for the years 2007–2009.

Quantile-Quantile (Q-Q) Plots

Quantiles are calculated from daily TMPA precipitation values for each region and plotted together to determine if the distribution of the rainfall from 2010 (y-axis) is statistically significantly higher or lower compared to the previous 12 years of the TMPA record (x-axis). The two time periods are considered to be from different distributions if the quantile values diverge from their joint linear distribution. The quantiles are plotted against a 1:1 line (green) and an interquartile line (red), which represents the distribution between the 25th and 75th quantile for each sample. The Kolmogorov-Smirnov (K-S) test statistic is defined as the maximum difference between the datasets’ cumulative distributions. The corresponding K-S statistic and p-values determines if the null hypothesis (similar sample distributions) at a given significance level can be rejected, meaning the quantile distributions are statistically significantly different.

Results: Landslides and Precipitation

Central America

The Central America study area extends from the southern tip of Mexico to Costa Rica and includes 355 TRMM pixels (approximately 221,900 km^2) and 86 landslides from 2007 to 2010. The monthly climatology shown in Fig. 2a illustrates a peak in boreal summer rainfall, characterized by a mid-summer drought in July.

During the months of May through September, both the monthly precipitation totals and the regional threshold exceedance rate (Fig. 2b) are considerably larger for 2010 compared to the previous years. The landslide reports show a similar peak in reporting during May, August–September, and November, with three times more landslides with fatalities and over four times more total reports. The Q-Q plot (Fig. 2c) illustrates that quantiles at higher precipitation intensities (above 10 mm/day) diverge from the red interquartile line, with higher rainfall intensities distributed towards the 12-year sample. However, the interquartile line clearly diverges from the 1:1 line (green), suggesting that within the 25th to 75th quantile region, the rainfall quantiles for 2010 are higher for 2010. Table 1 provides results from the K-S test for values above the 75th quantile, showing a K-S test statistic of 0.1792 and p-value of 0.0026 which suggests that the null hypothesis can be rejected at the 99.7 % confidence level. Overall, Fig. 2 indicates that accumulated monthly rainfall as well as extreme rainfall values are significantly higher for 2010 and monthly patterns correspond to an increase in landslide reports and fatal events over the same periods.

One source of the positive precipitation anomalies over this region could result from the fairly active 2010 tropical cyclone season in the tropical Atlantic. The peak in landslide

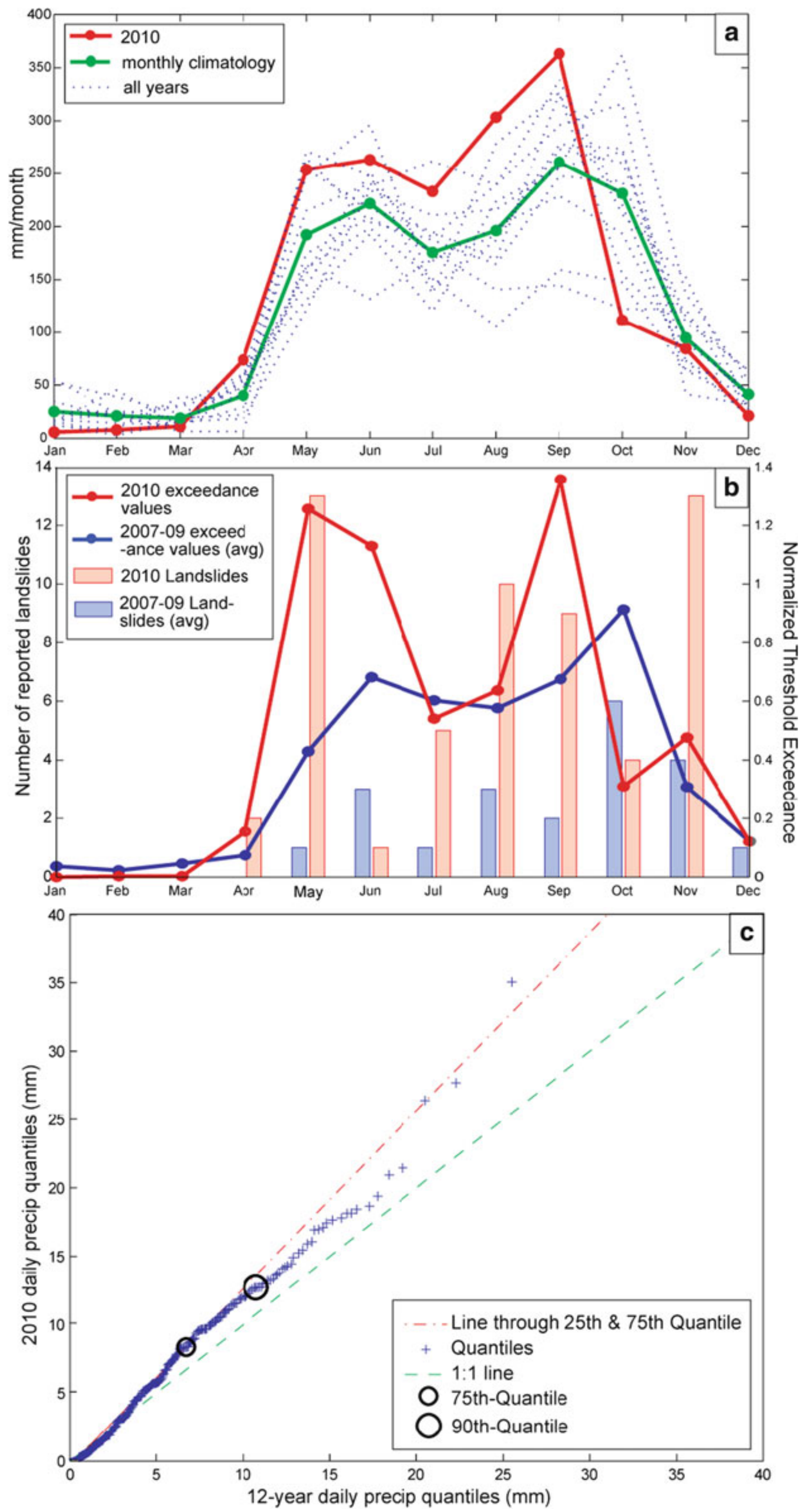

Fig. 2 Results from the Central America study area, showing: (**a**) monthly rainfall accumulation for 2010 (*red*) with 12-year monthly climatology (*green*); (**b**) normalized threshold exceedance values (39 mm/day threshold) summed for each month in 2010 (*red*) and average values for 2007–2009 (*blue*) compared with the reported landslides for 2010 and average values from 2007 to 2009; (**c**) Q-Q plot with daily precipitation showing the distribution of quantiles for the 12-year TMPA record (x-axis) versus the 2010 daily values (y-axis). The interquartile line (*red*) and 1:1 line (*green*) provide a reference to compare the distributions of quantiles for both periods

reports during May and November were the result of two events: tropical cyclone Agatha impacted Guatemala on May 29–30th and caused approximately nine landslides with fatalities in Guatemala, and tropical storm Tomas affected affected Costa Rica in early November and caused two landslides that were fatal in Costa Rica and many other reports along roads. Global ocean–atmosphere feedbacks such as El Niño Southern Oscillation (ENSO) have also been shown to modulate interannual tropical cyclone frequency and redistribute precipitation extremes. A study by

Table 1 Test statistics for the three study areas, showing the 75th quantile, K-S test statistic and p-value, and confidence level at which the null hypothesis was rejected, if applicable

Study areas	75quantile (mm/day)	K-S test statistic	p-value	Conf. level (null rej.)
Central America	6.63	0.1792	0.0026	99.7 %
Himalayan Arc	3.02	0.2119	0.0004	99.9 %
China	2.42	0.0985	0.3776	n/a
	At 90th Quantile	0.2213	0.0553	96 %

Curtis (2002) found that during the summer *before* a La Niña event, such was the case for 2010, precipitation follows a similar pattern to El Niño or Neutral patterns at the beginning of the summer, but then considerably increases in September. This interannual pattern can be linked to both to sea surface temperature changes and moisture due to ENSO as well as enhanced tropical cyclone activity.

Himalayan Arc

Along the Himalayan mountain range, including portions of India, Nepal, and Pakistan, monsoon rains trigger large numbers of damaging and fatal landslides each year. The study area encompasses 700 TMPA pixels and 284 landslide reports, covering an area of roughly 468,000 km^2. Figure 3a shows a pronounced peak in monthly rainfall for 2010 approximately 100–150 mm higher than the monthly climatology during July through September, when the monsoon signal is strongest.

Figure 3b plots the daily threshold exceedance rates for 2010 and 2007–2009 using the 79 mm/day threshold. The exceedance rate values appear to scale with reported landslides for each time period, and show a larger number of both reported landslides and threshold exceedance rates for 2010. The Q-Q plot (Fig. 3c) illustrates that daily precipitation quantile values for the 2010 data diverge from the joint distribution (interquartile and 1:1 line) after approximately 3.7 mm/day. Results from Table 1 indicate that given the high K-S test statistic (0.2119) and low p-value (0.0004), the null hypothesis may be rejected at the 99.9 % confidence level, suggesting that the extreme precipitation values for 2010 are significantly higher than the 1998–2009 record.

One source for the increase in monthly and daily precipitation values may be due to the connection between the Indian Monsoon rainfall and ENSO phases, resulting from coupling of tropical ocean-atmospheric modes over the Indian Ocean (Krishnamurthy and Goswami 2000). In the summer following an El Niño event, there is a tendency for above-normal precipitation, with the most pronounced signal in August and September (Park et al. 2010). This finding is consistent with summer precipitation totals for 2010, which were strongest during August and September in 2010. While ENSO is not the only circulation pattern contributing to the variability of boreal summer rainfall, results indicate that the strong ENSO signal during 2010 may play a sizeable role in the positive precipitation anomalies over this region.

China

The study area over China contains 810 TRMM pixels (roughly 512,700 km^2) and 34 landslides. Figure 4a illustrates a pronounced peak in the 2010 monthly totals for July and August, which is consistent with the peak in landslides during the same months (Fig. 4b). The rainfall threshold exceedance rates for 2010 and 2007–2009 indicate that while July is the peak month for extreme daily precipitation, the monthly accumulation and landslide record were both anomalously for July and August in 2010. The higher number of reported events may be a function of increased soil moisture conditions as well as lower intensity but longer duration storms, which may also trigger landslides.

The precipitation quantiles shown in Fig. 4c diverge from a similar distribution after the 95th quantile, with higher 2010 daily rainfall quantiles. However, the K-S test does not reject the null hypothesis at the 75th quantile but only after the 90th quantile at a 96 % confidence level (Table 1). Results over the China test area were much less conclusive due in part to variations and uncertainty in landslide reporting over the GLC record, the limited number of landslides over the test area, and the complex precipitation patterns over this region.

Evaluating the sources of interannual and annual variability of summer precipitation over China is challenging due to diverse climate zones and topography throughout the country as well as multiple ocean–atmosphere feedbacks influencing precipitation. One study links the strength of the Asian monsoon to tropical ocean waters and the propagation of atmospheric circulation over the western Pacific (Yang and Lau 2004). While there may be some connection to ENSO activity in affecting the modulation of the Asian monsoon, the anomalous precipitation patterns observed for 2010 for the months of July and August may also be related to several short duration cloud bursts or longer-duration storms occurring throughout the study area's mountainous area.

Discussion

Evaluation of the rainfall signals and corresponding landslide reports in each study area indicates that both the monthly accumulations and extreme daily rainfall were

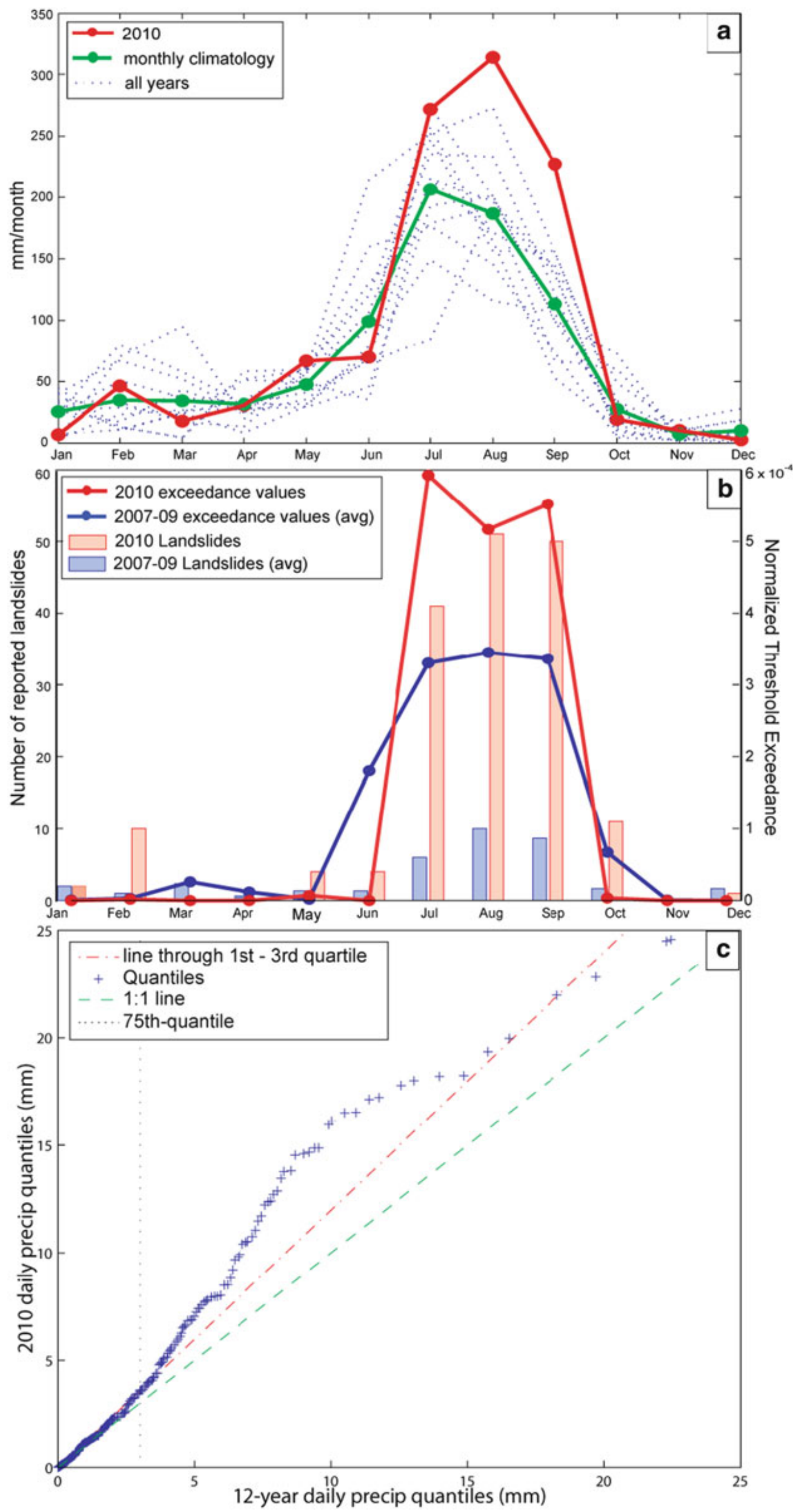

Fig. 3 Results for the Himalayan Arc test area, showing: (**a**) monthly climatology (*green*) and 2010 values (*red*); (**b**) normalized threshold exceedance (79 mm/day threshold) and reported landslide events for 2007–2009 and 2010; and (**c**) Q-Q plot showing daily rainfall quantiles for the 12-year record (x-axis) and 2010 results (y-axis), compared with the 1:1 line (*green*) and interquartile line (*red*)

anomalously high in 2010 and roughly correlate with the increase in landslide reports. There are many challenges in extending the scope of this study to estimate global relationships between rainfall and landslide activity. First, this study only considered three areas with a large number of landslide reports over a relatively short record (2007–2010). The percentage of fatal reports for 2010 indicates a clear increase, suggesting that despite global heterogeneities there is an observable pattern in landslides with fatalities both within the three study regions as well as at the global scale.

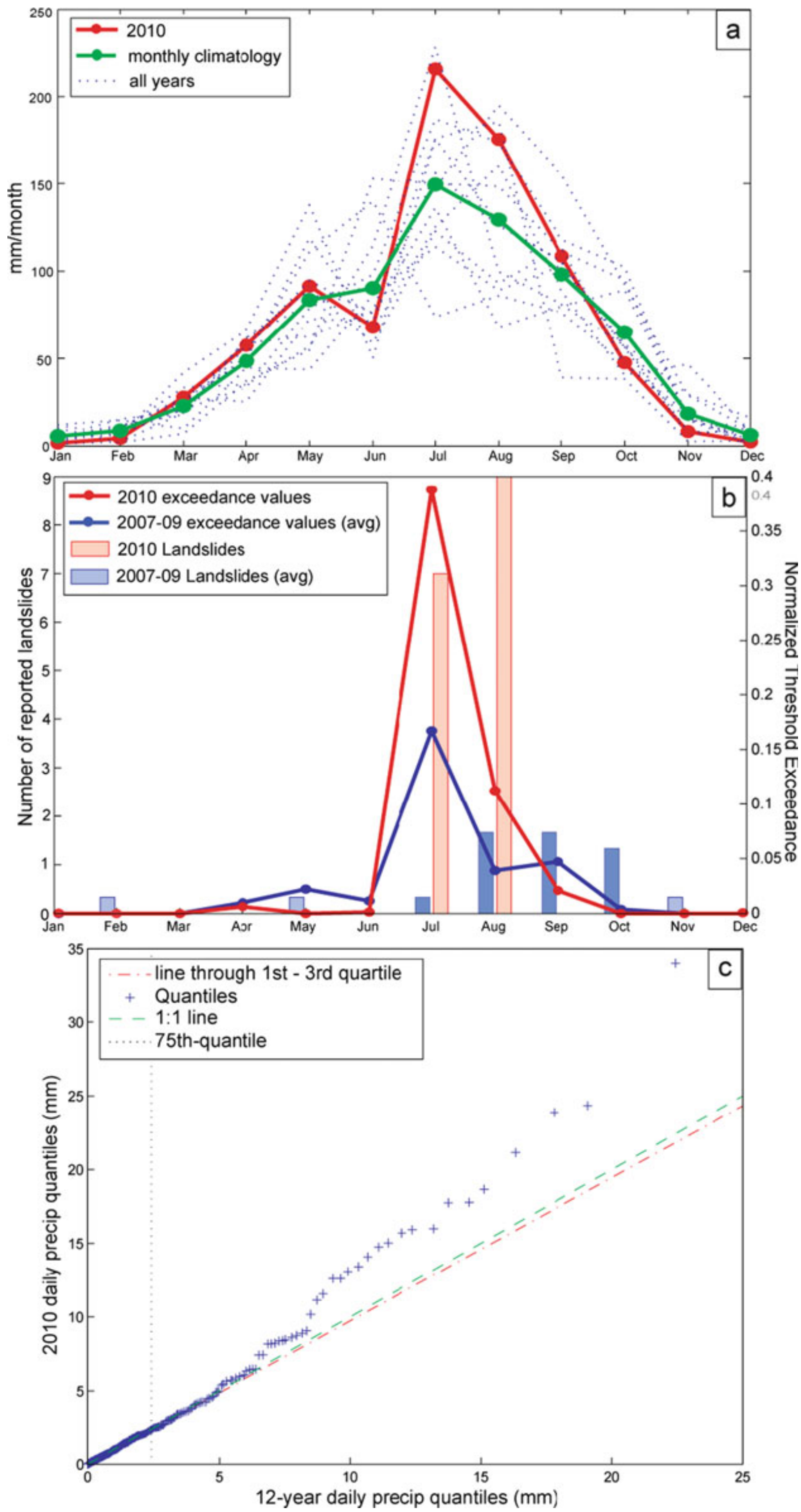

Fig. 4 Results for the China study area, showing: (**a**) a monthly climatology (*green*) and 2010 values (*red*); (**b**) normalized threshold exceedance (79 mm/day threshold) compared with landslides over the same periods; and (**c**) Q-Q plot showing the distribution of precipitation quantiles for the 12-year TMPA record (x-axis) versus the 2010 daily values (y-axis)

Representation of rainfall extremes at the global scale constitutes another challenge in this study. We compare precipitation signatures from a 1-year dataset (2010) directly with a 12-year record of rainfall, leading to representation biases in the distribution of daily precipitation extremes within the quantile calculations. Merged satellite products offer a unique perspective on rainfall distribution by providing an intercomparison framework amongst regions and through time; however, the sampling frequency of current microwave sensors does not allow for continuous monitoring of precipitation features and as a result, short cloud bursts or peak intensities may not be accurately resolved by the TMPA precipitation product.

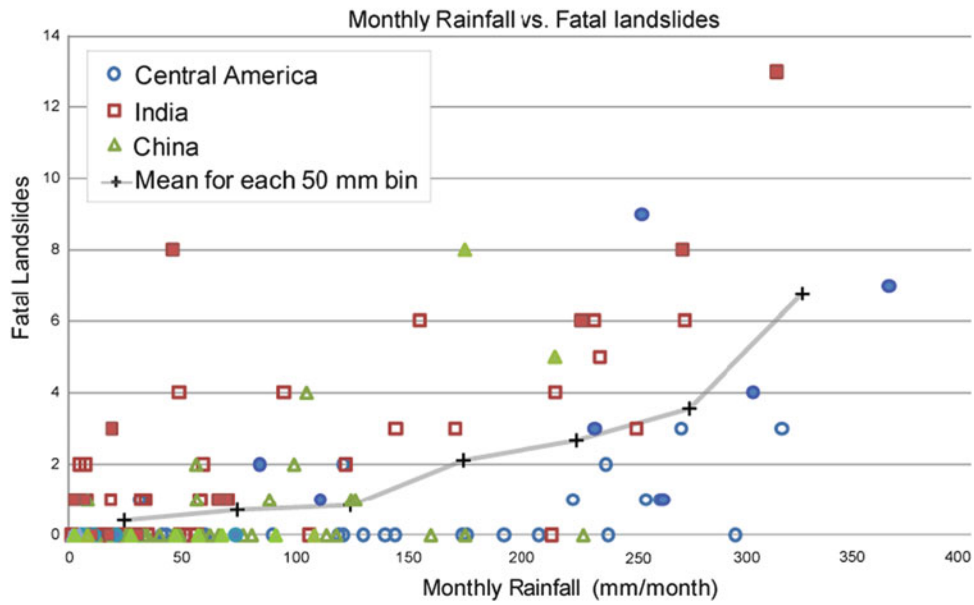

Fig. 5 Comparison of monthly rainfall (x-axis) versus landslides with fatalities for each month (2007–2010) within the three study areas. *Filled in symbols* indicate 2010 values. The mean number of landslides with fatalities are averaged for each 50 mm bin and plotted as '+'

Lastly, antecedent soil moisture can significantly contribute to landslide triggering. Moving forward, this research will consider the joint relationship between antecedent precipitation and precipitation intensity to better characterize potentially susceptible regions based on weekly, monthly or seasonal precipitation accumulation.

Despite the cited challenges, results shown here suggest that the global landslide catalog may have some scaling relationship with extreme or cumulative precipitation, which could possibly be extrapolated to regional or global levels. The plot in Fig. 5 illustrates the distribution of monthly rainfall and landslides with fatalities for each month in the GLC over the three study areas. The mean number of landslides with fatalities within each rainfall bin (represented by + markers) indicate that there is a faint but observable signal between the increase in monthly rainfall and increased landslide with one or more fatalities. We anticipate that if this evaluation were expanded to other study areas with a more comprehensive landslide database, there would be a more robust relationship between landslide occurrence and precipitation.

This study seeks to better characterize the relative relationship between precipitation activity and potential landslide triggering. Through these relationships, we may improve understanding of where landslides may impact populations based on natural and anthropogenic variability. Future satellite missions such as the Global Precipitation Measurement (GPM) mission[2] will help to extend coverage of precipitation and allow for higher spatiotemporal precipitation information for improved characterization of extreme precipitation and potential landslide activity.

[2] www.gpm.nasa.gov

Conclusions

The GLC provides a new, freely available global picture of rainfall-triggered landslides over multiple years. Analysis of the 2010 precipitation signatures over the three identified study areas illustrates an observable trend between increases in reported landslide activity and increases in precipitation accumulation and daily extremes. While other factors can modify this relationship including anthropogenic influence and tectonic weakening, understanding the relative distribution of extreme precipitation may help to shed new light on potential landslide activity at daily, monthly, and yearly scales. We plan to re-evaluate these trends once we have built a larger record of reported events. Through continued evaluation of the global precipitation triggering – landslide relationship, this type of evaluation may serve as a way to approximate the spatiotemporal distribution of landslide activity and forecast variability as a result of changing ENSO patterns and future climate change scenarios.

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Impact of Disasters in Mediterranean Regions: An Overview in the Framework of the HYMEX Project

Olga Petrucci and Maria Carme Llasat

Abstract

A review of recent articles concerning the Natural Disaster Impact Assessment (NDIA) has been performed according to the HyMex (*Hydrological cycle in the Mediterranean Experiment*) framework. HyMex is an international project focused on quantifying the hydrological cycle in the Mediterranean, analyzing high-impact weather events in the context of global change. According to their approach, the articles have been sorted in three groups: (a) those that focus on short-to-medium term effects directly involving people and goods impacted by the disaster; (b) those that focus on medium-to-long-term socio-economic effects; and (c) those that focus on short-to-long-term physical and physiological effects on individuals. The aim is to highlight the approaches used to address this issue in various scientific fields and thereby to promote the sharing of both data and methodologies and facilitate the use of an advanced multidisciplinary approach to the NDIA.

Keywords

Natural disasters • Impact • Damage

Disaster Impact from the HyMex Perspective

The population of the Mediterranean area is increasing and as a result, it is experiencing an increase in urban sprawl, even in areas threatened by weather-related hazards such as floods and landslides. Mediterranean countries are socially and politically diverse, but in the context of climate change, they must confront challenging, short-time extreme events (i.e., flash floods) and long-term changes (i.e., drought).

HyMeX is an international research project intended to quantify the hydrological cycle in the Mediterranean, with an emphasis on high-impact weather events in the context of global change (http://www.hymex.org/ index.php). HyMeX-Working Group 5, which focuses on societal and economical effects, aims to (a) improve knowledge of high-impact weather events in the Mediterranean basin, (b) monitor vulnerability factors and adaptation strategies developed by different societies to adjust to climate change, (c) point out the lessons that can be learned from different societies and individuals seeking to cope with climate change and hydro-meteorological extremes, and make these lessons beneficial for all Mediterranean communities, and (d) identify changes in the vulnerability of humans and ecosystems under future global change. In this context, it is essential to collect data on weather-related disasters and to improve the procedures for assessing their impact.

The social and natural science communities working on weather-related disasters in Mediterranean countries are currently fairly limited, and there is no systematic procedure used to determine the impact of the disasters. Thus, we decided to widen the scope of our survey, selecting articles that address the impact of all the types of natural disasters all around the word. The hope is that we may thereby isolate approaches used in those contexts that would also be suitable for the Mediterranean area.

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Natural Disaster Impact: Definitions and Usefulness

The definition of *Natural Disaster Impact* (NDI) changes according to both the aim of the study and the scientist assessing it. It can be defined as constituting the *direct, indirect* and *intangible* losses caused on environment and society by a natural disaster (Swiss Re 1998).

Direct losses include physical effects such as destruction and changes that reduce the functionality of an individual or structure. Damage to people (death/injury), buildings, their contents, and vehicles is included, as are clean-up and disposal costs.

Indirect losses affect society by disrupting or damaging utility services and local businesses. Loss of revenue; increase in cost; expenses connected to the provision of assistance, lodging, and drinking water; and costs associated with the need to drive longer distances because of blocked roads are included.

Intangible losses include psychological impairments caused by both direct and intangible losses that individuals personally suffer during the disaster.

The *Natural Disaster Impact Assessment* (NDIA) is crucial in helping individuals to estimate replacement costs and to conduct cost-benefit analyses in allotting resources to prevent and mitigate the consequences of damage (UNEP-ECLAC 2000). Possible end users of NDIA include the following (Lindell and Prater 2003):

1. *Governments,* which have an interest in estimating direct losses to report to taxpayers and to identify segments of the community that have been (or might be) disproportionately affected.
2. *Community leaders*, who may need to use loss data after a disaster strikes to determine if external assistance is necessary and, if so, how much.
3. *Planners,* who can develop damage predictions to assess the effects of alternative hazard adjustments. Knowing both the expected losses and the extent to which those losses could be reduced makes it possible to implement cost-effective mitigation strategies.
4. *Insurers,* who need data on the maximum losses in their portfolios to guarantee their solvency or even to undertake additional measures to alleviate the risk that they would face in case of a disaster (i.e., the use of catastrophe bonds) (Noy and Nualsri 2011).

Data availability and reliability represent constraints in the NDIA context because of the following issues:

1. In most countries, there are no agencies responsible for gathering damage data.
2. Long-term losses must sometimes be determined over a period of multiple years. Slow landslides, for example, can cause damage over long periods. Intangible damage like disaster-related stress also requires years to be detected (Bland et al. 1996).
3. Data on property damage can depreciate the value of property, thus they would not be available (Highland 2003).
4. For disasters as landslides or floods, the costs of damages to structures such as roads are often merged with maintenance costs and are therefore not labeled as damage. In addition, when heavy rains trigger both landslides and floods (Petrucci and Polemio 2009), it is difficult to separate landslide damage from flood damage.
5. Developing countries have an incentive to exaggerate damage to receive higher amounts of international assistance; thus, data may not be entirely reliable (Toya and Skidmore 2007).

Review Approach

Using Google Scholar, articles and books from academic publishers, online repositories, universities, international organizations and other web sites were selected by looking for terms related to natural disasters (natural disaster*, cyclone*, drought, earthquake*, flood*, hurricane*, landslide*, tsunami, volcan*) and their effects (accident*, damag*, econom*, homeless*, impact*, injur*, loss*, morbidity, mortality, victim*, wound*, stress). The terms followed by asterisks were truncated so that we could search for all words commencing with those letters (Ahern et al. 2005). Because we only searched for articles whose year of publication was 1990 or later, approximately 100 articles were selected. First, papers concerning general aspects of NDIA were separated from articles presenting specific case studies. Then, some articles were excluded because the approaches proposed therein were the same as those reported in others of the selected articles. Finally, 50 case studies were selected and sorted in three groups as described in the next section.

Short-Medium-Term Effects Directly Involving People and Goods Affected by a Disaster

Group 1 includes 22 % of the sample (Table 1). In the articles employing the simplest approaches, the impact is expressed by the list of damaged structures that does not include monetary figures or any other assessment (Ngecu and Ichang'i 1999; Whitworth et al. 2006; Bilgehan and Kilic 2008). Frequently used impact indicators include numbers of victims and damage to buildings, roads and agriculture. In these studies, damage data are obtained by state agencies or even collected by directly asking people involved in the disaster. Both the number of victims and the percentage of people affected are used to compare the impact of a disaster on various

Table 1 Group 1: articles focusing on *short-medium-term effects directly involving people and goods affected by the disaster*

N.	Authors	Study area	Disaster
1	Bilgehan and Kilic (2008)	Turkey	Landslides
2	Brunkard et al. (2008)	Louisiana	Hurricanes
3	FitzGerald et al. (2010)	Various	Floods
4	Jonkman et al. (2009)	Louisiana	Hurricanes
5	Msilimba (2010)	Malawi	Landslides
6	Ngecu and Ichang'i (1999)	Kenya	Landslides
7	Patwardhan and Sharma (2005)	India	Tropical cyclones
8	Rappaport (2000)	Various	Tropical cyclones
9	Shajaat Ali (2007)	Bangladesh	Floods
10	Whitworth et al. (2006)	Spain	Landslides

communities (Msilimba 2010) or that of disasters that have occurred in different time and places.

Some articles focus on damage to people, analysing the circumstances leading to loss of life and assessing them in relation to vulnerability factors (e.g., age, race, and gender) (Jonkman et al. 2009).

Medium-Long-Term Socio-Economic Effects

Group 2 contains 46 % of the selected articles (Table 2). After individuating the affected population and the pre-disaster situation, the researchers isolated effects on social sectors (the population, housing, health and education), service infrastructure (drinking water and sewage, communications, electricity and power), and production sectors (agriculture, industry and trade). All of the effects were then aggregated to measure the disaster's impact on the macroeconomic indicators during a period of 1 to 2 years after the disaster (ECLAC 1991).

In such studies, natural disasters are seen as a function of a specific *natural process* and *economic activity* (Raschky 2008). The indicators used to detect the impact on national economies include (a) long-term recovery businesses (Webb et al. 2002); (b) changes in flow variables such as annual agricultural output (Patwardhan and Sharma 2005); (c) variations in fiscal pressure (Noy and Nualsri 2011); and (d) effects on the labor market (Belasen and Polachek 2007; Zissimopoulos and Karoly 2010).

The value of human life can be tentatively assessed using two approaches that assign different values to people in different income groups or in countries at different stages of development (AusAID 2005):

(a). The *human capital* approach involves calculating the average expected future income that the deceased would have generated assuming that he (or she) had achieved normal life expectancy.

Table 2 Group 2: articles focusing on *medium-long-term socio-economic effects*

N.	Authors	Study area	Disaster
1	Barredo (2009)	Various	Flood
2	Barredo (2010)	Various	Windstorm
3	Belasen and Polachek (2007)	Florida	Hurricane
4	Birkmann et al. (2008)	Sri Lanka, Indonesia	Tsunami
5	Cavallo et al. (2010)	Haiti	Earthquake
6	Guimaraes et al. (1993)	South Carolina	Hurricane
7	Gupta and Sah (2008)	India	Flood
8	Kellenberg and Mobarak (2008)	–	Nat. disasters
9	Luechinger and Raschky (2009)	Europe	Flood
10	Noy and Nualsri (2011)	Various	Nat. disasters
11	Noy (2009)	Various	Nat. disasters
12	Padli and Habibullah (2009)	Asia	Nat. disasters
13	Pielke et al. (2008)	United States	Hurricane
14	Raschky (2008)	Various	Nat. disasters
15	Rodriguez-Oreggia et al (2010)	Mexico	Nat. disasters
16	Schuster and Highland (2007)	Various	Landslide
17	Smith and McCarty 1996	Florida	Hurricane
18	Toya and Skidmore 2007	Various	Nat. disasters
19	Webb et al. 2002	California, Florida	Nat. disasters
20	Wilhite et al. 2007	United States	Drought
21	Wilson et al. 2011	Chile, Argentina	Volcanic ash fall
22	Xiao 2011	Various	Flood
23	Zissimopoulos and Karoly 2010	Various	Hurricane

(b). In the *willingness to pay* (WTP) approach, surveys assess how much an individual is willing to pay to reduce the risk of death.

Even environmental damage can be assessed using the WTP approach, either by asking people to state a WTP amount or by inferring this amount based on costs incurred for environmental services (Dosi 2001).

Economically, disasters can act as a barrier to development, increasing poverty and having a small but significant negative effect on economic growth (Raschky 2008). This effect can return a society to the level of human development it had achieved 2 years prior to the disaster (Rodriguez-Oreggia et al. 2010). Indirect societal effects such as decreases in productivity in people affected by disaster can influence economic growth (Popp 2006). Human capital can be *directly* affected by these disasters through death or injury and *indirectly* affected when damage to schools decreases human capital accumulation (in poor countries, decreasing school attendance rates caused by reductions in family expenses can occur). Even demographic effects such as migration have been detected (Smith and McCarty 1996).

Nevertheless, natural disaster can also produce positive effects. Disasters can create *Schumpeterian creative destruction* (Cuaresma et al. 2004), especially if there are injections of funds for assistance and/or reconstruction. They can represent an opportunity to update capital stock and improve an economy, thereby producing a long-term positive effect on the growth of the Gross Domestic Product (GDP) (Skidmore and Toya 2002). Activities in the construction sector may reactivate the economy, and the demand for construction materials may generate windfall profits (ECLAC 1991). Outside the disaster area, income increases can accrue for owners of commodities whose price is inflated by disaster-induced shortages (CACND 1999). For instance, in the case of drought, when agricultural production decreases, farmers in affected areas experience the negative effects of the disaster, and the price of agricultural products increases. Then, farmers outside affected area, who are experiencing normal production, will reap the benefits of these higher prices (Wilhite et al. 2007). Even ways of thinking and acting can be modified by major disasters, resulting in personal and community growth (Birkmann et al. 2008).

Disasters are more costly for developing countries: as economies develop, there are fewer disaster-related deaths and damages/GDP (Toya and Skidmore 2007). Nevertheless, increasing wealth causes relatively higher losses in high-income nations (Raschky 2008). Increases in income increase the private demand for safety; higher income enables individuals (and countries) to employ additional, costly precautionary measures. Nevertheless, in countries that experience a concentration of assets that is larger than the counter-measures put in place, the income-vulnerability relationship can be inverted, especially in the case of disasters related to behavioral choices such as floods and landslides. It seems that in countries with a GDP per capita below $4,500–$5,500, disaster deaths increase with income; however, they start decreasing if GDP is beyond that threshold (Kellenberg and Mobarak 2008).

Disasters in South, Southeast, and East Asia are more costly than those occurring in the Middle East and Latin America. These results might be tied to the higher population density of Asian countries. Small island developing states are severely impacted by such events (Meheux et al. 2007): the number of victims and affected individuals and the degree of damage are twice as large on average as in any other region (Noy 2009).

Normalization procedures are used to assess what the magnitude of economic losses over time would be if a past disaster took place today. It seems that societal change and economic development are the principal factors responsible for the increasing losses from natural disasters to date (Pielke et al. 2008; Barredo 2009, 2010). For weather-related disasters, Bouwer (2011) pointed out no trends in losses – corrected for increases in population and capital at risk – that could be attributed to anthropogenic climate change.

Table 3 Group 3: articles focusing on *short-to-long-term physical and physiological effects on people*

N.	Authors	Study area	Disaster
1	Bland et al. (1996)	Italy	Earthquake
2	Cao et al. (2003)	China	Earthquake
3	Catapano et al. (2001)	Italy	Landslide
4	Chou et al. (2003)	Taiwan	Earthquake
5	Fonseca et al. (2009)	Louisiana	Hurricane
6	Hussain et al. (2011)	Thailand	Tsunami
7	Lazarus et al. (2002)	–	Nat. disasters
8	Liao et al. (2004)	Taiwan	Earthquake
9	Lutgendorf et al (1995)	Florida	Hurricane
10	Montazeri et al. (2005)	Iran	Earthquake
11	O'Neill et al. (1999)	North America	Flood
12	Phifer (1990)	Kentucky	Flood
13	Ramachandran et al. (2006)	India	Tsunami
14	Seplaki et al. (2006)	Taiwan	Earthquake
15	Suzuki et al. (1997)	Japan	Earthquake

Short-to-Long-Term Physical and Physiological Effects on People

The articles in Group 3 (32 %) focus on natural disasters and their effects on people's health from either a physical or a psychological point of view (Table 3). Pre- and post-disaster conditions were compared in these studies to detect the onset of diseases and/or the worsening of pre-existing illness, and to assess if and when disaster-related symptoms appear/disappear. The data collection processes mainly involved standardized questionnaires used to collect self-reported information on symptoms quantified using numerical scores (Catapano et al. 2001; Cao et al. 2003) that could measure the disaster's impact. The risk of developing physical and/or psychiatric disorders is related to the extent of the losses suffered (Cao et al. 2003), and it is greater in families that have lost a family member in a disaster (Lindell and Prater 2003), have experienced evacuation, or have worse finances (Bland et al. 1996). This probability can also be increased by a lack of information on the probability that the event will re-occur (Catapano et al. 2001). Two sub-sets of articles were isolated that focused on *psychological* and *physical* effects, respectively.

Psychological effects. According to the *Conservation Resource Model*, people try to protect resources such as objects (housing, possessions, etc.), social roles (employment, marriages, etc.), energy (time and monetary investments), and personal characteristics (e.g., self-confidence). The threatened or actual loss of these resources as caused by a natural disaster leads to psychological distress (O'Neill et al. 1999). Frequently observed conditions such minor emotional disorders seldom come to the attention of psychiatrists but may negatively affect social relationships and work performance. Commonly detected symptoms are fatigue (Lutgendorf et al. 1995), tics, and cognitive experiences such as confusion, impaired concentration, and attention deficit disorder. *Emotional* signs such as anxiety, depression, and grief, as well as *behavioral effects* such as sleep and appetite changes and substance abuse, were also reported (Lindell and Prater 2003). Even effects on suicide rates were detected: earthquake victims (people who had lost family members residing with them, were injured, or experienced property loss) were 1.46 times more likely than non-victims to commit suicide (Chou et al. 2003).

These effects can be mild and transitory or can lead to *Post Traumatic Stress Disorder* (PTSD). The mental states of victims can include three stages (Sadeghi and Ahmadi 2008): (a) an *immediate reaction* involving distressing symptoms accompanying adaptive stress; (b) the *post-immediate phase*, which includes symptoms of maladaptive stress (confusion, agitation, and occasionally neurotic or psychotic reactions); and (c) the *long-term sequel* phase, which involves a return to normal health or the onset of PTSD, which can sometimes yield a *chronic phase* that involves personality changes. These surveys make it possible to monitor the most fragile segments of the population, including people with preexisting mental illness, racial and ethnic minorities, and children, in which symptoms may differ depending on age (Lazarus et al. 2002; Overstreet et al. 2011). Gender differences arise as well: for instance, after an earthquake, women report greater emotional distress and mental health problems than do men (Norris et al. 2002), but the occurrence of addiction disorders among women is much lower (Montazeri et al. 2005).

Physical effects encompass symptoms affecting people who have not been directly involved in a disaster. The deterioration of hygiene, housing, and basic services can induce the outbreak of diseases such as *leptospirosis* (AusAID 2005) or increase the risk of morbidity and mortality caused by communicable diseases (Waring and Brown 2005). In developing countries, for instance, contagious and non-contagious diseases are reported during the first weeks after floods. Moreover, in some environments, even the incidence of snake bites can increase (Shajaat Ali 2007).

Disaster-related stress can have several secondary impacts on human health, such as effects on the human immune system (Solomon et al. 1997), diabetes (Ramachandran et al. 2006; Fonseca et al. 2009), and gastro duodenal ulcers (Suzuki et al. 1997). Also increases in serum *leptin* levels have been detected in subjects with PTSD, which explains the hypervigilance of people who have faced danger and uncertainty (Liao et al. 2004). In addition, after major earthquakes, the number of patients with *Acute Myocardial Infarction* (AMI) has been reported to increase 3.5-fold, and the part of women with AMI seems significantly greater than in the years preceding the disaster (Suzuki et al. 1997).

Concluding Remarks

Direct economic cost is not a sufficient indicator of disaster seriousness: estimating indirect and intangible losses is crucial to assessing the effects of disasters for welfare. Restricting research to the effects in a single sector can result in fragmented coverage of the impacts (Meheux et al. 2007). This review highlighted techniques and findings in the economics and medical literature, which are not well known by those researchers working on physical aspects of natural disasters. A general NDIA procedure has not yet been developed; the applicability of the available approaches depends on the data accessibility. Only 12 % of the selected articles concern landslides impact: four dealing with *short-medium-term effects directly involving people and goods*, one focusing on *medium-long-term socio-economic effects* and one on *short-to-long-term physical and physiological effects on people*. This low attention to landslides impact depends on two factors: (a) landslides could be classified as *minor* disasters if compared to earthquakes or hurricanes; (b) landslides can be secondary consequence of *major* disasters such as earthquakes. Thus it is basic to develop impact assessment procedures planned for landslides, more spatial-oriented, and even taking into account that exposure can be related to behavioral choices.

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Rainfall-Related Phenomena Along a Road Sector in Calabria (Southern Italy)

Olga Petrucci and A. Aurora Pasqua

Abstract

This paper proposes an approach for the relative assessment of damage caused along roads by *landslides* and *floods*, which are known as Rainfall-Related Phenomena (RRP). The proposed approach aims to obtain (a) the trend of phenomena occurrences through the analysed period, classified in terms of both the type of triggering phenomenon and relative damage; (b) the location of damage data, allowing the creation of a map of *critical points* that must either be monitored during rainfall periods or urgently need defensive work; and (c) a sketch of the primary circumstances that lead to human injuries along the analysed road. Finally, an application for a road track in Calabria (Southern Italy) is presented.

Keywords

Landslides • Floods • Damage

Introduction

Episodes of severe weather conditions may cause diffuse occurrences of Rainfall-Related Phenomena (RRP) such as *landslides* and *floods* (Petrucci et al. 2009, 2010) that can result in damage to properties and people.

One of the elements most frequently and heavily damaged by RRP is the road network. Damage can occur on roads as either static (the actual road) or dynamic elements (cars and pedestrians using the road). Human injuries, damage to vehicles, and the cost for restoration and repair of infrastructure represent direct damage. Indirect damage entails the effects on society from disruptions to utility services and local businesses, which result in a loss of revenue and tourism (Van Westen et al. 2006) as well as increased expenses from longer driving distances due to road blockages (Zêzere et al. 2007). The vulnerability of roads depends on both the natural characteristics of the terrain along road tracks (i.e., the presence of either landslides or a river along the road path) and road design criteria (i.e., the slope angle increased by excavations, a removal of slope support in road cuts, or an alteration of surface runoff paths). The vulnerability of people moving along roads depends on the type of RRP they must cope with, its speed and magnitude, and the mental alertness of people.

Communities using a road network should become aware of the hazards that they face, and they should learn both responsible behaviours and how to respond in an emergency. Such awareness can best be maintained by public information programs designed on the basis of a population's existing perception of landslides or floods (Solana and Kilburn 2003). Knowledge of the leading causes of fatalities should inform public awareness programs and public safety police enforcement activities (FitzGerald et al. 2010). Information from historical events can provide more detailed data about both factors that determine mortality (Jonkman and Vrijling 2008) and individual vulnerability factors, providing a basis for the formulation of education strategies.

Concerning floods, the literature shows a high percentage of drivers among floods victims (Coates 1999; Rappaport 2000; Jonkman and Vrijling 2008; Maples and Tiefenbacher 2009; FitzGerald et al. 2010), often depending on behaviour and individual vulnerability factors (Jonkman and Vrijling 2008).

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The average age of victims can be different from one area to another (Ruin et al. 2008; FitzGerald et al. 2010). Males seem to be highly vulnerable to dying in floods (Maples and Tiefenbacher 2009; Jonkman and Vrijling 2008; FitzGerald et al. 2010). The likely causes are that males drive and partake in risk-taking behaviour more frequently (Jonkman and Kelman 2005). Often, people deliberately drive through flooded roads, and those who did not take warnings seriously, typically aged 18–35, are more likely to drive through flooded roads (Drobot et al. 2007). The following factors can lead to fatalities: (1) improved safety of automobiles leading to an erroneous belief in motorist invulnerability; (2) neglecting the risks associated with flooded roadways, including ignoring warnings and traffic safety barriers; and (3) roadway familiarity, based on the proximity of the flooded road to either the driver's home or place of employment, which seems to increase drivers' attempts to surmount water rushing across a road (Maples and Tiefenbacher 2009).

Even landslides triggered by rainfall can induce severe road damage (Irigaray et al. 2000). According to Wilson et al. (2005), injuries or deaths can occur on the road as a result of the following factors: (a) vehicles running into landslides; (b) vehicles being hit by landslides; (c) vehicles involved in collisions while swerving to avoid landslides; and (d) vehicles running into voids created by landslides. In these cases, vehicle vulnerability depends on many of the following elements: (a) the type and size of the landslide; (b) the type of infrastructure; (c) the speed and type of vehicle (Jaiswal et al. 2010); (d) traffic volume; (e) the length of the landslide risk section of the route; (f) the number of occupants in the car (Budetta 2002); and (g) driver alertness. Quantitative landslide risk analyses at a local scale can be performed by deterministic methods on limited road sectors only where detailed data on both road characteristics and traffic volumes are available (Jaiswal et al. 2010). Moreover, the combined analysis of the historical recurrence of rockfall events, the frequency/volume statistics of rockfalls, and a simulation model can be used to determine the associated hazards (Guzzetti et al. 2004).

Materials and Methods

The proposed methodology is based on an analysis of RRP that occurred in the past along a road network and an attempt to transform these data into a *lesson from the past*. The aim is to obtain some clues for preventing future damage by individuating the road sites most frequently and heavily affected by RRP (defined as *critical points*) and determining how people are injured at these sites.

The methodology was designed on a "limit" situation characterised by the absence of standardised data collection of both traffic and damage caused by RRP.

Data Collection

A detailed analysis of risk conditions along a road network should take into account the volume of traffic characterising the different roads analysed. Nevertheless, in several regions, the scarcity of gauges for surveying traffic and the consequent lack of systematically collected traffic data do not allow such rigorous analysis. A simplified approach must therefore be used; in the absence of data on traffic, roads can be sorted by type (highway, railway, state road, and urban road), indirectly accounting for their characteristic traffic volume.

Concerning RRP data, in several geographical frameworks, there is no (or no single) public agency that collects data on damage caused by RRP to roads. Thus, to obtain these data, a specific historical investigation must be planned and conducted.

Data sources available for historical research are numerous (e.g., *artefacts, chronicles, diaries, local administration archives, private and ecclesiastical archives, archives of local and regional agencies, press archives,* and *scientific papers*), and their availability changes with time. Despite historical data being affected by several types of complications (Glade 2001; Glaser and Stangl 2004; Petrucci and Pasqua 2008; Petrucci and Gullà 2010), they may represent the only information source for reconstructing the historical series of damaging cases. Information concerning older events is generally less plentiful than information pertaining to newer events, and often the greatest amount of data exists for the most severe events, whereas less severe cases are rarely mentioned. Depending on the type of historical documents and the skill of the documents' authors, either a detailed or incomplete description of RRP can be obtained. As a result, the historical series is made of heterogeneous data that usually do not contain economic figures.

Historical data may lack precision in the localisation of places affected by RRP; unless the document is a scientific article, the author does not supply maps of the impacted areas, which means that the area actually affected can be individuated but not delimited.

For the purposes of this work, the most useful documents come from two types of sources: (a) archives of the agencies involved in road management or Public Work Departments and (b) press archives. The first type mainly focuses on damage to roads, even describing in detail the phenomena and remedial works proposed or realised. However, daily newspapers ensure continuity in information flow and report detailed descriptions of human injuries by supplying the age, gender, and names of the people involved and details on either the causes of death or prognosis for the injured.

Damage Index Assessment

Because the majority of data sources used lack economic damage appraisals, a monetisation of damage caused by RRD is impossible to perform. Thus, a *relative assessment of damage* to roads and people can be performed using a simplified approach (Petrucci et al. 2009, 2010; Petrucci and Gullà 2010). A Damage Index (DI), assessed both on a single-event basis and per year, permits a comparison of damage caused by RRP occurring in different places and times and allows the detection of yearly damage trends.

This approach is based on the assumption that damage can be considered to comprise two components: damage to roads and human injuries. For both components, the damage can be expressed by the product of the *value of the element* (V) and *level of loss* (L) suffered by the element because of RRP. Both the value of the element and level of loss are expressed by fixed coefficients that supply a relative element value, thus allowing ranking of the damage value.

In the case of roads, V is fixed according to the road type: highway: $V = 30$; railway: $V = 30$; state road, $V = 20$; urban road: $V = 10$. On the basis of information described in all damage reports, the level of loss (L) is assumed to be represented by three possible conditions: road damaged without traffic interruption: $L = 1$; road interruption for a short time (hours): $L = 2$; and road interruption for a long time (days): $L = 3$.

For people, V is fixed according to the number of people involved, sorted in three classes (> 5 people: $V = 30$; from 2 to 5 people: $V = 20$; 1 person: $V = 10$). The level of loss is represented by three possible conditions: people involved: $L = 1$; people injured: $L = 2$; and people killed: $L = 3$.

To use the proposed approach, historical documents concerning RRPs must have been stored as database records. Each record is identified by the date of RRP occurrence, the type of phenomenon, the municipality in which it occurred and a damage description. The records must have been chronologically sorted; each record can report the occurrence of one or more RRP that caused damage in one or more places on a certain day. Next, each record must have been analysed to define V and L for both people and roads according the previously described criteria. Considering that more than one type of road can be damaged and that different numbers of people can be involved, injured or killed in each record, the DI is defined as the following expression (1):

$$DI = \sum V_r x L_r + \sum V_p x L_p \quad (1)$$

where V_r and L_r are the coefficients expressing the value of the damaged roads and level of damage suffered by the roads, respectively.

DI can be assessed on a yearly basis (yearly Damage Index: DI_y), even taking into account the number of episodes when damage occurred. In this way, information on recurrence, trends and the severity levels of the different cases can be indicated. Damage localisation on maps can supply a further indication about the *critical points* of the road network more frequently/intensely affected by damage. Finally, a separate analysis of all cases involving people can supply information about the most common causes/types of human injury, highlighting behaviours in different emergency situations.

A Case Study in Calabria (Southern Italy)

A narrow belt of territory located on the southwest coast of Calabria was selected as the study area. In this area, metamorphic rocks outcrop, overlapped by plio-pleistocenic and quaternary coarse deposits of marine terraces. Terrain instability is increased by the presence of both a thick weathered cover above the metamorphic substratum and deep eroded gullies. Additionally, man-made trackways, which modify the natural drainage network, increase slope instability (Bonavina et al. 2005).

On several of the dates in which RRP caused damage in this area, further RRPs were not recorded in any other sectors of Calabria. This finding highlights a high susceptibility of this area to be damaged by RRP (Diodato et al. 2011).

From an administrative viewpoint, the area is in the Reggio Calabria province, and it extends through the municipalities of Scilla and Bagnara Calabra, two touristic summer villages. Bagnara C., the northernmost of the two municipalities, has an area of approximately 24.7 km^2 and a population density of 454.66 inhabitants/km^2. Scilla has an area of approximately 43.7 km^2 and a population density of 118.44 inhabitants/km^2.

The Road Network of the Study Area

Because of the touristic vocation of the area, the urbanised sectors of both municipalities have been developed along the coast. Because of both the position of villages and rugged morphology of the innermost sectors, the main roads lie on a coastal zone about 3 km in width. These roads have in some ways acted as a "detector" of RRP occurrence by recording a very long series of RRP. The main types of roads passing through the area are listed as follows:

(a) *Urban roads*, developing inside the urbanised sectors of the area and showing very heterogeneous characteristics from track to track.
(b) *SS 18*, a state road that used to be the main North–South road before 1972, the year in which the highway was opened. Today, this road, which passes through the main coastal urbanised centres, is used for regional and local traffic, but it still ensures North–South communications when, as often occurs during rainy periods, landslides and/or floods cause traffic interruptions along the highway. The technical standards of this road are low; it is a one-lane road with a width ranging from 7 to 8 m and develops along a curvilinear path that runs along the flank of the area mountains. The slopes on which this road develops are very steep and drop abruptly to the sea. Rockfalls and debris flow are the most frequent type of RRP, and where the road crosses ravines, even floods can damage it.
(c) *A3*, a two-lane highway with a width of 24.20 m, is the unique highway of Calabria and conveys North–South regional and national traffic. Compared with other Italian highways, it is in very poor condition, and for this reason, renovation work is currently in progress. The track of A3 passing through Scilla and Bagnara C. was opened in 1972, and it is almost parallel to SS 18. Because of the rugged morphology of the area, its layout mainly develops either in tunnels or viaducts. It is affected by the same RRP affecting SS 18 where the road runs on the flank of reliefs.
(d) *FFSS* is the acronym indicating the Italian railway. We use a double track opened in 1886 that carries North–south national and regional railway freight and passenger traffic. Regarding other communication lines, it is located more inland although in Scilla, a stretch is so near the coast that it is often damaged by sea storms.

Historical Data Collection in the Study Area

In Calabria, there are no public agencies that collect data on damage caused by RRP. Nevertheless, since 2000, we at CNR-IRPI of Cosenza have been implementing and updating a regional historical archive of the effects of RRP. Currently, this archive contains more than 10,000 documents coming from various Calabrian agencies, such as the Department of Public Works and municipal offices, concerning the period from approximately 1890 to the present. Studies on regional sites hit by landslides or floods and commissioned by Civil Protection offices have also been conducted using this archive (Petrucci 2005a, b, 2006).

Table 1 RRP (Rainfall-Related Phenomena) that caused damage along the roads of the municipalities of Scilla and Bagnara C. (Calabria, Italy) between 1900 and 2011

RRP	Scilla	Bagnara C.	Total	Percentage (%)
Flood	10	18	28	15
Landslide	86	75	161	85
Total	96	93	189	100
Percentage	51 %	49 %		

A historical investigation of RRP occurring between 1900 and the present along the roads listed in the previous section was performed in the abovementioned archive. The documents analysed primarily came from the Department of Public Works and Calabrian Civil Protection offices. In addition, a systematic survey of the newspaper library of a regional daily newspaper (La Gazzetta del Sud) was conducted.

Results

The total number of damage-related reports collected was 189 over 110 years. The number of cases recorded in each of the two analysed municipalities was almost equal (51 % versus 49 %) (Table 1). Damage caused by landslides (85 %) was more numerous than that caused by floods (15 %).

Analysing the temporal distribution of data, we found that the number damage-related reports was low in the 1900–1950 period. This result can be due to either a lower availability of historical sources or a lower number of damage cases related to the minor presence of vulnerable elements that characterised that period. The highway was opened in 1972, and in the seventies, the urban road network was expanded to reach previously uninhabited sectors because of increasing touristic exploitation.

For the entire temporal window, the number of cases of damage per year was 1.66. The same ratio, assessed for the 1951–2011 period, increased to 2.9 cases/year. Human injuries have been occurring from 1950 to the present, with a frequency of 0.3 cases/year in the last 60 years.

The values of DI_y for the 1950–2011 period are shown in Fig. 1. To emphasise the difference between damage affecting roads and damage suffered by people, the two terms were divided by 20 (roads) and 10 (people), respectively. In the last 20 years, there was an increase in the number of cases of damage, and the DI_y shows high values (Fig. 2). The highest annual values pertain to 1968 and 2005. These two cases were different; in 2005, damage to roads was more prevalent, whereas in 1968, damage primarily affected people.

Analysing the 21 cases in which damage to people occurred, in 16 cases (76 %) the damaging phenomena were landslides, while the phenomena were floods in only

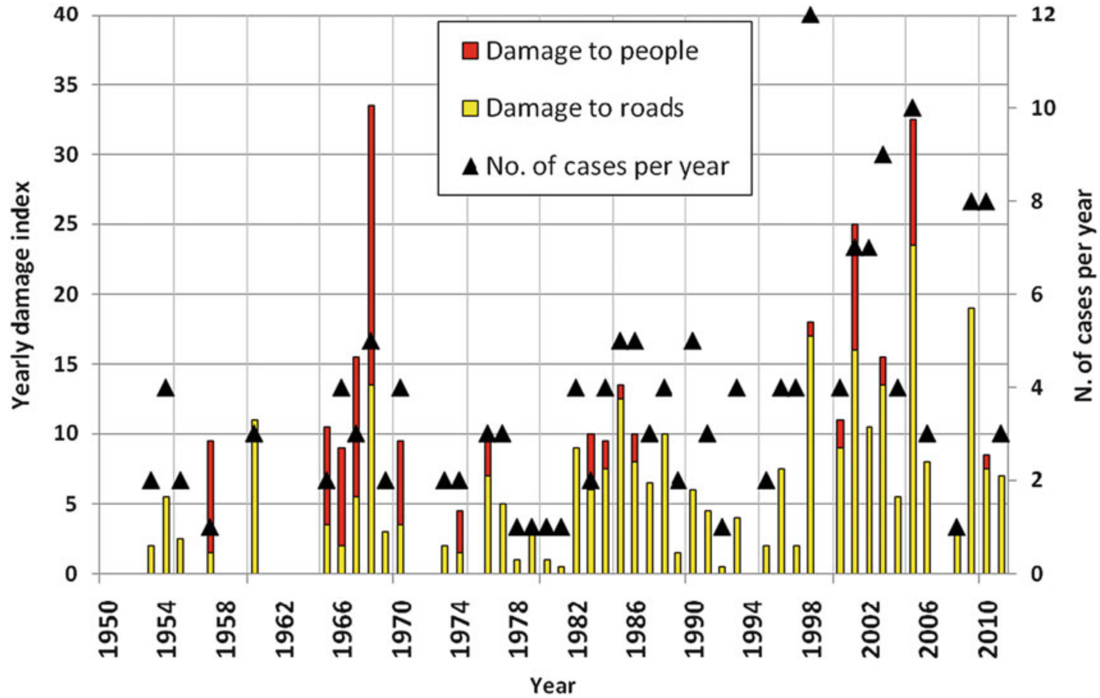

Fig. 1 Yearly damage index (*bars*) representing damage along the Scilla and Bagnara C. road network (1950–2011 period), and the number of cases of damage per year (*triangles*)

5 cases (24 %). In total, 10 people were killed, 104 were injured, and about 300 people were involved. In 10 of the 21 cases, people were involved but managed to escape injury.

The most severe cases concern labourers killed and injured by landslides during the construction of tunnels (three were killed and one was injured in 1957 in a FFSS tunnel, three were killed and two were injured in 1967 in the construction of a tunnel on A3 and 1 was killed and three were injured in another tunnel on A3 in 1968) or retaining walls (one was killed and one was injured along the SS 18 in 1966). Only two motorists were killed hit by boulders: one along the SS 18 in 1965 and another along an urban road in 1974, respectively. In Fig. 2, the points at which human injuries occurred along the main roads are shown. The most frequently affected road is SS 18, followed by A3 (Fig. 3) and FFSS.

Train derailments occurring in 1968 (50 injured), 2001 (14 injured) and 2005 (25 injured) show the highest numbers of injured persons. In this last case, a flash flood associated with landslides along the valley sides became a destructive concentrated flow that ran down from the hills on all the roads located perpendicular to their path (A3, FFSS and SS 18). The locomotive and two *vagon-lit* were hit by mud and boulders, but the low velocity at which the train was passing avoided more serious consequences for the passengers.

In two cases, some motorists passing on the road fortuitously managed to survive after a landslide abruptly fell onto the road, and in one case, more serious consequences were avoided because two motorists realised that a landslide was coming and blocked traffic. The people involved in these cases all lived in of one of the two municipalities analysed in the study.

Concluding Remarks

A methodology for assessing relative damage caused by RRP such as landslides and floods on a road network has been presented and applied to a Calabrian study area. The aim of the methodology was to provide a relative damage assessment, even in cases in which economic data on damage and traffic volumes on the road network were unavailable.

The long series of damage caused by RRP along the road network passing through the Scilla and Bagnara Calabra municipalities shows that landslides are the most common cause of damage to roads and people. The total number of RRP was 189 in 110 years, but the frequency of damage seems to have increased in the last few decades (Fig. 1). Death among drivers occurred in only two cases in 110 years. Nevertheless, eight workers died because of

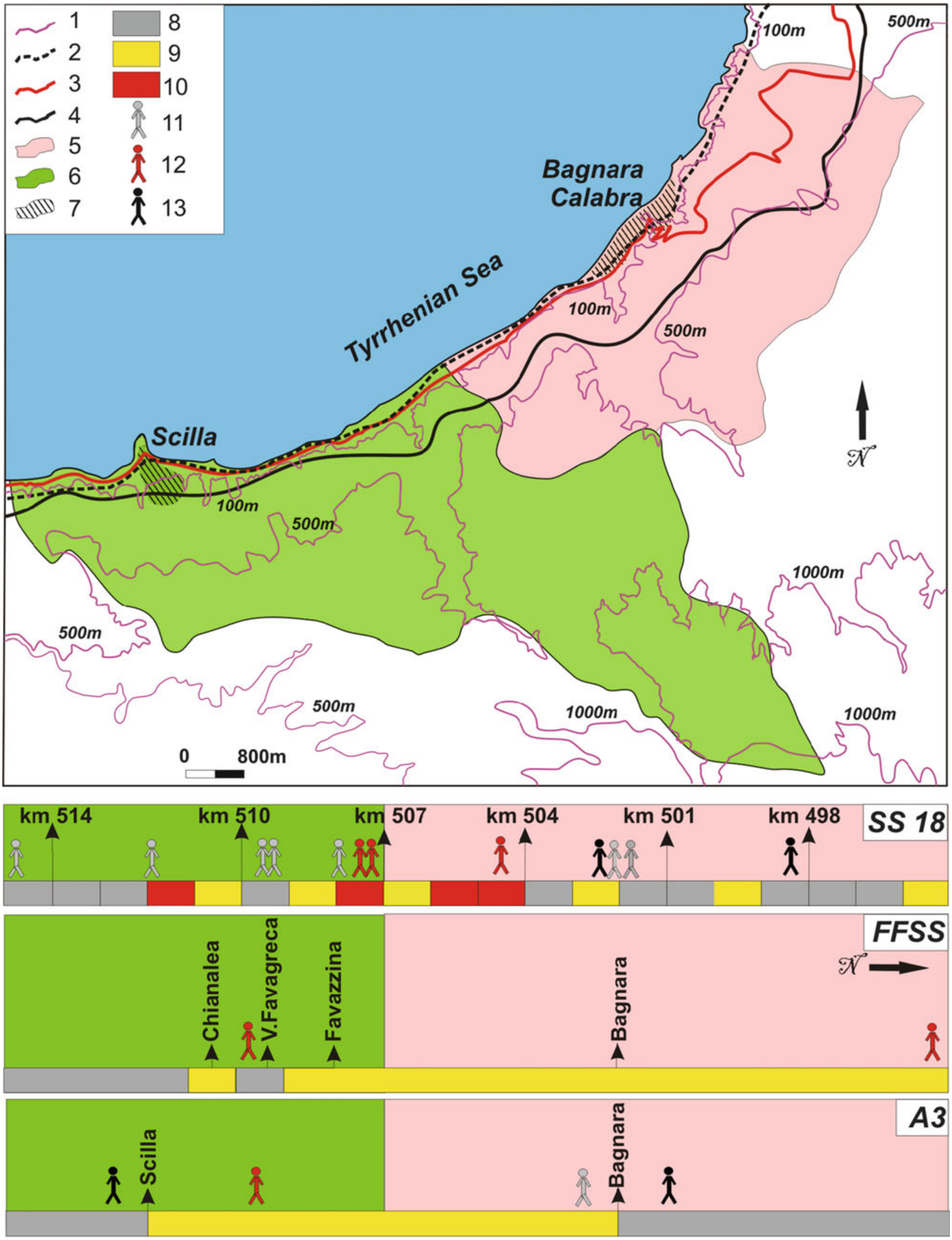

Fig. 2 Geographical representation of the damage caused by RRP along the road network of the study area (1900 and 2011). The map area contains contour lines (*1*), SS18 (*2*), FFSS (*3*), A3 (*4*), Bagnara C. municipality (*5*), Scilla municipality (*6*) and main urbanised sectors (*7*). The bottom contains linear sketches (not in scale) of the main roads of the area (SS18, FFSS and A3). *Coloured bars* represent the frequency of damage caused by RRP during the study period (8 = 1 case; 9 = 2–5 cases; 10 > 5 cases). Tiny figures are placed at the points at which damage occurred and are coloured according to DI value (*grey*: DI < 30; *red*: DI between 30 and 90; and *black* DI > 90)

Fig. 3 A block of rock on the A3 (May 12, 2010)

landslides triggered by rainfall during the construction of tunnels and retaining walls along the roads.

The local community seems aware of the hazards, as witnessed by some websites on which people collect and share information about frequent road interruptions, especially along the SS 18.

No reckless behaviours have been detected in drivers. On the contrary, based on the damage descriptions, residents pay great attention to the landslide problem. Nevertheless, it must be taken into account that non-residents unaware of the dangers of RRP use both the SS 18 and A3.

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THE SECOND WORLD LANDSLIDE FORUM

Economic Valuation of Landslide Damage in Hilly Regions: A Case Study from the Flemish Ardennes, Belgium

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Abstract

Several regions around the globe are at risk to incur damage from landslides. These landslides may cause significant structural and functional damage to public and private buildings and infrastructure such as houses, schools, hospitals, administrative, industrial and commercial buildings, electricity grid, roads, railways and underground cables. Many studies investigated how natural factors as well as human activities control the occurrence or re-activation of landslides. However, few studies have concentrated on the overall damage caused by landslides, particularly in low-relief areas, and on the policy instruments which policymakers can use to prevent further damage. This study therefore aims at developing a methodology to estimate the overall damage caused by landslides in low-relief areas. In this study we combine two economic valuation methods. On the one hand, we estimate the decrease in the value of real estate due to their location in areas with a high landslide risk. On the other hand, we estimate the costs to restore the damage to private buildings and public infrastructure which is caused by landslides. This methodology provides a range of the maximum and minimum economic value of the damage caused by landslides. In addition, we provide an overview of landslide prevention and remediation measures and estimate the associated costs. This methodology will then be applied to the Flemish Ardennes (Belgium), a hilly region susceptible to landslides.

Keywords

Landslide loss assessment • Direct and indirect cost • Prevention and remediation measures

Introduction

Several regions around the globe are at risk to incur damage from landslides. These landslides may cause significant structural and functional damage to public and private buildings and infrastructure such as houses, schools, hospitals, administrative, industrial and commercial buildings, electricity grid, roads, railways and underground cables (e.g. Alexander 1989; Glade 1998; Olshansky 1990; Schuster 1995a; Schuster and Fleming 1986; Swanston and Schuster 1989). Many studies investigated how natural factors as well as human activities control the occurrence or re-activation of landslides (e.g. Crozier 1986; Popescu 2002; Van Den Eeckhaut et al. 2007b). However, few studies have concentrated on a quantitative estimate of the overall damage caused by landslides at

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a regional scale, particularly in low-relief areas, and on the policy instruments which policymakers can use to prevent further damage.

Landslides lead to economic losses and both direct and indirect costs have to be considered. The former are costs of replacement, repair or maintenance resulting from landslide-caused economic damage and destructions of property, while the latter cover all other landslide-caused costs (e.g. Schuster and Fleming 1986; Schuster 1996; Schuster and Highland 2001). For local governments, landslides, including reactivated landslides, have direct economic consequences because they might face costs to repair and rebuild public infrastructure. Homeowners also incur direct costs because their privately-owned houses are damaged due to the occurrence of a landslide.

In addition, there might also be psychological consequences for the owners of properties located in areas that are susceptible to landslides (Hereafter referred to as **LSPA-** landslide-prone areas) Natural hazards such as earthquakes, floods and hurricanes are known to affect the psychological well being of humans (e.g. Chae et al. 2005; K.I.N.T 2001; Logue et al. 1979; Wang et al. 2000) and the same holds for landslides (e.g. Catapano et al. 2001). However, these non-tangible costs are often neglected or insufficiently taken into account because they are difficult to measure and value (Schuster and Fleming 1986; Middelman 2007). Owners of property located in LSPA might for example be stressed because the real estate property in which they invested loses value due to the fact that it is located in a LSPA. Another worry relates to the fact that insurance companies might be unwilling to insure a property located in a LSPA or might not cover certain types of damage. As a consequence, the owner will not only face higher costs if a calamity occurs, but the impossibility of fully insuring the property will also affect its market value.

Governments at different levels (federal, regional and local), become increasingly aware of the fact that private owners face considerable physical and psychological consequences if they build in LSPA. Societies are becoming reluctant to invest in structural measures that can reduce natural risks because of the high costs associated with these engineering and technical works (Guzzetti et al. 1999). Instead, there is a tendency towards the development of non-structural mitigation measures, such as land-use planning and regulation and building codes, and to move away from investing in long-term costly projects of slope stabilization to minimize the loss of property damage (Guzzetti et al. 1999; IDNHR 1987; Kockelman 1986; Schuster 1995b; Schuster and Fleming 1986; Spangle Associates 1988; UNDRO 1991; U.S. Geological Survey 1982).

Consequently, governments become more cautious in granting permits for building projects in LSPA for several reasons. On the one hand, if they grant permits to build in a LSPA, the government has to ensure accessibility to the site and the availability of utilities at the site. If maintaining the good state and availability of this public infrastructure in LSPA is much more costly than in a non-LSPA, this will reduce the likelihood of granting building permits as governments will have to bear additional costs.

On the other hand, private owners might incur problems and damage while constructing their houses or after it has been built. If they were not aware of the landslide risk in the area, while the local government who issued the permit was aware, they might consider the government responsible for the damage because the government neglected to warn them about the landslide risk or because they consider that the government never should have issued the permit to build in a LSPA. The indirect costs related to such claims and lawsuits can be very large. For example, after a landslide occurrence in the San Francisco Bay area in 1982, a large number of claims and lawsuits were filed against city and county for a value triple the amount of the direct losses incurred by the destruction of houses, businesses and public infrastructure (Smith and Hart 1982).

One landslide damage mitigation strategy could be to completely forbid development of the LSPA. However, the hazard of landslides is typically largest on scenic areas and expanding population increases the pressure to expand the built environment so that governments will have to make trade-offs. If governments want to design appropriate policy measures to minimize societal damage due to the occurrence of landslides, they will need to assess the costs and benefits of different mitigation scenarios. As a first step, one needs to get a picture of the overall direct and indirect economic damage due to the occurrence of landslides. In addition one needs to know which measures can be taken to remediate and prevent landslide damage and what the accompanying costs are. This study therefore aims at developing a methodology to estimate the overall direct and indirect damage caused by landslides in low-relief areas. This methodology will then be applied to the Flemish Ardennes (Belgium), a region susceptible to landslides. In addition, this study will provide an overview of landslide prevention and remediation measures and estimate the associated costs.

Study Area

This study focuses on 27 municipalities affected by landslides located in or nearby the Flemish Ardennes, a region in the West of Flanders (Belgium). The study area is a hilly region characterised by altitudes ranging from 10 m to 150 m a.s.l. and hillslope gradients are generally less than 0.15 m m^{-1}. In this study area (see Fig. 1), previous studies identified 291 areas where landslides occurred in the (recent) past (Van Den Eeckhaut et al. 2005, 2007a, 2011). In the

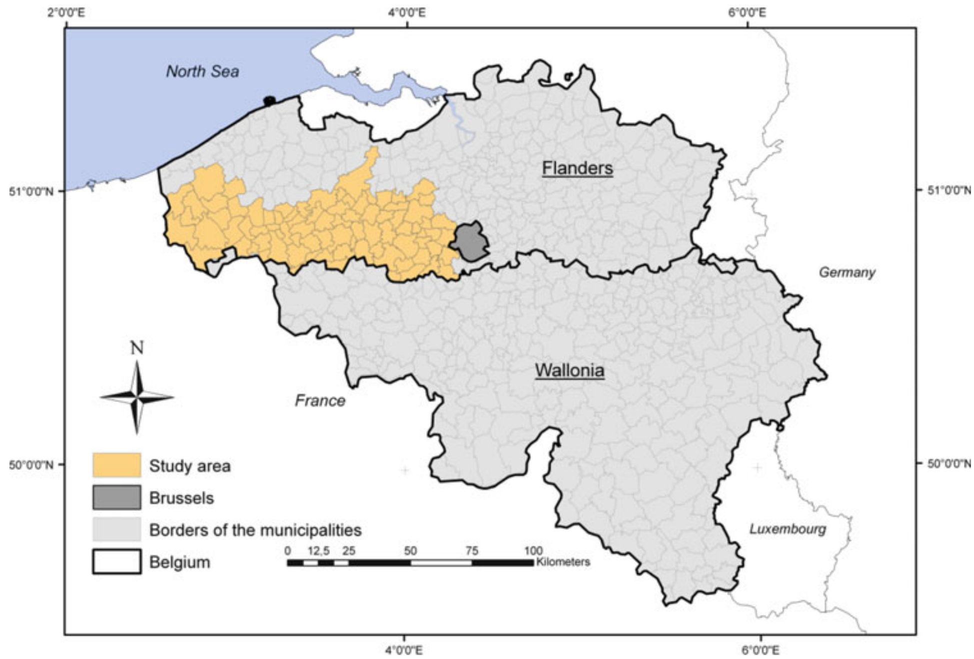

Fig. 1 Location of study areas in Belgium

LSPA of the study area, the (re-)activiation of a landslide has never led to physical injuries to human beings, nevertheless there was physical damage to both public and private infrastructure such as houses, administrative, industrial and commercial buildings, electricity grid, roads, railways and underground cables (Van Den Eeckhaut et al. 2007b). Some of these LSPAs are covered with forests so that the economic damage due to landslides or reactivation of landslides is limited, while others were converted into residential areas in the last decades, resulting in larger economic damage to both private properties as well as to public infrastructures (roads and utilities) due to landslide activity.

Data Collection

To produce an overall picture of the economic damage caused by landslides in low-relief areas such as the Flemish Ardennes, data will be collected in two ways. On the one hand, semi-structured interviews will be conducted from June 2011 till September 2011. Therefore, two different questionnaires will be used. One questionnaire is designed to obtain information about damage to public infrastructure, while another questionnaire is designed to gather information about damage to private properties. The former questionnaire will be used when conducting interviews with civil servants (e.g. from the technical service from the various towns in the study area), or with the owners and providers of utilities such as electricity, sewage, water, etc. and other stakeholders that might be knowledgeable about the damage to public infrastructure.

Additionally, focus interviews will be conducted with experts to collect information about damage to very specific public infrastructure. To get information about the additional costs of the prevention measures taken for very large-scale infrastructure projects such as railways or highways, focus interviews will provide more useful site-specific data on the economic costs related to landslide damage prevention than will semi-structured interviews.

The study aims to provide a complete picture of all damage to public infrastructure due to landslide occurrence in the region, while damage to private properties will only be illustrated based on a few case studies. To ensure all damage to public infrastructure and buildings is covered in the study, we identified 13 villages or towns in which roads, railways or power transmission lines were located in at least one of the LSPAs located in the village (see Fig. 2). In those villages or towns damage to public buildings or infrastructure might have occurred and therefore civil servants from the various technical town services will be interviewed.

Methodology

To estimate the economic damage, one may rely on different methods. For private properties, one might rely on the hedonic pricing method (Perman et al. 2003). This method estimates the damage based on the difference in house prices using econometric regression techniques. In particular, the sales price of a house which is located in a landslide-prone area is compared with the sales price of house with similar characteristics but which is located outside a LSPA. Unfortunately, the number of house sales in a LSPA of the Flemish

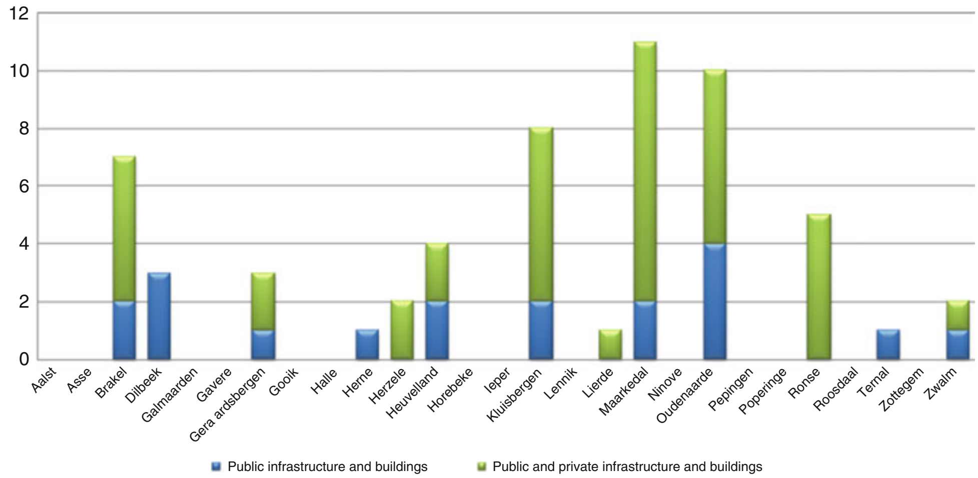

Fig. 2 Number of landslide-prone areas (LSPA) with public infrastructure or buildings per village/town

Ardennes is too small to conduct any formal econometric analyses. Therefore, we have to rely on second best solution. We will rely on the value estimates of real estate agents and surveyors. They will be asked to value a property (i.e. estimate its sales price) located in a LSPA and how their valuation would differ if the same property was located outside a LSPA. This value loss of a private property will provide us an upper limit of the economic damage due to landslides.

While the decrease in the value of real estate due to their location in areas with a high landslide risk might be the most appropriate measure of the damage to private properties, this method cannot be used for damage to public infrastructure. In addition, certain private persons will argue that the property might remain usable and does not lose value because they take measures to repair or prevent damage caused by landslides and as such that there is no decrease in the value of the real estate. Therefore, we also estimate the cost to repair the damage caused by landslides according to the substitution cost method (Pearce et al. 2006). This goes from the costs to repair a crack in a wall over the cost to rebuild a certain (part of a) wall of a house to the cost of the complete removal and rebuilding of an entire part of a house. For public infrastructure like a road, this will range from the costs of repairing a crack by filling with asphalt to the costs of rebuilding part of the road (including the foundations as well the top layer). In addition, we will ask whether certain roads in each LSPA have to be repaired or rebuilt more frequently. If this is the case, this will also result in higher costs which will also be taken into account in the overall estimate of the damage cost. If, for example a certain part of a road of 10 m in length located in a LSPA has to be re- asphalted every 10 years, while roads located outside a LSPA but with similar characteristics have to be re-asphalted every 5 years, the maintenance cost of the road in the LSPA is twice as high as the maintenance cost of a road in the LSPA. The difference in maintenance cost will be considered as an integral part of the economic damage due to occurrence of landslides.

Finally, certain private agents as well as public institutes will take measures to prevent the occurrence of damage by landslides. For example, they might shore or prop up their house so that they will not face problems such as cracks in walls or the subsidence of the house if a landslide is (re-) activated. We assume that private as well as public agents behave rationally and they explicitly or implicitly make a cost benefit analysis before they take any preventive measures. In particular, if they take certain measures, they will only do so if they assume that the cost to repair damage would be larger than the cost to prevent damage. As such the cost of measures to prevent landslides damage can be seen as a lower limit of the damage that would be caused by the landslide activity.

The above-mentioned costs of repair and prevention measures will be estimated using the data collected in the semi-standardized and expert interviews (see previous section). As such, the methodology will provide a range of the maximum and minimum economic value of the damage caused by landslides to public as well as to private buildings and infrastructure.

The interviews will not allow us to end up with a detailed cost estimate of every square meter of road that has been repaired. However, we will be able to attain index numbers for the reparation of specific road types (according to the frequency and type of vehicles that drive on the road). These index numbers will be applied to all roads located in a LSPA to arrive at an overall figure of the damage to roads located in the study area. A similar index number approach will be used to estimate the damage to other public infrastructure such as the electricity grid, sewage system etc.

So far we mainly focused on damage by landsliding to buildings as well as damage to public infrastructure such as roads and utilities. However, other types of immovable assets might also be affected. For example, the occurrence of landslides might affect tree growth in the wooded areas (Van Den Eeckhaut et al. 2009). Tree-trunks will have a crooked, irregular shape (e.g. curved) so that the wood production value of the trees is lowered. Based on expert interviews with foresters we will derive an index number of the decrease in wood value (forest productivity) due to its location in a LSPA.

Pastures will be affected as well. The topography of a pasture located in a LSPA might be altered resulting in swampy zones or ponds. Consequently, part of the pasture land may no longer be used for grazing animals. In such circumstances, a good proxy for the economic consequences of landslides would equal the difference between the unit value of pasture land and nature area multiplied by the surface that can no longer be used as pasture land.

Landslide Loss Reduction Strategies

The methodology described above will allow us to make a retrospective loss assessment of the landslides that occurred in the study area. This loss assessment together with the susceptibility maps of the region (Van Den Eeckhaut et al. 2006, 2007a, 2011; Van Den Eeckhaut and Poesen 2009) can then be used to make a first step towards a risk assessment.

The loss assessment together with the (preliminary) risk assessment will allow governments to set up a loss reduction strategy of which mitigation is a key component (Spiker and Gori 2000). Mitigation measures include for example land-use planning and regulation, engineering, building codes, but are often not easy to implement (Committee on the Review of National Landslide Hazard Mitigation Strategy 2004). In such circumstances, there is an important role for the development and dissemination of incentives for landslide hazard mitigation. Outreach activities can focus on informing people about human activities that trigger or contribute to landslides, the seriousness of building in a LSPA and the advantages of not only recognizing but also dealing with the landslide problem. The latter can be achieved by linking hazard maps to land-use planning and restrict or discourage (through information provision) the expansion of the built environment in a LSPA. Additionally, there is also a role for the dissemination of engineering and construction approaches to mitigate landslide hazards and to protect existing buildings or new buildings on high-value land for damage. Conversely, disincentives can be established for example, by allowing owners to build in a LSPA but only if they disclose to potential purchasers that they are buying property with a potential natural hazard.

Results and Conclusions

Since data collection is still ongoing, the results and conclusions can not yet be presented, but will soon be available.

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Index-Oriented Methodologies for Landslide Consequence Analysis: An Application to a Mountain Community in the French Alps

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Abstract

Consequence analysis is a key aspect of anchoring assessment of landslide impacts to present and long-term development planning. Although several approaches have been developed over the last decade, some of them are difficult to apply in practice, mainly because of the lack of valuable data on historical damages or on damage functions. In this paper, two possible consequence indicators based on a combination of descriptors of the exposure of the elements at risk are proposed in order to map the potential impacts of landslides and highlight the most vulnerable areas. The first index maps the physical vulnerability due to landslide; the second index maps both direct damage (physical, structural, functional) and indirect damage (socio-economic impacts) of landslide hazards. The indexes have been computed for the 200 km^2 area of the Barcelonnette Basin (South French Alps), and their potential applications are discussed.

Keywords

Consequence analysis • Vulnerability • Risk analysis • Mapping • Landslide

Introduction

Landslide risk combines the likelihood of a landslide to occur, or landslide hazard, with an assessment of the impact or potential consequences of the hazardous event (Fell et al. 2008). The studies focussing on regional scale quantitative landslide hazard assessment are relatively numerous (Del Gaudio et al. 2003; Guzzetti et al. 2005; Cascini 2008). Yet, the number of studies dealing with regional scale (semi-)quantitative consequence or vulnerability analysis is still rather low (Hollenstein 2005). However, in many cases the consequences determine the losses to a greater degree than does hazard (Alexander 2004). Consequences are generally defined as the potential outcome arising from the occurrence of a landslide expressed qualitatively or quantitatively, in terms of loss, disadvantage or gain, damage, injury or loss of life (Glade et al. 2005). For quantitative consequence analysis, information on the vulnerability or the degree of loss (expressed on a scale of 0- no loss- to 1 -total loss-) of elements at risk and on their value (cost) are required.

Five different types of loss can be distinguished: (1) Physical injury, referring to the physical and mental health of persons; (2) Physical and structural consequences, referring to the damage of buildings and infrastructures (transport, pipelines, telecommunications and energy supply lines, etc.); (3) Socio-economic consequences, referring to

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socio-politico-economical losses; (4) Environmental consequences, referring to the impact on stream environments, wildlife, pollution due to leakages, etc.; and (5) Cultural heritage consequences, referring to the damage to historical monuments. Puissant et al. (2006) provides an overview of the possible approaches for consequence analysis at different geographical scale, distinguishing between macro-scale analysis based on expert knowledge, meso-scale analysis based on more reproducible qualitative or semi-quantitative methods (Papathoma-Köhle et al. 2007), and micro-scale analysis based on quantitative analysis (Galli and Guzzetti 2007; Li et al. 2010). Generally, a full quantitative method is difficult to apply due to the lack of statistics on past landslide losses and fatalities in the region and on the absence of reference events of a given landslide type (Glade 2003).

The objective of this work is to present two index-oriented methodologies to map landslide consequences in order to identify the main vulnerable zones and possibly prioritize the resources for risk prevention. An exhaustive and detailed database on elements at risk has been developed for the Barcelonnette Basin, one of the mountainous area in France which is most exposed to multiple hazards (landslides, floods, snow avalanches, earthquakes; van Westen et al. 2010) The database is explored for both the mapping of the physical vulnerability to hazards (landslides, floods, snow avalanches) and the mapping of the potential consequences of hazardous events. The study completes a preliminary assessment (Puissant et al. 2006) where the authors have tested a semi-quantitative regional scale consequence analysis using a limited set of building and infrastructure indicators. The possible application of the two indexes for the assessment of landslide potential consequences is discussed, though the indexes can be used for other types of hydro-geological hazards.

Study Area

The study area is the Barcelonnette basin (South east France), a 200 km^2 area covering the municipalities of Saint-Pons, Barcelonnette, Faucon, Enchastrayes, Uvernet-Fours and Jausiers in the Department 'Alpes-de-Haute-Provence' (Fig. 1).

This area has an important administrative, touristic, commercial, and communication role. Currently winter and summer tourism constitutes one of the major economic activities. Apart from houses, the region contains several administrative buildings, schools, hospitals, shops, hotels, ski infrastructures and industrial parks. The most important lifeline is the main road ensuring the relation with Italy. Due to its predisposing geological structure consisting of strong limestones or sandstones overlaying black marls, the hillslopes are affected by severe gullying, shallow landslides, large deep-seated landslides, debris flows and rockfalls (Malet et al. 2005).

The tourism activities have lead to an intense use of previously unoccupied, sometimes landslide susceptible, portions of slopes.

Database of Elements at Risk

In Europe, only the largest urban cities have spatial databases in which the elements at risk are carefully described for vulnerability analysis. They are usually provided by the national mapping agency of each country, or by the large municipalities. This is often not the case in the mountainous areas where this basic information has to be collected. The exposed elements (EE) generally considered as relevant at a 1:10,000 scale to evaluate the damage are (Léone et al. 1996):

- *Landcover/landuse* which gather *natural and semi-natural surfaced areas* such as forests (coniferous or broadleaved trees), agricultural lands, grasslands, wetlands and open-areas without any vegetation and *artificially surfaced areas* such as car parks, camp sites or leisure areas;
- *Buildings* which refer to man-made objects (residential block, individual house/chalet, warehouse, etc.) built either in highly resistant structure (concrete, breeze-block, stone) or medium resistant structure (steel, wood). Each building is associated to one or several urban functions (residential, commercial, industrial, and agricultural), has a certain number of (occupied) floors and a certain age;
- *Lifelines* which correspond to different type of networks (power, water, sewerage, communication), the transport of essential supplies, as well as the infrastructure essential for the economical activities (motorway, national road, municipality road, etc.). Lifelines supporting touristic activities (ski lifts) are also integrated in this category.

Among these EE, buildings (according to their height or their number of occupied floors) and transport lifelines (according to the number of traffic lanes) are the most discriminant for the identification of the damages. Indeed, the size and the number of buildings, and their spatial distribution enable the estimation of the potential number of casualties, the structural damages, and the functional disturbances that may affect the socio-economical activities. Furthermore, the identification of transport lines is useful to locate different networks, not directly included in the dataset, usually established at the edge or beneath the road.

In the database constructed for the Barcelonnette Basin (Fig. 2), building locations were either measured by GPS, extracted from the BD TOPO® (IGN 2004) or from aerial photographs. Indicators of buildings (building type,

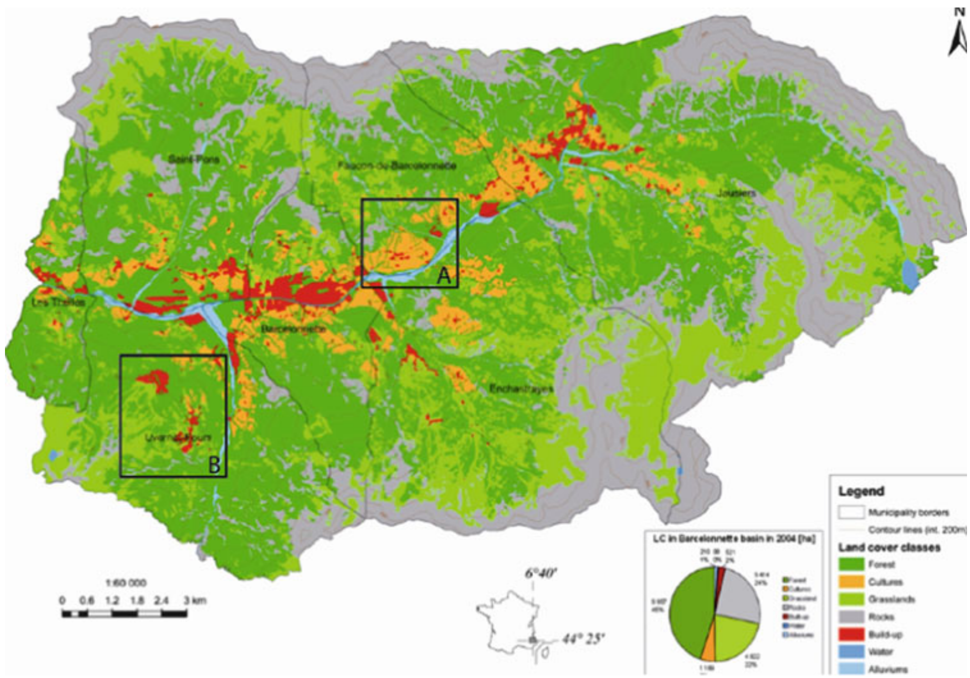

Fig. 1 Land cover map of the study area in 2004 with (*A*) Faucon municipality and (*B*) Uvernet-Fours municipality (ski ressort station of Pra-Loup)

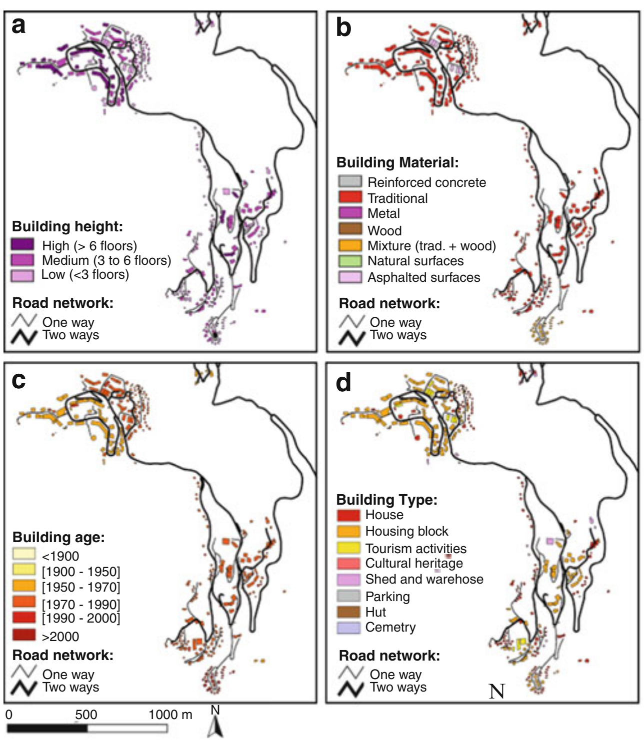

Fig. 2 Example of the elements at risk database available for the Barcelonnette Basin: the Uvernet-Fours municipality with Pra-Loup ski resort station (**a**) Building height; (**b**) Building material; (**c**) Building age; (**d**): Building type

function, number of floors, number of occupied floors, age, state and material) were mainly obtained from detailed field surveys using online GIS mapping, and partly completed with other sources (multi-temporal aerial photographs, Google Earth analysis). Missing information such as the number of floors for some buildings was obtained from the BD TOPO® or from a Street View analysis Given that in France the mean building height is about 2.8 m, the buildings floors were classified as:

- Low: <3 floors, corresponding to a height < 8 m
- Moderately high: 3–6 floors, corresponding to a height ≥ 8 to < 20 m
- High: >6 floors corresponding to a height ≥ 20 m

Huts and sheds were all assumed to have less than three floors. Information on lifelines including transportation systems (roadways, railways) and utility systems (electric power networks) were obtained from BD TOPO®, while land use and land cover were obtained from the analysis of an aerial photograph of 2004 (Fig. 1). As tourism is important for the region, a distinction between the areas characterized by winter and summer tourist infrastructures was made.

Methodology 1: Index of Physical Vulnerability (RVI)

From this database, it is possible to propose a first type of assessment of the direct damage through the mapping of a physical vulnerability index. A pilot case study in the Municipality of Faucon is presented. The method is based on a vulnerability index (e.g. PTVA; Papathoma Tsunami Vulnerability Assessment) originally developed for tsunami assessment (Papathoma and Dominey-Howes 2003).

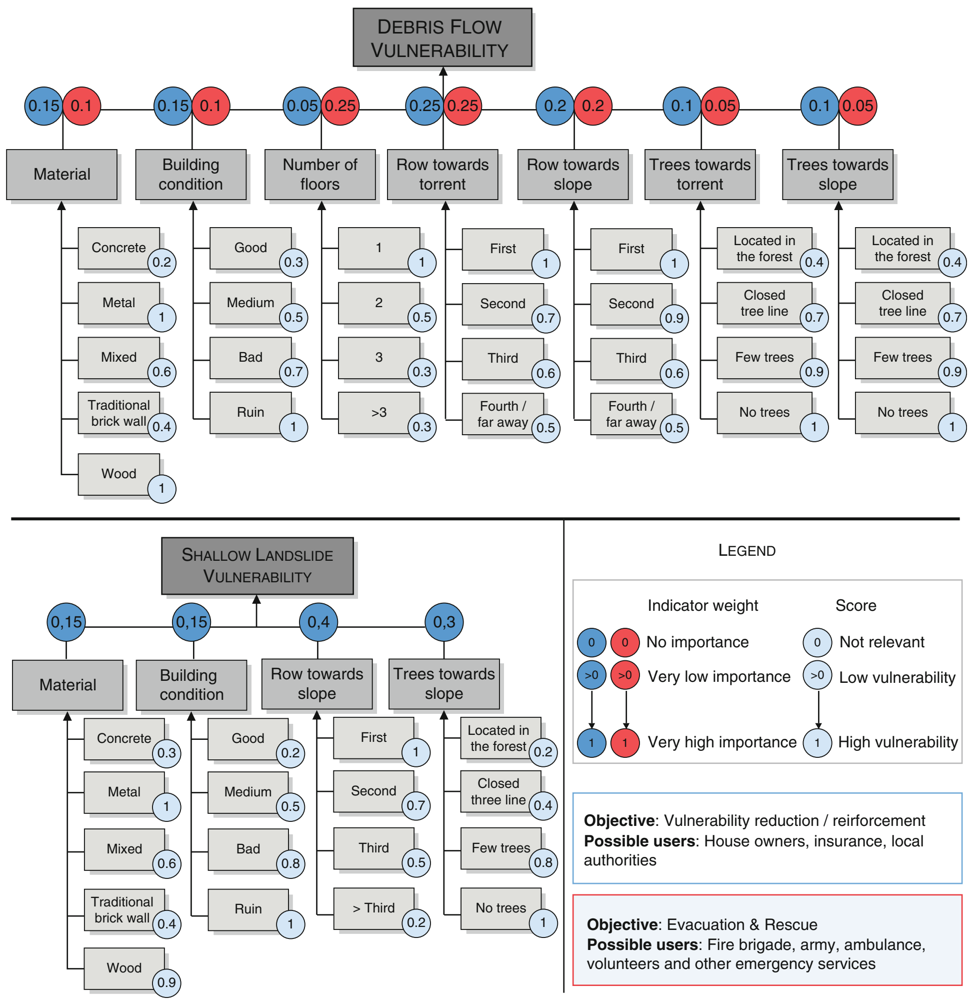

Fig. 3 Workflow for the calculation of the physical vulnerability index (RVI) for debris flow and shallow landslide hazard (Papathoma-Koehle et al. 2011)

The workflow to calculate the index is the following:

- Step 1: Identification of the relevant hazards and categories of stakes in the study area;
- Step 2: Data collection and selection of appropriate vulnerability indicators;
- Step 3: Weighting of indicators, and assignment of a *Relative Vulnerability Index* (RVI) for every building with the formula:

$$RVI = \sum_{1}^{m} w_m \cdot I_m s_n \qquad (1)$$

with the weights w_1-w_m for the vulnerability score $I_m s_n$ (s_1-s_n) for each indicator I_1-I_m.

This index takes into consideration all the characteristics of the EE that influence their vulnerability either to a single hazard or to a set of hazards. Figure 3 details the indicators for debris flow and shallow landslide hazards on the basis of expert appraisal and their weighting for different categories of users.

Methodology 2: Index of Potential Damage (PDI)

From the same database, it is also possible to propose a more complete assessment of potential damage taking into account both direct damage (physical, structural, functional) and indirect damage (socio-economic effects). This method evaluates damage by combining a characterization of the EE in terms of stakes and the estimation of their value with a spatial multi-criteria model. Damages are defined on a relative value scale (Maquaire et al. 2004). The workflow to calculate the *Potential Damage Index* (PDI) is the following (Fig. 4):

- The first step defines a typology of predominant damages observed for the area. The damages can correspond to (a) the people in their physical integrity '*physical injury*' (C_{PI}), (b) the direct and local effects on buildings, infrastructures and human activities over short time periods '*direct structural and functional effect*' (C_{SF})

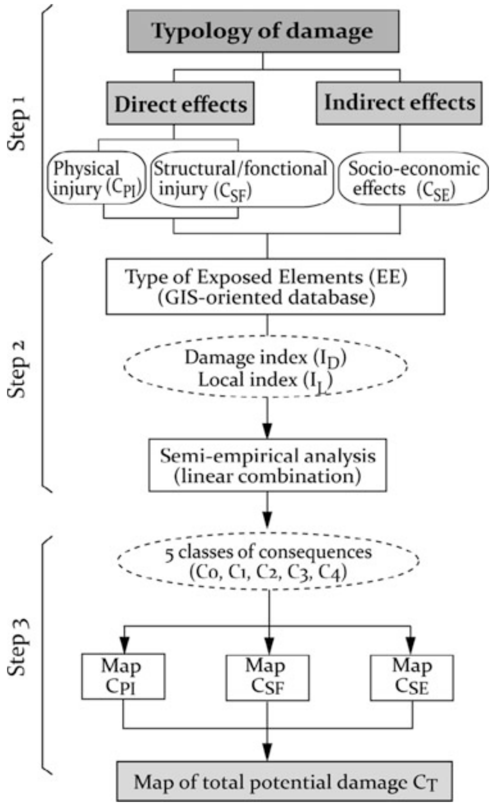

Fig. 4 Workflow for the calculation of the potential damage index for landslide hazard (Modified from Puissant et al. 2006)

and (c) the indirect and regional effects on socio-economic activities over long time periods '*indirect socio-economic effect*' (C_{SE}). Environmental and cultural damages are not included so far.

- The second step consists in selecting the EE concerned for each type of damage. Every element is then described by some attributes ranked by expert weighting. A relative value called '*damage index*' (I_D) is allocated to every attribute of the elements for all damage. Every attribute can be weighted to take into account the purposes of the assessment (prevention, emergency management, etc.), the type of end-users (local authorities, emergency services etc.) and the local socio-economic context of the region. This index is called '*local index*' (I_L).
- The third step creates a quantitative expression of consequence. A linear combination of the attributes of the EE for every damage associated with their respective indices (damage index, local index) evaluates the three types of damages (C_{PI}, C_{SF}, C_{SE}) and the potential damage (C_T).

The main improvements compared to the analysis of Puissant et al. (2006) are the inclusion of additional indicators in the analysis, a more detailed evaluation of the weights assigned and the production of consequence maps for the whole Barcelonnette Basin.

A damage index (I_D) for every attribute of the EE is allocated to characterize the possible losses (e.g. costs) if the element is affected by a landslide through expert knowledge. The intensity of the hazard is not taken into account for this index, and the EE are supposed to be completely damaged when affected by a landslide. For the estimation of the physical injury, the number of persons occupying a building is not integrated as this information is currently not available; therefore, the number of occupied floors is used assuming the presence of a maximum of four persons (e.g. a family) per floor. By assigning a high damage index to buildings occupied by the most fragile persons (e.g. schools, hospitals), the index takes into account differences in the vulnerability of persons.

The local index (I_L) characterizes the socio-economic importance of the region, and is defined for the EE. High local indexes are, for example, attributed to building function and to lifelines, the latter especially for estimating the socio-economic consequences. The main reasoning behind this is that for the touristic activities in the region, these lifelines are of major importance. Disruption of roads joining ski resorts areas will, for example, have a major impact on the occupation rate of the buildings.

The PDI index can take into account the fact that vulnerability is a dynamic element, and varies through times (season, night/day). However, for the moment, no differentiation between expected consequences at different time of the day or of the year are available. Given the importance of the winter and summer tourism for the region, it was decided to only produce different maps for these two respective periods.

A quantitative expression of consequences is calculated through a multi-criteria model. For the three types of damage, a weighted linear combination of the attributes of the EE and of their associated indices (ID, IL) enables the calculation of a score for C_{PI} (2), C_{SF} (3) and C_{SE} (4); their summation corresponds to the possible total damage C_T (5):

$$C_{PI} = \left[\left(E_{Building\ type} \times I_D \times I_L\right) + \ldots + \left(E_n \times I_D \times I_L\right)\right] \tag{2}$$

$$C_{SF} = \left[\left(E_{Landcover} \times I_D \times I_L\right) + \left(E_{Landuse} \times I_D \times I_L\right) + \ldots + \left(E_n \times I_D \times I_L\right)\right] \tag{3}$$

$$C_{SE} = \left[\left(E_{Building\ function,} \times I_D \times I_L\right) + \ldots + \left(E_n \times I_D \times I_L\right)\right] \tag{4}$$

$$C_T = C_{SF} + C_{PI} + C_{SE} \tag{5}$$

The scores are then classified in five or six classes using a slicing method. The possible consequences in terms of

Table 1 Classes of possible total damage (C_T) defined for the study area (according to French PPR methodology '*Plan de Prévention des Risques*')

Total damage	Definition of damage
Negligible	No consequence on the EE
Very low	Minor consequences on building and lifelines
	Low, local and short-time perturbations of human activity
Low	No casualties. Low to moderate consequences on building and lifelines. Moderate perturbations of human activity during a few days to a few weeks
Moderate	Low or serious casualties due to high damages on buildings. Moderate to high perturbations of human activity. High, direct or indirect consequences on thelocal territory, during a few months
High	Serious casualties or deaths due to the total destruction of buildings. High, direct or indirect consequences that cannot be managed locally. Domino consequences are expected
Very high	Serious casualties or deaths due to the total destruction of buildings. Very high, direct or indirect consequences that cannot be managed locally. Domino consequences are expected

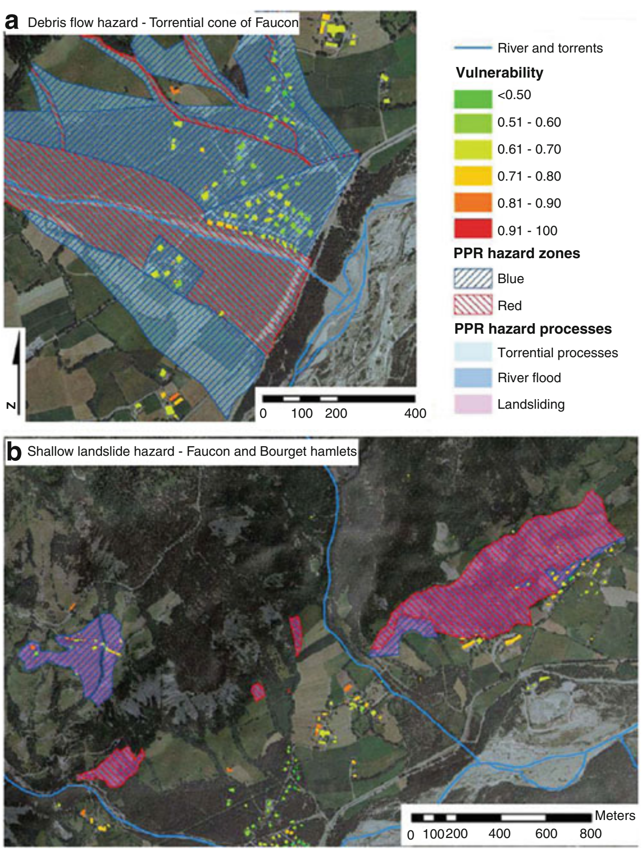

Fig. 5 Physical vulnerability assessments and mapping of RVI on the Faucon municipality (see location on Fig. 1, Excerpt A)

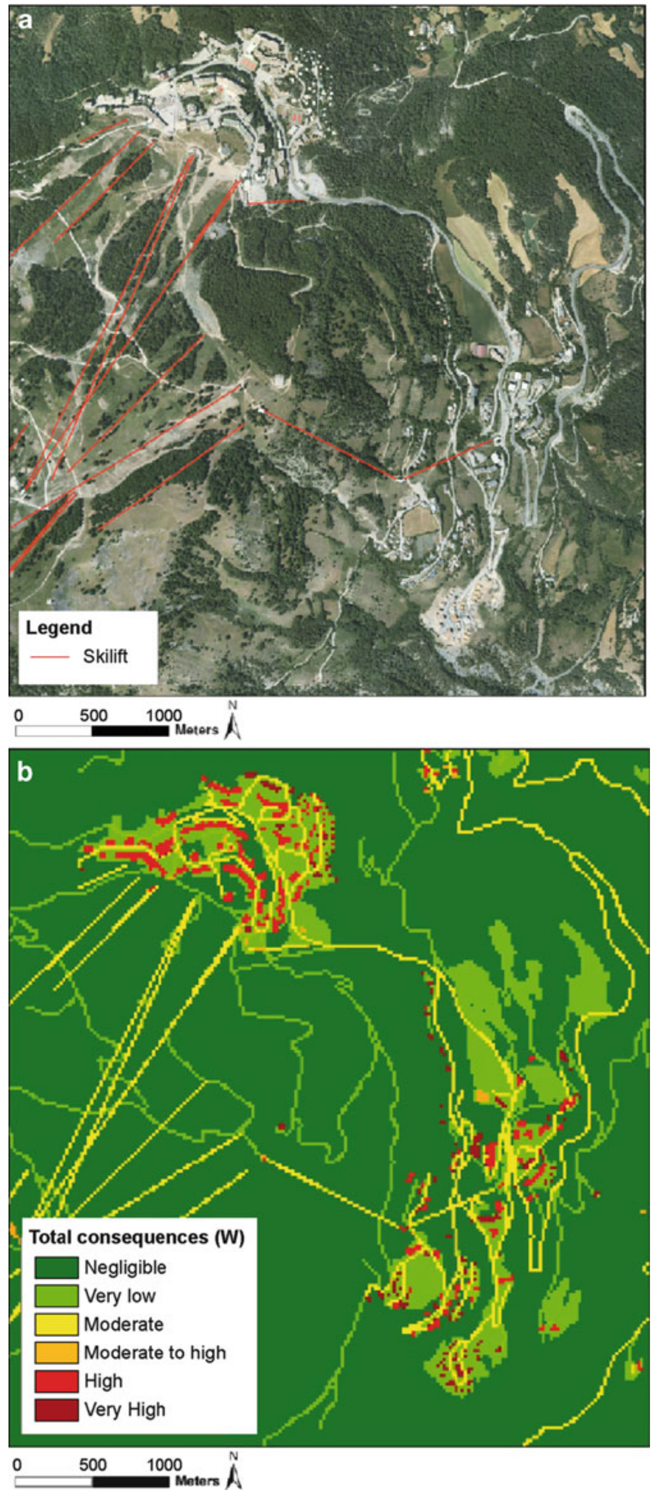

Fig. 6 Detail of the ski resort Pra-Loup (see location on Fig. 1, Excerpt B), and mapping of the PDI in terms of total consequences: (**a**) Orthophotograph (2004); (**b**) Excerpt of classified total consequence map (CT) for the winter season

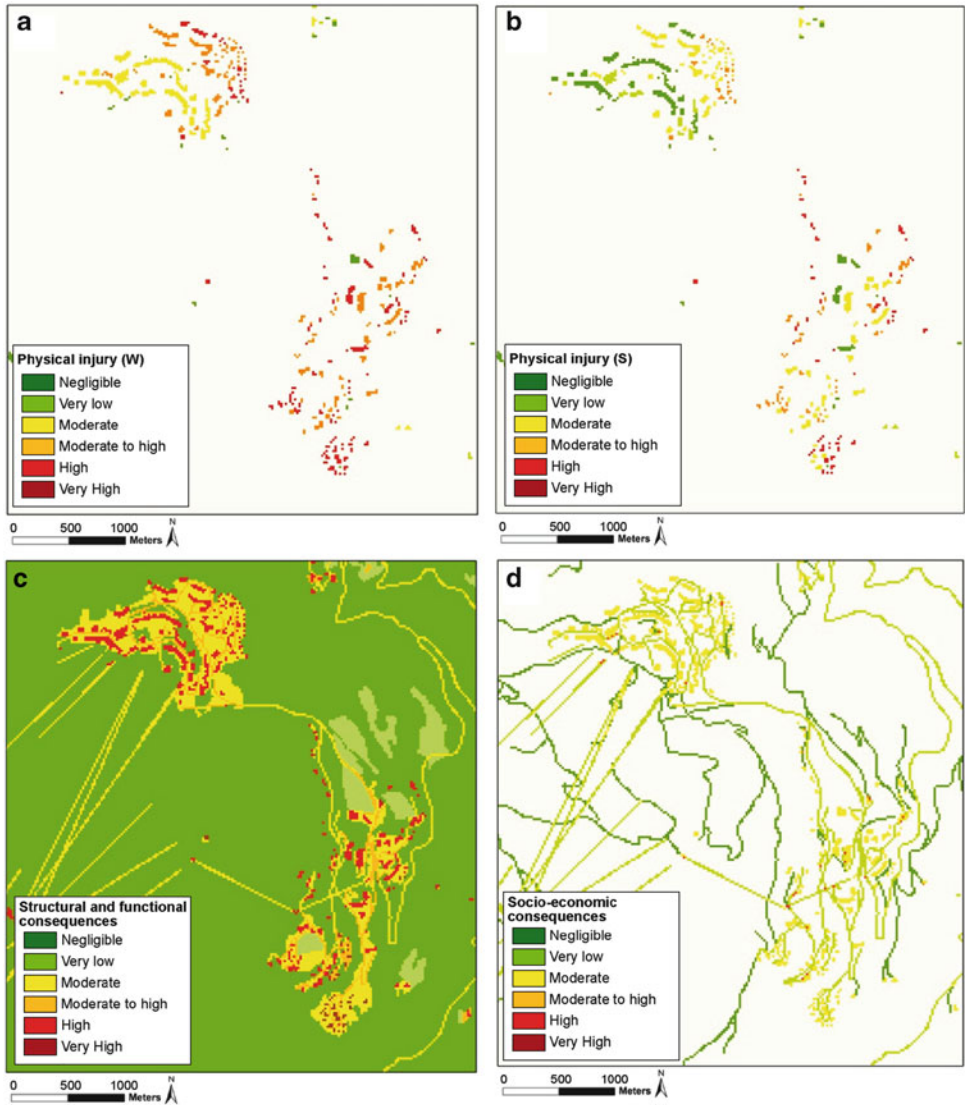

Fig. 7 Excerpts of classified consequence maps of the ski resort Pra-Loup (see location on Fig. 1, Excerpt B): (**a**) Physical injury for winter season; (**b**) Physical injury for summer season; (**c**) Functional and structural consequences; and (**d**) Socio-economic consequences

physical injury and socio-economic effects are classified in five classes; for the structural and functional injury and the total damage, six classes are created. For the latter, it was not possible to sufficiently differentiate between the expected losses of buildings, roads and agricultural lands, using five classes (Table 1).

Results

Mapping of Index 1: Relative Physical Vulnerability (RVI)

In Fig. 5, the relative physical vulnerability index (RVI) is plotted for debris flow hazard (Fig. 5a) and shallow landslide hazard (Fig. 5b) over the Faucon municipality.

The results are nearly in agreement with the risk prevention measures already implemented by the local stakeholder (*Plan de Prévention des Risques* – PPR). The results indicate that the methodology can provide information to different stakeholders in order to identify hotspots and focus their efforts in specific buildings and areas; however, they also demonstrate the need for the implementation of other indicators for the buildings (such as the presence of small garden walls or of tree lines in the uphill direction) and better documentation of damage to define the different weights.

Mapping of Index 2: Potential Damage (PDI)

The Potential Damage Index (PDI) has been calculated for the whole Barcelonnette basin for different scenarios (winter and summer periods).

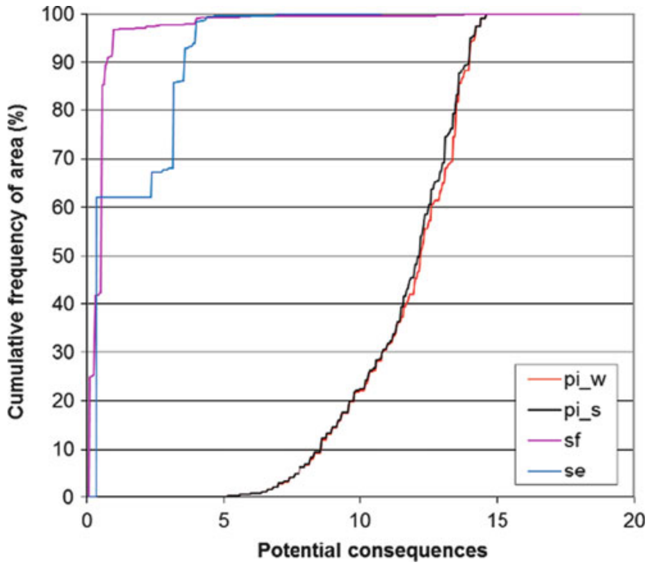

Fig. 8 Cumulative curve of values obtained for physical injury in winter (pi_w) and summer (pi_s), structural and functional consequences (sf) and socio-economic consequences (se)

Figures 6 and 7 show detailed excerpts of the resulting maps, and Fig. 8 presents an example of the cumulative curves used to classify the continuous consequence values into discrete classes.

Discussion and Conclusion

In this study, two index-oriented methods for estimating and mapping the possible consequences of hydrogeological hazards (with a focus on landslide) are presented, and tested on the Barcelonnette basin. The results are presented in different maps (e.g., RVI, C_{PI}, C_{SF}, C_{SE} and C_T) that can be used for different purposes such as land use planning and emergency management decision-making. Each of these maps is a useful tool for various stakeholders of the community such as local authorities, rescue teams, individuals and insurance companies. The indexes are very flexible and allow, by the combination of detailed indicators of elements at risk and associated weights, to create scenarios of possible consequence (temporal pattern of the exposure of elements at risk to hazards, possible exposure to multi-hazards).

The methodologies will be further extended, and their application to the study area will be finalized by testing the sensitivity of the attributes and the weights to observed damage. Afterwards, the maps produced with the two methods for corresponding scenarios will be compared and evaluated.

Acknowledgments This work was partly supported by the European Commission through the Project FP7 '*SafeLand: Living with landslide risk in Europe*' (2009–2012), and the FP6 Marie Curie Research and Training Network '*Mountain Risks: from prediction to management and governance*' (2007–2010).

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Part III

Landslides (and Legislation), Policies, Cost Benefit Analysis and Decision Makers

Introduction by Raoul Carreno[1], Giuliano Di Baldassarre[2], and Tiziana Guida[3]

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3) Italian Ministry for the Environment, Land and Sea, Rome, Italy

This session dealt with legislations, policies, cost benefit analysis and decision makers for landslides. Different presentations showed a variety of cases ranging from records and implications for landslides risk reduction strategies in India to economic and social impacts of floods and landslides in Italy. There was a general consensus on the fact that risk mitigation and prevention needs to be promoted to reduce human losses and economic damages caused by water related disasters and, in particular, landslides around the world. For what concerns the existing methodologies for landslide risk assessment, most current lines (although different) focus on hazard, vulnerability and exposure. However, some relevant socio-economic and environmental aspects are not always properly considered. For instance, in many cases the stakeholder involvement was found to be limited as many communities are involved only towards the end of the risk management process. Anyhow, the different methodologies present in diverse areas of the world seem to represent a good starting point for landslide risk reduction, but there is room for improving both the natural aspects and the socio-economic ones and, more specifically, their integration. Another interesting discussion was about the costs of landslides. In fact, the impact of landslides disasters includes costs that are difficult (if not impossible) to identify and quantify as it comprises all direct, indirect, tangible and intangible costs. To assess landslide mitigation measures, cost-effectiveness approaches tend to be more appropriate than costs and benefit approaches because of the relevant limitations concerning the monetization of intangible damages.

Landslide and Flood: Economic and Social Impacts in Italy

Fabio Trezzini, Gianluigi Giannella, and Tiziana Guida

Abstract

We conducted an analysis of the damages caused by the natural disasters which have occurred in the last 60 years in order to demonstrate that prevention costs much less than repairing the damages, without considering the loss of human lives. Between 1951 and 2009, the total cost of the damages caused by landslides and floods in Italy, revalued on the basis of ISTAT indexes 2009, amounts to more than 52 billion euros, approximately one billion euros per year. The Ministry of Environment estimated at approximately 40 billion euros the financial need to mitigate the risk of landslide and flood. The annual available funding allows the mitigation of landslide and flood risk in over 100 years. On the other hand we are forced to use Civil Protection's funds to address emergency caused by landslides or flood at least once a year in Italy: these funds, if used for prevention, would mitigate risks in wider territories and to avoid the loss of lives, optimizing the cost-benefit ratio.

Keywords

Landslide • Flood • Prevention • Cost-benefit analysis • Risk • Mapping

Introduction

Relating to the natural hazards that characterize our country, today the risk of landslide and flood appears to have a high social and economic impact, second only to earthquakes. According to a report by the CNR-GNDCI (National Research Council – Working Group on Natural Disasters) 2001, the risk of landslide in Italy is the highest in Europe and worldwide second only to China, Japan and countries of Central and South America (Canuti et al. 2001). Italy has the highest cumulative number of deaths or missing people and the highest expected yearly loss of life in Europe, and, after Japan, the second highest landslide risk of the industrialised countries (Forli and Guida 2009).

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Damages are also bound to increase because of the continuous and progressive increase of the urban sprawl. There has been a significant increase in the human pressure on the country since the Second World War with the expansion of urban areas, road and railway infrastructures, often in unstable areas. In this context, landslide phenomena have become a major problem with regard to the safety of the population and damage to residential areas, infrastructures, service networks, environmental and cultural heritage.

We collected data showing the damages caused by the events that occurred over the past 60 years and we put them in comparison with the costs of prevention, trying to demonstrate that prevention activities cost much less than repairing the damage, even without considering the loss of human lives. There isn't a national body responsible for a systematic collection of data relating to natural disasters and the estimated costs of the damages. Also uncertain is the total expenditure related to prevention activities, due to different funding sources.

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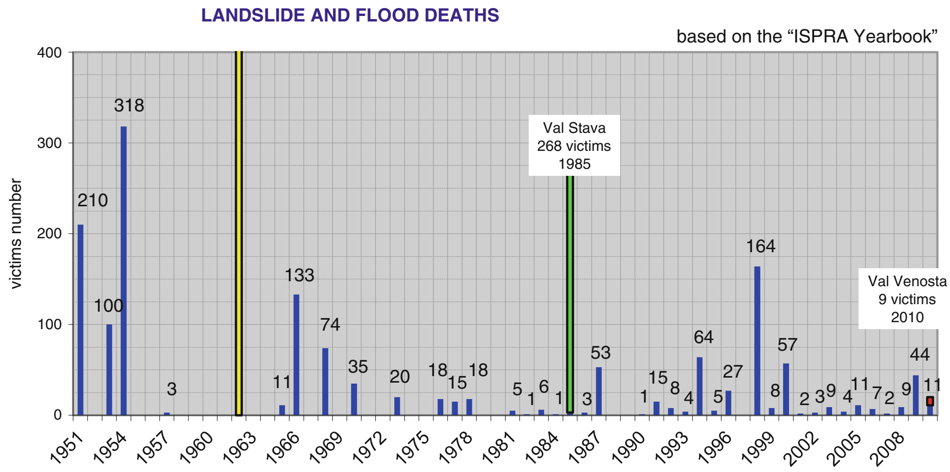
Table 1 Landslide and flood deaths from 1951 to 2010, based on the ISPRA Yearbook. Out of scale (*yellow*) the Vajont landslide 1963



Landslide and Flood Victims and Damages in Italy

The graph in Table 1, based on the "ISPRA Yearbook" (ISPRA 2010), shows that since 1950, almost every year there have been deaths caused by landslides (1,756 victims for the whole period). This figure does not include the 1,917 victims of the disaster of Vajont (1963). Another relevant landslide disaster occurred at Stava, on 19 July 1985, when 269 people were killed by a mudflow caused by the failure of two small reservoirs whose retaining walls were made of tailings (mining waste).

On the whole the victims of the last 60 years were 3,673 and are mainly due to phenomena such as sudden torrential floods, mudslides and landslides or debris (Guzzetti 2000). The worst disaster in the past half century was the flood of Salerno with 318 victims (1954).

Back to the chart, it appears that in the past, phenomena were less frequent but more devastating, but in recent times there are victims every year.

The AVI project CNR-GNDCI (which is now merged in the Hydrogeological Disasters Information System) is the most comprehensive and updated archive on landslides and floods of the twentieth century (Cardinali et al. 1993; CNR-GNDC 1994; Guzzetti et al. 1996; Basenghi and Bertolini 2001). Furthermore most of the information comes from newspaper sources: not strictly scientific and not homogeneous throughout the nation. Regarding the twentieth century, the project identifies round 10,000 victims including dead, wounded and missing, the destruction of thousands of houses and bridges and a lot of kilometers of broken roads and railways. Between 1900 and 2002, the catalogue contains 765 flooding and 883 landslide events with deaths or missing. The most dangerous season is autumn, with 62 % of landslide victims and 60 % of flood victims.

The "Map of landslides and floods with human consequences in Italy" by Salvati et al. (2003) shows that between 1900 and 2002 there were 4,016 events with serious damage. The number of displaced and homeless persons exceeds 700,000 (75 % due to flooding). The landslides with significant damages to the population occurred in 1,328 municipalities (16.4 %), and the floods have affected 1,156 municipalities (14.3 %). In the same examined period all the Italian provinces were hit by at least a landslide or flood. The study shows that the mortality rate for landslide far exceeds that for flooding. A very valuable source in order to estimate the economic damages is the study by Catenacci (1992) edited by the Italian National Geological Survey. The paper reports for each event the specific funding laws from which it is possible to observe that the financing lasts many years, as many as 30 in certain cases. The total expenditure, re-valued according to the ISTAT (Italian National Statistical Institute) index, is about 30 billion in 40 years. The author states that this figure is approximate due to a non systematic identification of the different expenditure items in the State Budget.

The latest assessment relating to damages is the Yearbook of environmental data processed by ISPRA (Institute for Environmental Protection and Research). It lists the disasters between 1951 and 2009, mainly driven by intense meteor phenomena, in order to highlight their impact in terms of economic damage and personal injury. The data is drawn from technical reports and/or records prepared by ISPRA, ARPA (Environmental Protection Regional Agencies), public bodies, various institutions, ministries and offices, from news sources, and relates the number of victims and amount of resources needed for environmental restoration and/or risk mitigation. The total cost of damages, according to the Yearbook, caused by landslides and floods from 1951 and 2009, re-valued according with the ISTAT index to 2009, is more than 52 billion euros, i.e. about one billion euros per year. It's basically useless to analyze the expenditure over time, moving

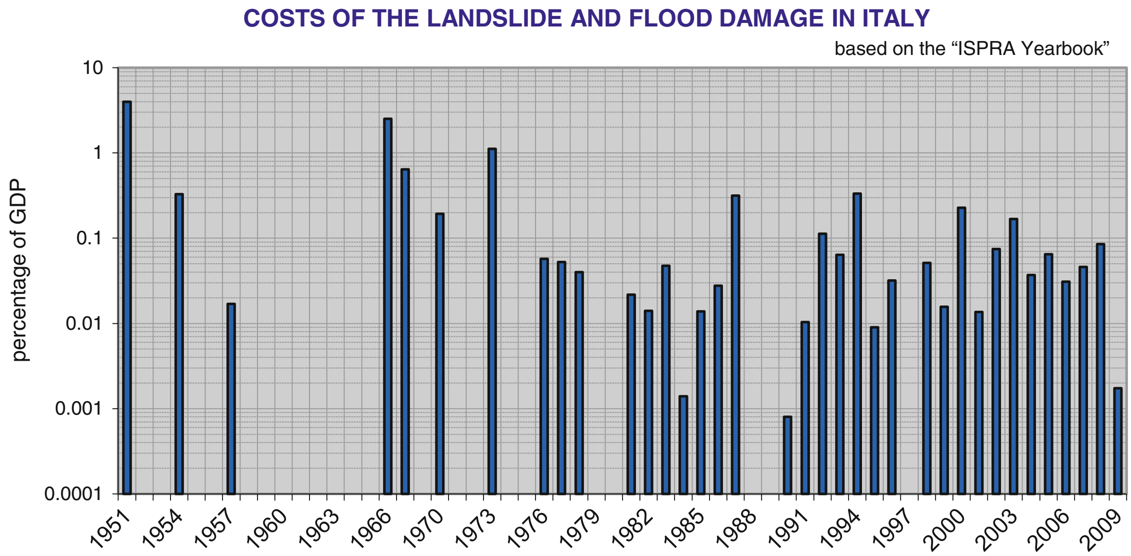


Table 2 Total cost of the damages caused by landslides and floods in Italy, revalued on the basis of ISTAT indexes 2009, between 1951 and 2009

it to pulse on the basis of the occurrence of catastrophic events. Furthermore, while between 1950 and 1990 the total expenditure was about 30 billion euros, on average 750 million euros/year, for the last 20 years the expenditure was about 22 billion euros, with an average of 1.1 billion €/year.

In the quantification, social and environmental damages are generally not included: for example several landfills are in flood risk areas.

The reactivation of landslides and new occurrences in flood risk areas, are by far the most common phenomena of collapse in Italy. The analysis of historical data in the AVI project shows that, among 9,000 locations affected by landslides, over 25 % have been hit more than once and that 40 % of the localities are affected by floods on a recurring basis.

Risk Mapping and Measures Funding

The IFFI project (Inventory of Landslide Phenomena in Italy), developed by ISPRA and the Regions, is the first landslide Italian inventory and supplies a detailed picture of the distribution of landslide phenomena (APAT 2007). The inventory lists 485,000 landslides, covering an area of 20,721 km^2, i.e. 6.9 % of the country. The project identifies, in 2006, more than 223,000 active landslides, reinstated or suspended, and therefore subject to reactivation (46 % of the surveyed landslides), about 189,000 as quiescent (39 %) and 19,400 wrecks or stabilized (4 %) (Table 2).

In order to ensure comparability in hazard and risk maps across the whole territory the law n. 180/1998 (so called "Sarno Decree") introduced a standardized methodology for landslide and flood hazard/risk assessment at the national level. In fact it identifies an official definition of "risk", according to the "Risk Equation": $R = H \times V \times E$, where the Hazard (H) represents the probability of occurrence of the event within a certain time and in a given area; the Vulnerability (V) represents the degree of loss determined on a certain element or group of elements exposed to risk arising from the occurrence of the event; the value of risk (E) represents the value (which can be expressed in monetary terms or number or quantity of units exposed) population, property and economic activities, including public services, subject to risk in a given area.

According to the same law, the identification of landslide areas that interfere with human activities and of the flood risk areas has been implemented through the river basin management Plans concerning landslide and flood risk (PAI), by the River Basin Authorities. These Plans include areas related to different risk levels (1 = min, 4 = max). An overall picture provided by the PAI shows that the extension of areas with the highest risk level are some 9.8 % of the whole national territory, 6.8 % of which are directly involved with urban centres, infrastructure, production areas, etc., closely linked to the country's economic development. Over 80 % of municipalities have at least an area at highest risk of landslide or flood (source: Ministry of Environment 2008).

According to a study by the Ministry of environment related to the whole nation, there are over 500,000 "critical areas" due to high landslide and flood (hydrogeological) hazard and/or risk identified by the river basin plans (PAI) (Ministero dell'Ambiente 2003). More than 6,600 municipalities are affected by at least one high critical area (81.9 % of Italian municipalities). In Valle d'Aosta, Umbria, Molise, Calabria and Basilicata 100 % of the municipalities has high critical areas (see Fig. 1).

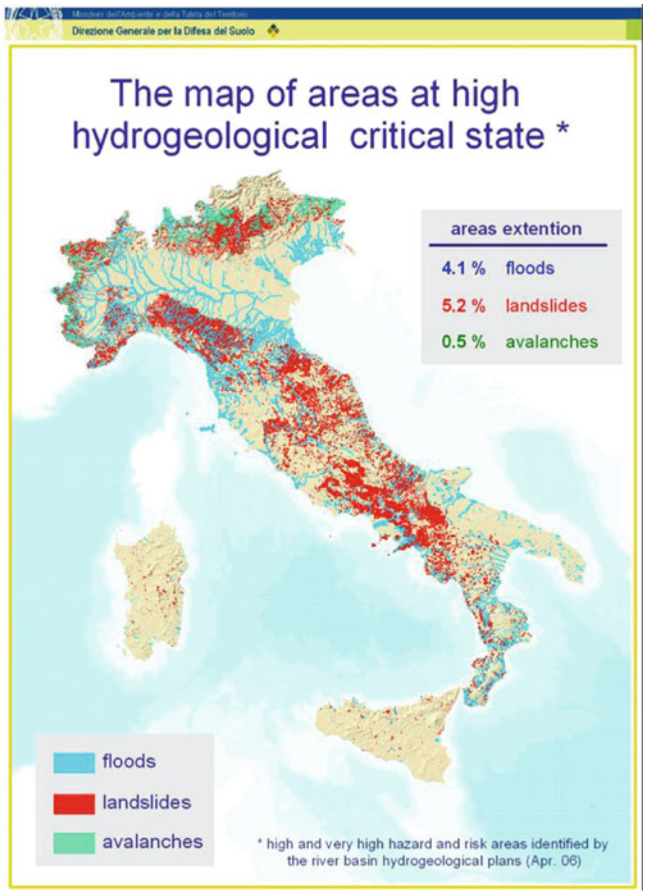


Fig. 1 Distribution of critical areas due to high landslide and flood (*hydrogeological*) hazard and/or risk (Source: Ministry of Environment)

The PAI provide building restrictions related to risk zoning. In most situations, however, the risk reduction is pursuit through the structural initiatives, following which the areas can be partially or completely released. The PAI determine over 11,000 works, in order to reduce flood and landslide risk throughout the country, with a comprehensive estimated expenditure of some 40 billion euros, 11 billion of which only related to highest risk areas. This figure does not include indirect costs of non-structural measures, neither maintenance costs of the existing defensive works, whose real effectiveness is moreover very hard to check.

A specific risk map implemented by CRESME shows that 3,458 school buildings and 89 hospitals are located in high risk areas.

Recent surveys provided by the provincial administration in South Tyrol have shown that a very large number of defensive works, built in the first half of the twentieth century, are no more effective to the original purpose. The need of extensive maintenance activities requires an action plan aimed at identifying priorities, according to the financial sources shortage.

Moreover, possible effects of climate change are not taken into account.

Recent studies in some regions of the Alps reveal that the average temperature increase currently favours the mobilization of large geological masses, now unstable by the melting of permafrost. There are therefore, in altitude ranges never affected before, typologically different phenomena.

The funding sources concerning defensive works are mainly represented by:

– EU Funds
– National Government Funds: Ministry for the Environment, Land and Sea; Ministry of Economy (CIPE funds); Department of Civil Protection
– Regions and Autonomous Provinces
– Local Authorities
– Private funding

Every year the Ministry of Environment draw up a national landslide and risk prevention program, according to the financial resources provided by law.

Even in the "highly financed" years (between 1998 and 2005) the average government funding has been about 400 million per year, then 1/100 of total needs! It would take more than 100 years for the safety of the whole country. Moreover, at least once a year, it's necessary to make use of emergency funds. The same amounts, if aimed to prevention activities, could have been more cost-effective.

According to the law 180/98, 3,248 works were funded from 1998 to 2009 by the Ministry for the environment, land and sea (total expenditure: 2,386 M€). The state of implementation of works is currently monitored within the RenDiS project carried out by ISPRA for the Ministry for the environment (ISPRA 2012). The percentage of accomplishment relating to the works funded in 1999, 2004 and 2008 is 85 %, 68 % and 35 % respectively. The delay in execution is mainly due to lack of spending capacity by the competent bodies, lack of specific planning and the complex authorization procedures and the role of stakeholders.

Landslide and Flood Mitigation Risk Policy

The Ministry for the environment, land and sea is responsible for the national program of risk mitigation works, general criteria and technical guidelines and coordinates the River Basin District Authorities. The Regions are responsible for the whole execution and management process of the mitigation works, that they contribute to finance.

The 1966 Florence flood would have nowadays more serious consequences (the estimate of the municipality is around 20 billion euros in damages) because, in spite of the realization of various structural measures, the intense urbanization has transformed in the last 40 years vast land in densely populated areas or industrial areas. The estimated costs for the risk mitigation are some 1.5 billion euros.

In the Po river basin from 1994 to 2005 were spent over 12.5 billion for emergency civil protection activities, compensation and work following natural disasters (Guido Bertolaso, the Environment Committee of the Chamber of Deputies, February 2009). The PAI of the Po River Basin, which was approved in 1999, provides a global need for the prevention activities of about 13.1 billion euros (16.3 billion re-valued), and approximately three billion only for priority actions.

In Italy the systems implemented more effectively relate to structural measures. However prevention is not just about creating defensive works, but also non-structural measures such as applying for appropriate land use, civil protection plans, monitoring of the phenomena but, more importantly, the spread of a deep-rooted and extensive knowledge of the level of risk exposure that can assure the development of an adequate policy of prediction and prevention aimed at reducing the vulnerability of the territory. We must therefore consider whether the risk of particular disasters seems somewhat inevitable, the same cannot be said of the damage suffered.

In general it can be noted that in Italy many regions present, at the same time, population decrease and mostly unplanned extension of urban areas.

Historically, the growth of cities in Europe, has always been determined by the increase in urban population. Today even in cases where population pressure is irrelevant or nonexistent, the phenomenon of urban sprawl is significant. Only by overcoming the fragmentation of local governance and improving the regional planning can be put under control a model of urban development that makes public and collective costs unsustainable.

In the case of our country, however, the need to limit the consumption of soil is combined of course with the need to protect one of the country's most important assets: the beauty of the Italian countryside.

The lack of landslide and flood risk culture turns into a fatalistic attitude towards natural disasters, which might otherwise be predicted and prevented. An appropriate approach to mitigate the effects of disasters has therefore based on knowledge of the phenomena and scenarios that they can produce and the definition of behaviour at all levels that must be taken to manage the risk.

Defensive works along the rivers have contributed to the economic value of large tracts of land and also eliminated the ordinary flood. This has also led to a loss of memory of the risk by the population, only to amplify the damage associated with meteorological phenomena of particular intensity.

Some European countries such as France and Switzerland, promote communication that provides the knowledge and therefore the awareness of risk by the population.

In other countries the citizens are protected against damage only through insurance. Citizens are thus enticed to invest to reduce the vulnerability of its assets, thereby reducing the overall risk and, consequently, the insurance premium.

In the rest of the world, in parallel to the increase in the value of damage, increases over time the number of insured claims, that only in 2003 reached a total of 18.5 billion dollars. This gives some idea of the gradual empowerment of collective security strategies through the use of sophisticated financial instruments to provide assurance that include the monetization of the "safety measures" and the payment of insurance premiums. In Italy the tendency for self-empowerment is still low because of the perception of a sort of "safety" – theoretical – with respect to events which by their nature, occur intermittently on the time, with a relatively low frequency events that are experienced directly. The effect of total delegation to the institutions is combined with the tendency of individual irresponsibility, with fatalistic attitudes of tolerance and, thereby discouraging the collective capacity to "gear up" to living with the risk (Censis Report on the Social Situation of the Country, 2004). In this context it is therefore necessary to address the identification of risk areas, connected with the costs sharing with the problem of possible insurance coverage. This is a never resolved question in Italy, unlike in the rest of Europe.

In many countries, which have adopted insurance systems, have been adopted at the same time rules for sharing the cost of insurance protection between the public and private sectors, depending on the risk class of the area where the establishment is located.

Moreover, insurance companies set premiums based on the risk zoning identified by public authorities and not on their own, as happened in Italy, where companies have actually done their own risk zoning.

Hearing in the Environment Committee of the Chamber of Deputies (Guido Bertolaso, head of the national civil protection Department, July 29th 2009):

The amount of requests for repair of damage caused by adverse weather conditions during the period October 2008–June 2009 amounted to 4.6 billion euros.

These estimate is affected by a number of factors: for example, the knowledge that, if you ask a hundred, maybe it makes up twenty or thirty; also indicate real but previous damage that may not have been caused by this specific phenomenon etc. . .

But even if there were one billion euros in damages it would still be a considerable amount and 4.6 billion is a figure more than one hundred times the funds that the Ministry of Environment has provided for the prevention measures.

The Chamber of Deputies (Environment Committee) promoted in 2009 a survey on national prevention policies. Among the conclusions of the work can be noted the highlight on financial resources shortage aimed to prevention activities and maintenance activities. Among the final proposals presented by the Committee there is the restoration of adequate resources to implement preventive interventions. Moreover, given the high demand, has been proposed a lightweight programming, which includes informing the population, the development of civil protection systems, but also the building restrictions, i.e. measures that result in lower cost and which are fundamental for the maintenance and protection of the territory.

The Committee also expressed in favour of a strengthening of the technical support from the Higher Council of Public Works, in order to improve the planning process and the execution of defensive works to mitigate flood and landslide risk.

Conclusions

The highest landslide and flood risk areas are about 10 % of the whole Italian territory. Over 80 % of the municipalities includes at least one high landslide and/or flood risk area.

According to ISPRA:

- Over the past 10 years occurred seven events per year with extensive damage and requiring the declaration of emergency rule;
- Over the past 20 years 22 billion euros have been spent to repair the damage caused by landslides and floods, i.e. over one billion euros per year (in spite of an estimated required amount about 60 billion).

The maximum annual Government funding for preventive interventions in the last 20 years reached about 400 million euros (1/3 of the expenditure for partial repair of the damage, about 1/8 of the damage caused by events).

The Ministry of Environment is carrying out the national program of risk mitigation works, funded with one billion euros provided by the law n. 191 of 23 December 2009 (National Budget Law 2010), through single agreements with Basin Authorities, the Regions and Civil Protection Department.

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Setback Distance Between Natural Slope and Building Along the RN8 in Algeria

Boualem El Kechebour and Ammar Nechnech

Abstract

The objective of this study is to determinate the required distances between the natural slopes and the buildings located nearly to these slopes. This approach permits to determining the distance between a building and the crest of a natural slope. The analysis of this case uses the geotechnical engineering and the results are applied during the design of the master plan by the town planners and the engineers of the transport and pavement administration. This study is limited to only the stability of natural slopes and the phenomenon of erosion is not taken into account.

The work begins by to present the context of study and the reinforcement works required by the administration of pavement and transport. Then, the limit equilibrium method is used for to obtain the minimal distance, limited by the crest of slope and the building. This distance is verified by simulations and compared to the distance corresponding to the beginning of the first plastification zones. The checking of plastification is carried out by the finite elements method. The work terminates by the presentation of the obtained graphics on the setback distance, and by the recommendations on the implantation of buildings.

Keywords

Setback distance • Slopes • Buildings • Probabilistic method • Plastification

Introduction

The problem encountered by an engineer, an architect or a planner during the design of a master plan is the compromise between different priorities. Indeed, he must satisfy the stability of structure, the urban regulations regarding alignments and the economy of the proposed solution. The choice of building location is a work of composition between the architecture, the geotechnical constraints, the urban rules and economics. The slope stability is a general problem in civil engineering with special importance in Algeria due to the existence of the mountains and hills in the north of country. This zone is located near along the sea and represents an urban area where live most of 80 % of population. This geographical situation associated with the urban national grow, requires a good urban policy. Indeed, it must to satisfy the needs of the urban planning, of the economy and the urban risk.

Along roads, in hill areas, many buildings are constructed near to slope. The stability of hill slope with building loads needs to be checked. For an exactly study, it is required to find the factor of safety against the sliding failure of slope. Deformation and instability of a slope under loads on the top of slope is a common phenomenon. The Movement of a slope is always generated by the loads of structure or building situated on the top of the slope. The slope failing is an important issue and the rating of the limit load which causes instability is required. The origins of the loss of stability of

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natural slopes or artificial, even those that occur in granular soil are very different. The interactions between the solid and fluid are complex and largely govern the behavior of the entire massif. The movement of land caused by landslide natural slopes (sudden or slow) can cause significant damage to structures, with a significant economic impact, and sometimes loss of life. There are four factors predisposing to the onset instability under seismic loads (Bourdeau 2005): the topography, the geologic and geotechnical characteristics, the human action on the environment and the pore pressures.

Goal and Demarche

The principal goal is to find a solution that determines an approximation of the setback distance. The results of this study concerns two axes: provide some fundamental background information needed for City staff to understand and interpret the phenomena on the stability of natural slopes; and contribute to provide a guideline on the state-of-practice of the stability of natural slopes. For to concretize this objective, a slope stability analysis under the building action is necessary. The stability of the slope is carried out using the probability of failure of a slope using the limit equilibrium method, and the finite element method for the apparition of the plastification.

Presentation of the Problem

The technical literature no gives a detailed guidance for the location of the building near a slope. The designer has a lot of difficulties to solve to such a problem. Most authors, specialist in the mechanics of soils and urban engineering, recomend to give an angle equal from 40 at 45° and an distance, between the limit of slope and the building, necessary for the servitude and maintenance of the building, equal from 2.0 at 3 m. These values are given without taking into account the number of levels, the soil bearing capacity and the stability of slope. The absence of one simple tool which can resolves the setback distance between slope and buildings justifies this study.

The ratio of strength (the resistance) R and load (the solicitation) S gives the safety factor (FS). When the safety factor (FS) is smaller than 1.0, the slope is unstable. Considering a circular slip surface, there are several important methods, developed by Fellenius, Taylor, Bishop and others, that can help to determine the safety factor (FS). All these methods use several simplifying assumptions. In this project Bishop's method will be considered because they are the most frequently used method in engineering practice.

The case study is a natural slope, composed by two independent layers, and supports one building. Phenomenon of erosion is not taken into account.

Symbols and Terminology

$\mathbf{l_o}$: width of slope
H_o: height of slope
ϕ_o: repose natural angle of slope
H_e: equivalente height
Le: equivalente length
$\boldsymbol{\gamma}$: volumic masse of soil
$\boldsymbol{\phi}$: angle (in degres) of slope under load
$\boldsymbol{p}$: charge totale d'un plancher (1 T/m^2)
n: nunber of floors
$\boldsymbol{\sigma}_s$: tension on the soil corresponding to n
Fs: Factor of safety
dcrit: critical distance

Presentation of the Zone

The region of the axis Arba-Tablat is located at the south of the city of Algiers. The town l'Arba is distant from Algiers to 30 km and the length Arba-Tablat is 40 km. The length of section concerned by the works is 10 km: Haouch El Cadi-Sakamody. This section traverses the mountain Atlas and it is characterised by many curves.

Characteristics of the Site

The site is characterised by a mountain environment and by two parts. The first section have clay and send layer in surface and a clay layer in deepness, and the second section have brittle rock layer (schist) on surface and clay layer in deepness. The Fig. 1 shows the schema of the site cross section. The altitude of Haouch El Cadi is 400 m and the altitude of Sakamody is 900 m. The Fig. 2 shows the map of the region and the zone of landslides.

View on the Probabilistic Approaches

They are many methods for the study of slope stability founded on the shape of the failure (circle, logarithmic, etc.). For this work, the approach of circular failure is adopted (Durville and Seve 1996).

View on the Classical Approaches

Limit equilibrium methods of slices are the most common used methods among others since simplicity and ease of use are the main advantages. Those methods satisfy either some or all of the equilibrium conditions. Due to the large number of possible slip surfaces, computers are used to facilitate

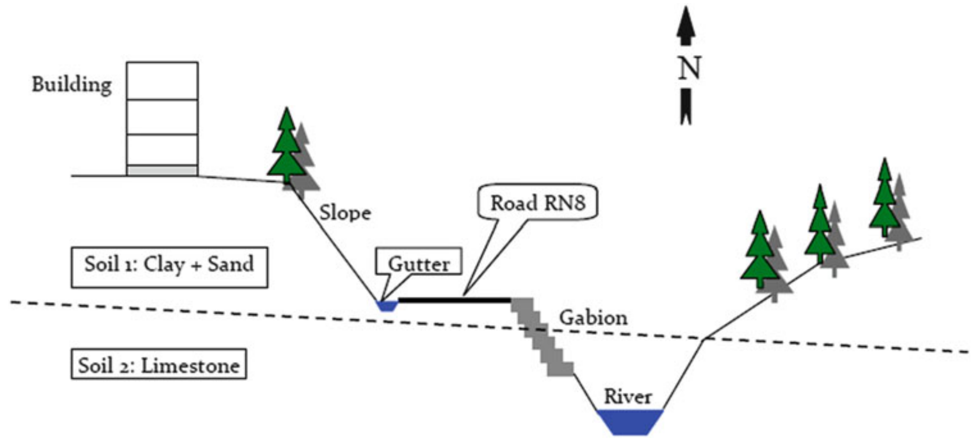

Fig. 1 Map of the region of Algiers

Fig. 2 Cross sections of the site

computations. Interestingly, factors of safety obtained from stability analysis methods that satisfy all limit equilibrium conditions are within 6 % of each other (Duncan 1992).

The Monte Carlo method is a specific approach based on the optimization by the probabilistic technique. A classical reference on the probability is (Feller 1968), and a more detailed textbook is (Grimmett and Stirzaker 2001). An accurate and accessible treatment of various stochastic processes is given in (Cinlar 1975). For convex optimization we refer to (Boyd and Vandenberghe 2004).

However, Bishop's method is implemented in most programs and was used as a reference method for comparison between programs and search techniques.

Recently, more advanced search techniques based on Monte Carlo technique were proposed by Greco (1996), and Malkawi Husein et al (2000, 2001a, b, 2002, 2003). This method is a structured random searching and optimization technique where the slip surface is located using either random jumping or random walking methods. Random jumping methods involve the use of a large number of independent slip surfaces while the random walking methods involve the use of a large number of dependent slip surfaces to examine the most critical failure surface. Slip surfaces are called dependent when each new slip surface is created based on the result of a preceding slip surface. Independent slip surfaces are all generated regardless of analysis results.

Monte Carlo techniques are very fast and easy-to-implement optimization techniques and can be used for most common slope stability methods. Unlike most slope stability analysis search techniques (Baker 1980) and (Chowdhury and Zhang 1990), no slip surface is rejected to achieve convergence in computations. Thus, limit equilibrium methods are used fully without the need to make any restraints in addition to the numerical simplifications that are already assumed in the analysis methods. On the other hand, the use of Monte Carlo techniques allows the increase of the number of slices used during slip surface analysis since computer analysis time can be optimized and more detailed and accurate results can be obtained.

In order to verify the power of implementing Monte-Carlo technique in slope stability analysis a comparison was made between results from finite element analysis using PLAXIS (Plaxis 1998), (Griffiths and Lane 1999), (Zhang 1993) or (Sigma/w 19) and limit equilibrium analysis using simplified bishop method (GEO-SLOPE/W 2004a, b) coupled to probabilistic method. The results give a difference of 6 % between the Monte Carlo Method and the limit equilibrium methods one hand, and secondly a higher safety factor of 10 % compared to the method of limit equilibrium.

View on the Monte Carlo Method

Deterministic slope stability analyses compute the factor of safety based on a fixed set of conditions and material parameters. If the factor of safety is greater than unity, the slope is considered to be stable. On the contrary, if the factor of safety is less than unity, the slope is considered to be unstable or susceptible to failure.

Deterministic analyses suffer from limitations; such as that the variability of the input parameters is not considered, and questions like "How stable is the slope?" cannot be answered. Probabilistic slope stability analysis allows for the consideration of variability in the input parameters and it quantifies the probability of failure of a slope.

The Monte Carlo method is a simple, but versatile computational procedure that is suitable for a high speed computer. In general, the implementation of the method involves the following steps:

- The selection of a deterministic solution procedure, such as the Spencer's method or the finite element stress method.
- The decisions regarding which input parameters are to be modeled probabilistically and the representation of their variability in terms of a selected distribution model.
- The conversion of any distribution function into a sampling function, the random sampling of new input parameters and the determination of new factors of safety many times.
- The computation of the probability of failure based on the number of factors of safety less than 1.0 with respect to the total number of converged slip surfaces. For example, in an analysis with 1,000 Monte Carlo trials, 980 trials produce a converged factor of safety and 98 trials produce a factor of safety of less than 1.0. The probability of failure is 10.0 %.

One or more most critical slip surfaces are first determined based on the mean value of the input parameters using any of the limit equilibrium and finite element stress methods. Probabilistic analysis is then performed on these critical slip surfaces, taking into consideration the variability of the input parameters. The number of Monte Carlo trials in an analysis is dependent on the number of variable input parameters and the expected probability of failure. In general, the number of required trials increases as the number of variable input increases or the expected probability of failure becomes smaller. It is not unusual to do thousands of trials in order to achieve an acceptable level of confidence in a Monte Carlo probabilistic slope stability analysis.

- Parameter variability

Soils are naturally formed materials; consequently their physical properties vary from point to point. This variation occurs even in an apparently homogeneous layer. The variability in the value of soil properties is a major contributor to the uncertainty in the stability of a slope. Laboratory results on natural soils indicate that most soil properties can be considered as random variables conforming to the normal distribution function. The variability of the input parameters is assumed to be normally distributed. The variability of the following input parameters can be considered:

- Material parameters for the various material strength models, including unit weight, cohesion and frictional angles,
- Pore-water pressure conditions,
- The magnitude of the applied line loads,
- The horizontal and vertical seismic coefficients

- Random number generation

Fundamental to the Monte Carlo method are the randomly generated input parameters that are fed into a deterministic model. The random numbers generated from the function are uniformly distributed with values between 0 and 1.0.

- Correlation coefficient

A correlation coefficient expresses the relative strength of the association between two parameters. Laboratory tests on a wide variety of soils shows that the shear strength parameters c and φ are often negatively correlated with correlation coefficient ranges from −0.72 to 0.35. Correlation between strength parameters may affect the probability distribution of a slope.

The SLOPE/W tool (GEO-SLOPE/W 2004a, b) allows the specifications of c and φ correlation coefficients for all soil models using c and φ parameters. Furthermore, in the case of a bilinear soil model, SLOPE/W allows the specification of correlation coefficient for φ and φ2. Correlation coefficients will always fall between −1 and +1. When the correlation coefficient is positive, c and φ are positively correlated implying that larger values of c are more likely to occur with larger values of φ.

Similarly, when the correlation coefficient is negative, c and φ are negatively correlated and reflects the tendency of a larger value of c to occur with a smaller value of φ. A zero correlation coefficient implies that c and φare independent parameters.

In SLOPE/W, when estimating a new trial value for φ and φ2, the normalized random number is adjusted to consider the effect of correlation. The (1) is used in the adjustment:

$$Na = N_1\ k + (1 - |k|)N_2 \tag{1}$$

Where:
k = correlation coefficient between the first and second parameters,
N_1 = normalized random number for the first parameter,
N_2 = normalized random number for the second parameter, and
Na = adjusted normalized random number for the second parameter.

- Number of Monte Carlo trials

Probabilistic slope stability analysis using the Monte Carlo method involves many trial runs. Theoretically, the more trial runs used in an analysis the more accurate the solution will be. How many trials are required in a probabilistic slope stability analysis? It has been suggested that the number of required Monte Carlo trials is dependent on the desired level of confidence in the solution, as well as the number of variables being considered. Statistically, the following (2) can be developed:

$$Nmc = \left[\frac{d^2}{4(1-\varepsilon)^2}\right]^m \tag{2}$$

Where:
Nmc = number of Monte Carlo trials,
ε = the desired level of confidence (0 to 100 %) expressed in decimal form,
d = the normal standard deviate corresponding to the level of confidence, and m = number of variables.

The number of Monte Carlo trials increases geometrically with the level of confidence and the number of variables. For example, if the desired level of confidence is 80 %, the normal standard deviate will be 1.28; the number of Monte Carlo trials will be 10 for 1 variable, 100 for 2 variables and 1,000 for 3 variables.

For a 90 % level of confidence, the normal standard deviate will be 1.64; the number of Monte Carlo trials will be 67 for 1 variable, 4,489 for 2 variables and 300,763 for 3 variables. In fact, for a 100 % level of confidence, an infinite number of trials will be required.

For practical purposes, the number of Monte Carlo trials to be conducted is usually in the order of thousands. This may not be sufficient for a high level of confidence with multiple variables; fortunately, in most cases, the solution is not very sensitive to the number of trials after a few thousands trials have been run.

Furthermore, for most engineering projects, the degree of uncertainty in the input parameters may not warrant a high level of confidence in a probabilistic analysis.

Probability of failure and reliability index.

A factor of safety is really an index indicating the relative stability of a slope. It does not imply the actual risk level of the slope, due to the variability of input parameters. With a probabilistic analysis, two useful indices are available to quantify the stability or the risk level of a slope. These two indices are known as the probability of failure and the reliability index.

Probability density functions:

There are five density functions:

– Normal
– Lognormal
– Uniform
– Triangular
– Generalized Spline function.

In equation form, the normal probability density function is (3):

$$f(x) = \frac{e^{\frac{-(x-u)^2}{2\sigma^2}}}{\sigma\sqrt{2\pi}} \tag{3}$$

Where:
x = the variable of interest,
u = the mean, and
σ = the standard deviation.

The probability of failure is the probability of obtaining a factor of safety less than 1.0. The probability of failure is determined by counting the number of safety factors below 1.0 and then taking this number as a percentage of the total number of converged Monte Carlo trials. For example, if there are 1,000 Monte Carlo trials with 980 converged safety factors and 98 of them are below 1.0. Then the probabilistic of failure is 10 %. The probability of failure can be interpreted in two ways:

– If a slope were to be constructed many times, what percentage of such slopes would fail, or
– The level of confidence that can be placed in a design.

The reliability index (β) is defined in terms of the mean (μ) and the standard deviation (σ) of the trial factors of safety as shown in the following (4):

$$\beta = \frac{(\mu - 1)}{\sigma} \quad (4)$$

The reliability index describes the stability by the number of standard deviations separating the mean factor of safety from its defined failure value of 1.0. It can also be considered as a way of normalizing the factor of safety with respect to its uncertainty.

One of the primary assumptions with a limit equilibrium analysis is that the global factor of safety is the same as the factor of safety for every slice. In a limit equilibrium analysis, the factor of safety does not change with position across the slip surface. In finite element stability analysis the same condition does not need to be satisfied and the stability factor varies across the slip surface.

Results of the Interactions Building and Slope

The Influence Zone of Building

The horizontal stress is calculated from plasticity theory, assuming zero wall friction and adhesion. The horizontal stress depends on the width of the surcharge. A strip surcharge is considered wide if the condition given by the (5) is true:

$$\frac{2y}{x} \geq 1 + tan^2\left(\frac{\pi}{2} - \frac{\varphi}{2}\right) \quad (5)$$

In this equation, x is the perpendicular distance between the wall and the nearest edge of the surcharge; y is the width of the surcharge; and N is the soil's angle of friction. The horizontal stress varies with depth below the surcharge (z) as shown below. The Fig. 3 shows the distance (le min) according to the substitution of the building load (P) by a soil layer having an elevation (He).

$$\begin{aligned} Le_{min} &= L_o + Le \\ &= H_o/tg\phi_o + He/tg\phi_o \\ &= H_o/tg\phi_o + (P/\gamma)/tg\phi_o \\ &= H_o/tg\phi_o + (n.p/\gamma)/tg\phi_o \end{aligned} \quad (6)$$

For simplification, a saturated sandy soil is taken.
p = 1 t/m2 (total load by floor);
n = 3 m (elevation of one story building);
γ = 2 t/m3 (masse volumique du sable compact saturé);

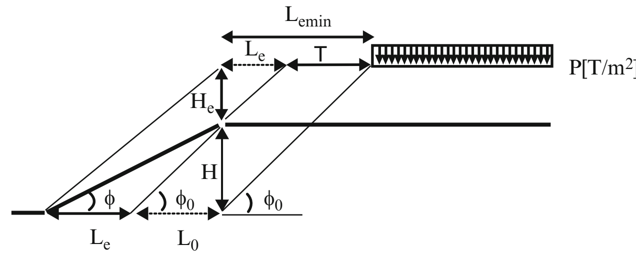

Fig. 3 Schematization of setback distance

$$\begin{aligned} Lemin &= H_0/0.5 + (n*0.7/1.8)/0.5 \\ &= 2*H_0 + n*0.77 \\ &= 2*H_0 + (h/3)*0.77 \\ &= 2*H_0 + 0.26*h \end{aligned}$$

The value 0.26*h can to negligible confront the value 2Ho and one consider that the setback distance (L_{emim}) is:

$$L_{emin} > 2H_o. \quad (7)$$

Variation of the Slope Characteristics and the Number of Floors

The Fig. 4 shows the variation of the factor of safety (Fs) according to elevation of the slope (H0), and the Fig. 5 shows the variation of factor of safety (Fs) according to natural angle of repose of the slope. The Fig. 6 shows the variation of factor of safety (Fs) according to the number of floors (n) and the elevation of the slope (H0). The Fig. 7 shows the variation of the critical distance of failure according to elevation of the slope (H0), and the Fig. 8 shows the variation of the Factor of safety according to deep of the pore water pressure line.

Summary of Results

The study is carried out to understand the stability of slopes and hills. The more unfavorable cases are the non cohesive soils. In the parametric study, the effect of some parameters is studied by keeping the other parameters constant. The effects are summarized in the following observations:

- The value of the safety factor decreases with the increase in unit weight of soil in different layers.
- The safety factor decreasing with the rise in pore water pressure ratio in the soil.
- The safety factor decreasing with the rise in height of slope.
- The safety factor increases with increase in slope angle (friction angle Φ).
- The safety factor increases with very small values with the rise in cohesion ratio.

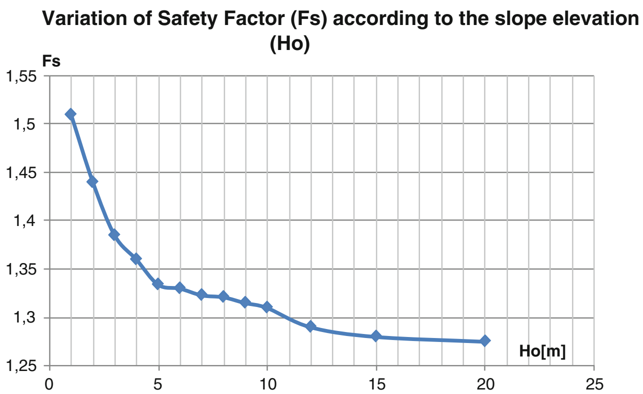

Fig. 4 Variation of the factor of safety (Fs) according to the elevation of the slope (H_0)

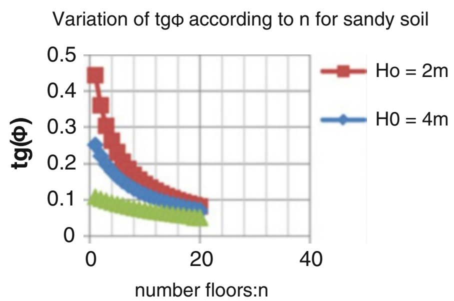

Fig. 5 Variation of the natural angle of repose of the slope according to the number of floors (n) and the elevation of the slope (H0)

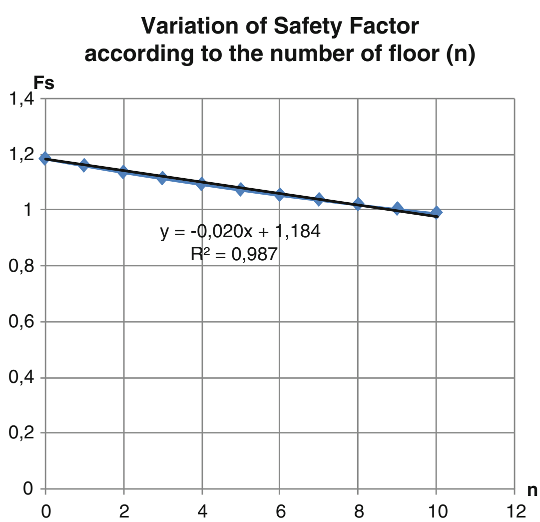

Fig. 6 Variation of the factor of safety (Fs) according to the number of floors (n) and the elevation of the slope (H0)

– The safety factor decreasing with the rise in seismic factor. These simulations are carried out in accordance with the Algerian code (Pappin et al 1985).
– The safety factor decreases with very small values when the number of floors increases. Every floor represents approximately an equivalent soil layer with 1 m.

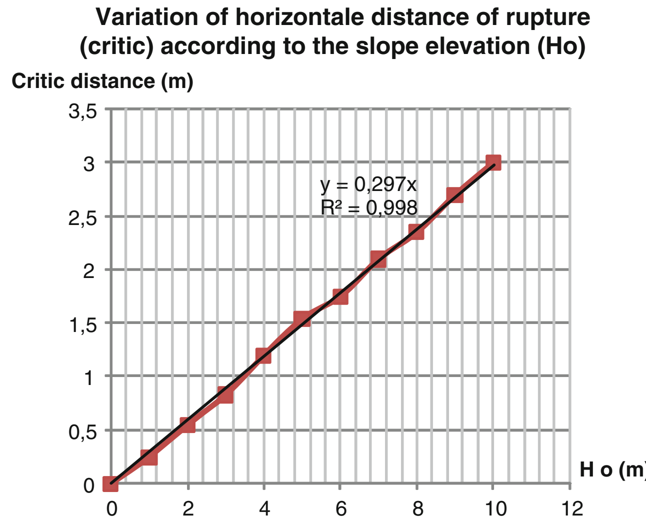

Fig. 7 Variation of the critical distance of failure according to elevation of the slope (H0)

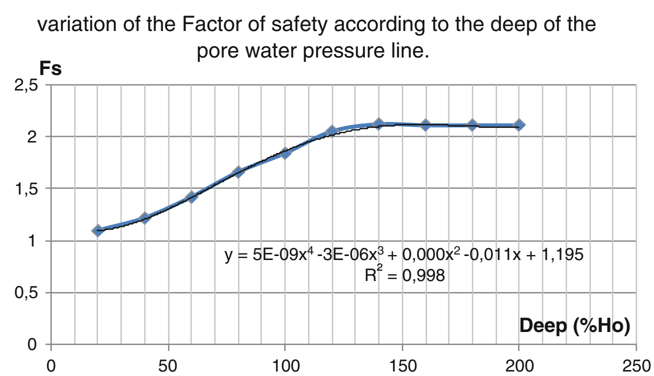

Fig. 8 Variation of the factor of safety according to the deep of the pore water pressure line

– The zone of influence of construction on the stability of the slope begins to twice the height of the slope (2 h) for the sandy soil and one times the height (h) for clay.

The safety factor increases with the rise of the deep of the pore water pressure line. The difference between the values of safety factors is negligible when the values of the deep are superiors to 1.5 Ho.

The seismic factors are computed according to the Algerian code (RPA 1999 Version 2003) which gives three zones (I, II and III), respectively: ah = 0.25 g and av = 0.10 g for the strong earthquake intensity; ah = 0.18 g and av = 0.07 g for the medium earthquake intensity; and ah = 0.12 g and av = 0.04 g for the weak earthquake intensity.

After many simulations, one obtains the values about the setback distances, illustrated by the Table 1. The Table 1

Table 1 Critical distance of failure for some typical soil

Nature soils	Critical distance (sliding in surface and deep) for medium seismic action	Critical distance (sliding in surface and deep) for high seismic action
Sand	(0.3–0.4)H	(0.4–0.5)H
Clay	(0.2–0.3)H	(0.3–0.4)H
Limestone	(0.1–0.2)H	(0.2–0.3)H

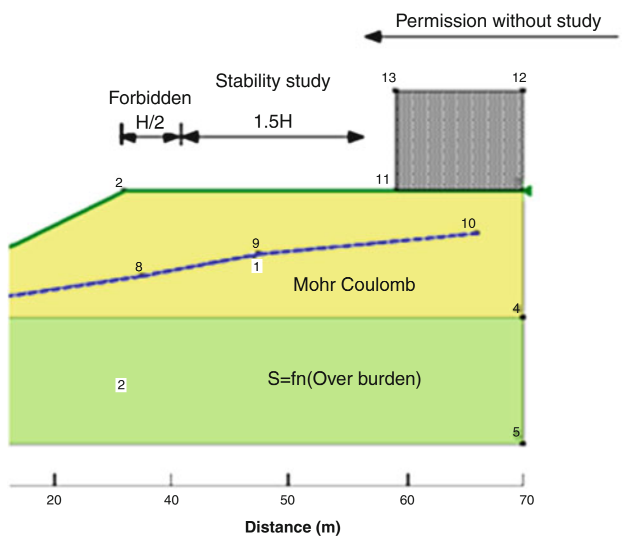

Fig. 9 Setback distance for the implantation of building nearly to a slope in a high seismic zone

shows the critical distance of failure for some typical soil computed according to zone I and zone II.

Discussion

The assessment of the stability of a slope and the determination of the limit of hazard lands should consider the most conservative conditions. The method of limit equilibrium cannot give the deformations of soil. For other types of soil, this value is lower. These situations correspond to the case where the values of safety factor vary from 1.5 to 1.6. The simulations, without load surcharge, shows that the plastification of zones begins for the values equal to twice the height of the slope (2Ho) for the sandy soil. According to the Table 1, one can advance some recommendations about the setback distance. These propositions are schematized in the Fig. 9 that illustrates the implantation of building nearly to slope in seismic zones with high intensity. In the seismic zones characterized by a medium activity, the indications of the Fig. 9 can to be reduced by 50 %.

This study is limited to only the stability of natural slopes, and not embankment, which requires deep analyses. The phenomenon of erosion is not taken into account.

The Monte-Carlo technique permits to search a great number of slip surfaces and to determinate the optimized case. All search techniques, with the exception of Monte Carlo, calculate the sliding surface, the most critical, with a small error. The differences between a seismic analysis and without seismic analysis are approximately: 75 % for strong seismic action, 50 % for medium seismic action and 25 % for weak seismic action. The results are obtained for shallow foundations and the load is approximately one ton per square meter per floor.

Conclusion

The development of hazard lands must be restricted. They should not be built with permanent structures and must be reserved to others areas such as: parking, roadways, parks and leisure. In this study it was shown that limit equilibrium methods are reliable and can be used with confidence to investigate the stability of slopes and to rate the setback distance.

Actually the administration of pavement requires, uniformly, a distance h/2 between crest of slope and the building. This study have determined the setback distance under technical rules form. The mastering of the knowledge of the implantation contributes to the mitigation of disaster risk and conflicts between administration and habitants. This demarche is compatible with the use of land in the urban sustainable development.

The analysis by finite element methods is expensive and not justified for the built permit.

Acknowledgement The author thanks the administration of the pavement of city BLIDA and the Laboratory: water, environment, geomecanic and works for his help on using of geotechnical software.

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Landslide Problems in Bulgaria: Factors, Distribution and Countermeasures

Nikolai Dobrev, Plamen Ivanov, Radoslav Varbanov, Georgi Frangov, Boyko Berov, Ilia Bruchev, Miroslav Krastanov, and Rosen Nankin

Abstract

The present paper aims to analyse and to discuss the state of landslide problems in Bulgaria. It separates the main factors of instability of slopes Bulgarian landslides: tectonic movements, earthquakes, erosion, abrasion, surface water and groundwater, precipitation and human impact. Landslides are concentrated in certain regions: Black Sea Coast, Danube bank, the Fore-Balkan, Rhodope Mts, active tectonic grabens in South Bulgaria and Maritsa-Iztok coal basin. 917 landslides affecting urban areas are presented on Map of landslides in Bulgaria, in scale 1:500,000. They are divided into three groups: (1) shallow landslides, (2) deep-seated landslides, conditionally stable, and (3) deep-seated landslides with periodic (re)activation of some parts of them. National Program for Landslide Mitigation has been made. The program envisages countermeasures on selected 170 most dangerous landslides in the country.

Keywords

Landslides • Bulgaria • Factors • Distribution

Introduction

Bulgaria is characterized with a high prevalence of landslides, which are the order of thousands. Every year, landslides cause serious problems in the country as damages and losses of properties in urban areas, interrupting major roads and railways, affecting agricultural areas. Damages are estimated at millions of euros. Although rare, they cause losses of lives. There is a clash between the high rate of urbanization and the severe consequences of the many active landslides. The possible outcome is only one – to reduce the landslide risk.

Landslides are one of the main elements forming the geological hazard in Bulgaria. They are widely but unevenly developed in the country territory. There are all known and described in the literature types of landslides: ancient and recent, active and potential, shallow and deep, etc. Almost all landslide types described in Varnes' classification (1978) are represented in Bulgaria.

Factors

The various mechanisms of landslide phenomena is largely determined by the diverse geological and tectonic structure of the territory, dissected topography, underground hydrodynamics and the relationship between geotechnical properties of different lithological formations. Key factors for landslide activity are tectonic movements, earthquakes,

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abrasion, erosion, rainfalls, ground water fluctuations and man-made impact.

Considering its small size (111,000 km^2), Bulgaria has a large variety of topographical features. The relief is characterized by diversity including high and low mountains, plateaus, hilly lands, valleys, Quaternary river basins, gorges and deep defiles. More than half of Bulgarian land is hilly and mountainous.

The complex geological structure and tectonics have determined the development of various mechanisms of landslides. Landslides are gravitational processes associated with the movement of land masses at different depth surfaces, which occur in the slopes: river banks, sea coasts, hilly land peripheries, foothills and mountain heights. Such areas are the high Danube bank and right sides of its tributaries, the Northern Black Sea coast, Fore-Balkan, steep banks of the rivers Iskar, Kamchia, Struma, Mesta, Vacha, Arda, and Chepelarska, outskirts of the grabens in South Bulgaria (Fig. 1). Significant parts of urban areas, resorts, roads and railways are situated on the slopes in areas of active or potential landslides.

The slopes are subjected to the influence of natural and human factors that contribute in varying degrees for the occurrence of landslides. For example, there is a close relation between areas with active erosion and abrasion and the occurrence landslide phenomena.

Neotectonic Movements

The interrelations between the thickness of the Earth's crust, the deep block structures and the neotectonic and contemporary vertical movements on Bulgarian territory are very complex.

Bulgarian territory is situated within the zone of N-S extensional regime. Established rates of tectonic movements at some places exceed 3 mm per year (Georgiev et al. 2007). Active regime of extension leads to a high dynamics especially in the grabens in South Bulgaria where landslide distribution is strongly correlated with fault lineaments (Dobrev and Boykova 1998).

Earthquakes

The effect of earthquakes is caused by the elastic fluctuations reaching the Earth's surface within a time interval of the order of several tens of seconds. The intensity in a given point, situated at a certain distance from the epicenter, is determined first of all by the earthquake magnitude, by its depth, properties and structure of the medium, in which the elastic fluctuations are propagating.

On Bulgarian territory there are a lot of examples i the relationship between earthquake events and landslide processes. During the earthquake on 31 March 1901 in the Shabla area (M7.2) a large landslide triggered affecting an area of ~300 decares at the village of Momchil, near the town of Balchik. Significant displacements of the landslide steps were observed in the town itself (Watzof 1903). After the Vrancea earthquake in 1977, activation of a number of landslides was observed along the Danubian bank and the northern Black Sea coast (Brankov 1983). The strong Turkish earthquakes in 1999 provoke some gravitational phenomena in the eastern part of the country (Frangov et al. 2006).

Comparing the landslide and seismic regions on the territory of the country, it has been established that the share of earthquakes for the origin and activation of a number of landslides is substantial (Iliev 1973). The impact of seismic forces on the landslide slopes is complicated and is still insufficiently studied – it depends to a significant extent on its intrinsic intensity, amplitude and duration, as well as on the geological structure of the slopes and their stability reserve.

River and Sea Erosion

The deep erosion is more active in the steep gullies or in the upper river courses. This type of erosion is developed in the riverbeds of short river tributaries – along the southern slopes of the Balkan Mts., in the East Balkan Mts., the Kraishte area, in the sands and gravels along the tributaries of the Struma and Mesta Rivers, in the East Rhodopes along the tributaries and main course of the Arda River. The influence of this type of erosion on the landslide phenomena activation is expressed in carrying away the material from the lower retaining parts of the slopes and disturbing the slope equilibrium.

The lateral erosion (toe-cutting) is observed mainly in rivers with constant water runoff. The activity of the rivers on their own sediments, when changes in the water level occur, leads to rapid alterations in the position of riverbeds. In this case it is possible that materials from the toe of an existing landslide, i.e. from its 'passive' part, are carried away. The effect of the lateral river erosion on landslide process activation is observed along the Danube River course near the towns of Lom, Oryahovo, Svishtov, Tutrakan, etc. (Fig. 1).

Abrasion (sea-erosion) is displayed approx. on 70 % of the length of the Bulgarian Black Sea coastline. The basic influence of sea erosion provoking sliding is the washing away and transporting of materials from the retaining part of the landslide, which is the reason for reduction of the

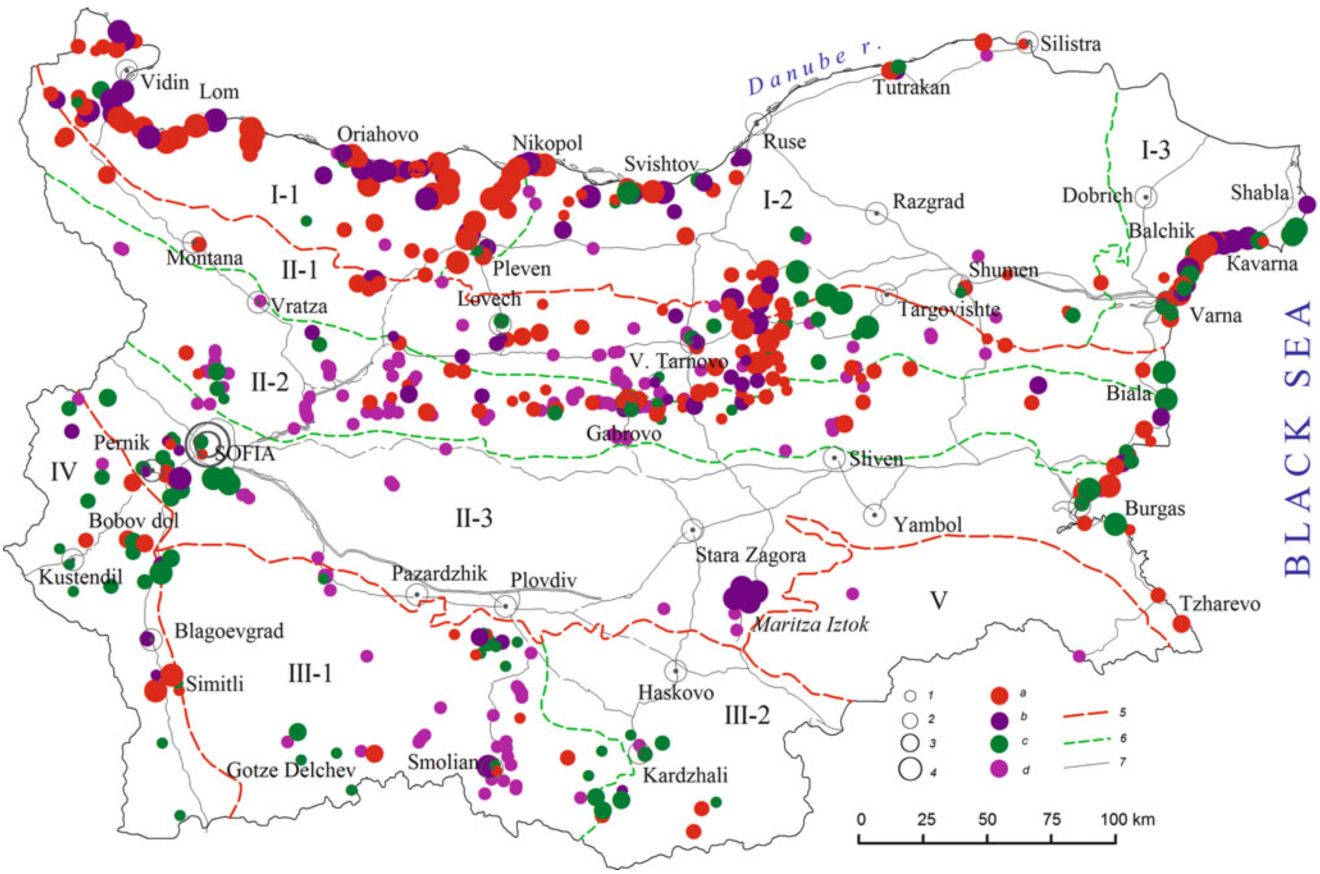

Fig. 1 Distribution of landslides in Bulgaria (Modified after Bruchev et al. 2007b): *1* – landslides with volume up to 10×10^3 m^3; *2* – landslides with volume from 10×10^3 to 100×10^3 m^3; *3* – landslides with volume from 100×10^3 to $1{,}000 \times 10^3$ m^3; *4* – landslides with volume more than $1{,}000 \times 10^3$ m^3; *a* – active landslide; *b* – dormant landslide; *c* – stabilized or abandoned landslide; *d* – no information about the state of activity; *5* – boundary of Engineering geological region; *6* – boundary of Engineering geological zone; I – Moesian region: -1 – Lom zone; -2 – Ludogorie-Dobrudja zone; -3 – Black Sea zone; – Balkanide region: -1 – Fore-Balkan zone; -2 – Balkan (Stara Planina) zone; -3 – Srednogorie zone and zone of kettles; – Rila-Rhodope region: -1 – West Rhodope zone; -2 – East Rhodope zone; V – Kraishte region; V – Strandja region; *7* – main roads and highways

retaining force. The maximum values for sea erosion are observed in the coastal sections near Kavarna, Balchik, Kranevo, Ravda, Sarafovo, etc. It was established that the most active landslides along the Black Sea coast are the areas with the most intense abrasion (Kamenov et al. 1973).

Surface and Ground Water

The stability of reservoir and river banks is often connected with the influence of surface and groundwater level fluctuations. In the most general case the rising of this level in the slope is due to the infiltrated precipitation water. This significantly changes the force proportion in the massif, i.e. the weight of the soil masses, the strength parameters, the hydrodynamic pressure.

The sharp changes in the groundwater regime in the bank sections may occur as a result of significant water level fluctuations in rivers and reservoirs. The rapid rising of the water level in the river, exceeding that of the groundwater drained in the river from the slope, alters the filtration stream direction – a process of recharging the aquifer horizon from river or water reservoir is started. Although the increase in the water level and the change in the filtration stream direction exert a back up effect, the strength parameters of the saturated masses are reduced and loss of consolidation and partial washing away are often observed in the contact zone.

The rapid lowering of the water level in the reservoir increases significantly the gradient of groundwater flow in the slope. As a result the weight of the soil masses and the hydrodynamic pressure are increased and often suffusion and sliding processes are developed.

Precipitation

The distribution of the monthly and annual sums of precipitation is different for the single landslide regions.

The towns of Lom, Nikopol, Oryahovo, Svishtov and Tutrakan are situated in the northern climatic region of the Danubian hilly plain. The main maximums of precipitation in these stations as well as the extreme values of their monthly sums are in the end of spring and beginning of summer (Bruchev et al. 2007a).

Balchik is situated in the climatic region of the Northern Black Sea coast. The monthly precipitation is the highest in November, with a secondary maximum in June-July. Extreme monthly precipitation values are recorded in June.

The precipitation regime in Veliko Tarnovo is typical for the moderate-continental climatic sub-region. The extreme monthly precipitation sums are observed in July and May.

Similar distribution of monthly precipitation is observed in Sofia City but with a more clearly expressed maximum in June.

In Radnevo (Maritsa-Iztok coal mine) the monthly precipitation sums in May and June are equal. There is a secondary maximum in November-December. In Gotse Delchev the precipitation maximum is in November-December, with a secondary maximum in June.

There is a close relation between precipitation and shallow and medium deep landslide activation. For this reason, it was found that most of landslide activation are either in spring or autumn, i.e. during the rainfall maxima (Frangov et al 1996; Berov et al. 2002).

Man-Made Impact

The most recent times, the human activity reveals as a main factor of the slope instability. The most common man-made factors in Bulgaria are as follows:

1. Undercutting of the slopes,
2. Watersaturation of slopes,
3. Overload of the upper parts of landslides,
4. Dynamic impacts.

The undercutting of the slope related with open-pit mining of mineral resources, road and railroad construction, deep excavations for building sites and underground structures, etc., are especially dangerous from the viewpoint of landslide stability. This is one of the most common anthropogenic factors in the country (Bruchev et al. 2007a).

The man-made changes in underground hydrodynamics are in many cases the basic factor for the occurrence and activation of landslide processes. Most often, the watersaturation of slopes is caused by faulty and missing sewerage, losses in water supply networks, and poor drainage systems. The groundwater regime is altered substantially as a result of dam construction and backwatering, undimensioned irrigation, concentrated leakages from pipelines and channels, household water infiltration, etc. The unfavourable effect of water soaking is more strongly expressed for the stability of shallow landslides, but in some cases it might be considered that the man-made changes in the natural underground hydrodynamic regime destabilize deeper landslides.

Overload of the upper parts of slopes is usually from construction of road embankments or new buildings that can change slope instability and to trigger a landslide.

Dynamic effects on the one hand reduce the shear strength of soils, on the other, generate additional stress decreasing the slope stability. Dynamic man-made impacts on landslide stability occur in the course of blasting works, heavy machine vibrations, etc. The effect of explosions is more pronounced and it is similar to that of earthquakes.

Landslide Distribution

The surface distribution of the large landslides on the territory of the country is not uniform. The greater part of the landslide phenomena occur in the basic landslide regions – the high Danubean bank in the area of the Lom depression and the right slopes of the tributaries, the regions around Svishtov and Tutrakan, The Northern Black Sea coast, the periphery of the plateaux in North-East Bulgaria and the canyon-like slopes of the rivers in the Fore-Balkan and the Balkan, the Tertiary coal basins and grabens in South Bulgaria – Maritsa-Iztok Basin, the Sofia, Pernik, Bobov Dol, Simitli and others, the East Rhodopes Mts. The parameters of the investigated landslides vary in a wide range: the volume is from 1 million m^3 to 450 million m^3, the depth – from 15–20 to 150 m. The geometric dimensions are in direct relationship with the geologic and tectonic composition, the geomorphological peculiarities of the slopes and the magnitude and intensity of the factors, determining slope stability (Bruchev et al. 2007a).

The distribution of the landslides in the course of time shows the existence of a certain cyclic recurrence, which is more clearly expressed in the wider range landslides (Frangov et al. 1996). The periods of higher landslide activity are repeated every 10–15 years. The seasonal distribution displays a concentration of the landslides in the spring period, which is connected with the precipitation maximum with additional influence of the snow thawing. The influence of the other destabilizing factors (especially erosion and abrasion) is very strong. The excavation activities accompanying the open pit mining are the basic man-made factor causing the origin and activation of large landslides. The influence of the seismic activity is also considerable, but no direct relationship has been established so far between the occurring earthquakes and landslides, which is probably due to the so called ‘delayed aftereffect’.

Detailed prediction zoning of the country could be performed according to the degree of the hazard for the origin and activation of large landslides. The most hazardous regions are determined to be built of slightly lithified Paleogenic and Neogenic clayey sediments, wide fault zones filled by finely crushed rock material and slopes with inverse geological composition subjected to the intensive action of erosion, abrasion, human activity and earthquakes. Such regions are the Western Danubean Bank, the Northern Black Sea coast, the Maritsa-Iztok basin, the Pernik and the Simitli grabens. The regions of a medium degree of hazard are the Veliko Turnovo and Svishtov areas, the peripheral part of the Sofia graben, the East Rhodopes Mts., the Bobov Dol coal basin, the valley of the Mesta river. The low degree refers to the peripheral zones of the plateaux in North-East Bulgaria, the marl slopes of the Fore-Balkan, the Paleogenic and Mesozoic flysch formations in the East and Central Balkan, etc. The possibility of occurrence of single large landslides in the rest part of the country, designated as hazardless, is not excluded under changed conditions of new terrain configuration.

Landslide Mitigation Measures

Landslide Map of Bulgaria

Permanent landslide events required the mapping of landslides in Bulgaria. It was completed in 1999 under the assignment of Ministry of Regional Development and Public Works of Bulgaria and it was later updated in 2006. The initial map included data of 917 landslides only in urban areas, cottage zones and resorts. In 2006, other 135 landslides were added, occurred in urban areas and railway network (Bruchev et al. 2007b).

Landslide mapping was assessed by three criteria: severity of consequences, frequency of activation and opportunities to prevent or reduce their impact. Three groups of landslides were separated: (1) shallow landslides, (2) deep-seated landslides, conditionally stable, and (3) deep-seated landslides with periodic (re)activation of some parts of them.

Landslides in the first group are the most numerous. They are developed along the river and valley slopes. Their depth range is from 2 to 8 m, affected area up to 2–3 dka. Activity is the most highly influenced by precipitation, erosion and man-made impact. Triggering is frequent during rainy periods. They cause relatively minor damages and their consequences are easily separable.

The second group covered a considerable part of recent and ancient landslides. Their size is larger: depth 30–40 m or more, areas over 10 dka. The danger of them is more potential ('dormant' acc. to WPWLI 1993), but under extreme conditions such landslides can be reactivated. Such factors are as human impact, earthquakes, storms, intense abrasion and others. Large dormant landslides existed on along the Danubean river banks, at the northern Black Sea coast, in central Fore-Balkan, Eastern Balkan Mts, and Rhodope Mts.

The most dangerous landslides are in the third group. They are large (deep-seated), complex type, more than 50 m deep, and their stability is in the limit state of equilibrium. Moreover, it is enough small destabilizing factor for the triggering the landslide movements, such as abrasion, intense rainfall, earthquake and man-made impact. On the one hand, there is a slow movement (creep) in the most deeply situated slip surface, and by other hand, the recent landslides trigger in the upper parts of the existing old deep landslides. Contemporary landslide activation reaching up to the primary (deepest) slip surface is rarely occurring. Landslide of this group are developed in Northern Black Sea coast (Zlatni Pyasatsi, Albena, and Balchik), Danube River bank, Rhodope Mts, Maritsa-Iztok coal basin, in the valleys of Struma, Mesta, Vacha, Kamchia, etc.

National Program for Landslide Mitigation 2007–2015

Sustainable regional development of Bulgaria depends on many conditions and factors, incl. and those arising from state resources and environmental risks. Risks of landslide events must be reduced to acceptable levels. The program covers all activities related to implementation of effective protection from widespread landslides. It applies to the entire territory and sovereignty attached. The duration is from 2007 to 2015. The main purpose of geo-protection activities is to protect life and health, reduce the effects of the devastating effects of abrasion, erosion and landslides on properties and economic activities, ensuring the normal functioning of transport and other communications and environmental protection. The National Program is a complex system of different activities within the territory and territorial sea of Bulgaria. Key elements of geo-protection are:

- Information Systems (GIS, cadastral maps, etc.);
- Tool control of active landslides;
- Preventive activities;
- Strengthening and protection through the construction of engineering facilities, their maintenance and management;
- Rapid measures in an emergency (rescue and emergency recovery activities).

Countering landslides is expressed in undertaking various development, hydrology, hydraulic engineering (drainage), geotechnical and composite protective measures. Key unresolved issues in this area are: lack of an overall assessment of the effectiveness of the constructed drainage engineering and earth retaining structures, poor maintenance, rehabilitation and operation of constructed facilities; unjustified underestimation of preventive action to prevent the activation of landslide processes. There is not conducted systematic monitoring to track developments of landslide processes.

Experience shows that local authorities and local administration are usually registrars of landslide phenomena. There is no unified system of permanent, preventive, operational control and coordination in all fields of geo-protection activities. Due to this reason, the program aims to correct the deficiencies in the prevention works. Funds have been provided for exploration, design, construction, operation and maintenance of protective measures.

Necessary amount of countermeasures against landslides and effective coastal protection against erosion and abrasion processes for the period 2007–2015 is estimated to 260 million BGN (~130 million euros). At present, the most affected administrative districts by landslides are Varna, Vidin, Vratsa, Veliko Tarnovo, Gabrovo, Dobrich, Kardjali, Montana, Pleven, Ruse, Silistra and Smolyan.

For the entire duration of the program (2007–2015), the necessary funds for coastal protection and landslide countermeasures along the national road network and railways is amounted to 540 million BGN (~270 million euros). Ensuring that financial resources and its effective implementation will contribute to strengthening of endangered sites and proper functioning of the national infrastructure (Bruchev et al. 2007c).

Discussion

The irregular distribution of landslides puts the question of regional zoning by hazard degree. A classical example of a high degree area is the strip of the Danubean Bank between the town of Dunavtsi and the Iskar River. The landslides are developed in Pliocene clayey deposits, situated in the Lom depression. They are characterized by large volumes – more than 15 million m^3. There is a continuous preparatory period when the formation of an active compression prism is observed years before the active stage. An activation cycle of 8–10 years has been established. The basic factors are ground water and man-made moistening.

The Black Sea coast has also a high hazard level. It is the strips at Balchik-Kavarna, Zlatni Pyasatsi-Kranevo, Ravda and Sarafovo (Kamenov et al. 1973). Neogenic sediments of diverse lithological composition participate mainly in these landslides. The basic destabilizing factors are the abrasion and the changes in the regime of ground water. The seismic from near and more remote centres (Shabla, Vrancea) exert also effect on the activation along the Northern Black Sea coast (Konstantinov and Konstantinov 1989). The degree of successful prediction is higher in the northern part (in Balchik), where short-term forecasts can be made on the basis of the ground water level. The landslides at Sarafovo and Ravda have comparatively more shallow slip surfaces – at about 15 m. The landslides along the Northern Black Sea coast are more complex and have a storey-like distribution – deeply positioned slip surface and 1–2 more shallow ones, the activations taking place mainly at the higher levels.

The observed frequency of occurrence is every 4–6 years on the average. Another hazardous landslide region is the valley of Cherna River in the Rhodopes. Sudden and difficult for prediction landslides with high speed can occur along its steep slopes, composed of alluvial-delluvial materials, without any noticeable evidence during the preparatory stage. The landslides in the Iskar gorge whose steep slopes are built of Paleozoic metamorphic rocks, covered by a thick layer of alluvial-delluvial materials, are also very difficult for prediction and might have heavy economic consequences. The regions with intensive open pit coal mining are characterized by very large landslides (Maritsa-Iztok, Pernik, Oranovo, Brezhani). They occur both on the borders of the open pit mines and as a consequence of collapse of terrains over underground spaces (Pernik, Oranovo, Brezhani). Sediments of Neogenic (Maritsa-Iztok, Simitli Graben) and Paleogenic (Brezhani and Pernik Grabens) participate mainly in the landslides. Suitable conditions exist also in Simitli Graben, where the hazard of the formation of large landslides is determined by the high seismic activity, linear erosion and changes in the ground water regime.

Regions with an medium degree of landslide hazard are the peripheral parts of Sofia Graben, the southern part of Pernik Graben, Bobov Dol, the valley of Mesta River, parts of the Central and East Rhodopes Mts., the Black Sea coast between the capes of Galata and Emine, the valley of Dvoynitsa River in the East Balkan, the volcanogenic complex in the Rhodopes Mts., the areas around the town of Veliko Turnovo, Alexander Stamboliiski Dam and the town of Svishtov. The geological formations building these terrains are mainly of Cretaceous, Paleogenic and Neogenic age.

The regions of low degree of deep landslide hazard are mainly the peripheral parts of the plateaux in North-East Bulgaria, the slopes of the Fore-Balkan, built of marls, and the Paleogenic and Mesozoic flysch formations in the Central and East Balkan. The latter are a favourable medium for the origin of landslides with volumes of up to 1 million m^3. Conditions for the origin and activation of larger landslides exist also in the Central Rhodopes. The block landslides along the Northern Black Sea coast (Roussalka-Taukliman, Yailata and others) are also characterized by a low degree of hazard. However, some of these landslides could be triggered after seismic impact. Such impacts were found at Madara and Dobrudja plateaux after seismic events in local and regional origin, for example Vrancea and Turkey (Frangov et al. 2006, and others).

Conditions for the origin of landslides are also available in the regions designated as hazardless in the rest part of the map – shallow landslides are found in many of them. Under certain new terrain circumstances however, the formation of single large landslides is not improbable.

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Landslide Risk Management in the Arno River Basin

Gaia Checcucci

Abstract

The Basin Plan is, under the Italian law, the legislative, technical-operational and knowledge instrument used to plan, programme actions, and use regulations for soil conservation, protection and valorisation, and for correct water use in context of the physical and environmental characteristics of the Basin territory (Fig. 1).

In specific terms, the Hydrogeological Management Plan (PAI), approved by the Arno River Basin Authority in 2005, faces the issues concerning landslide risk and geomorphological hazard. The Arno River Basin Authority constantly updates its landslide hazard zonation by identifying landslide prone sites on the basis of the Italian Landslide Inventory Criteria (IFFI project-ISPRA). Moreover, satellite-based radar interferometry detects assets at risk of landslide activity. A procedure that not only allows the maximum level of interplay and coherence between land use planning and river basin planning, but also influences and supports decisions at the different administrative levels. This allows the provisional cost-benefit assessment of landslide risk reduction actions with the general aim of environmental protection and efficient territorial management policy.

Under the European Legislation, that foresees the integrated management of the different basins belonging to each District, National Basin Authorities are assigned a coordination role as regards to the updating procedure of the River Basin District Management Plans, under Directive 2000/60/EC, and the drafting of the Flood Management Plans under Directive 2007/60/EC. This active role envisages the updating of the knowledge framework and data concerning slope instability and landslides. It will result in the consequent updating of the Landslide Hydrogeological Management Plan which is included, like the above mentioned plans, in the River Basin District Management Plan.

Keywords

IFFI database • WeBGIS project • River basin district management plan • Hydrogeological management plan • Radar interferometry • Financial framework • Landslide

Introduction

The Arno river basin covers a surface of 9,116 kmq: about 10 % of these area is interested in active or inactive landslides phenomena. The management of hydrogeological risks (i.e. flood and landslide risks) is therefore very urgent and challenging. The Basin Plan is, under the Italian law, the legislative, technical-operational and knowledge instrument used to plan, programme actions and use regulations

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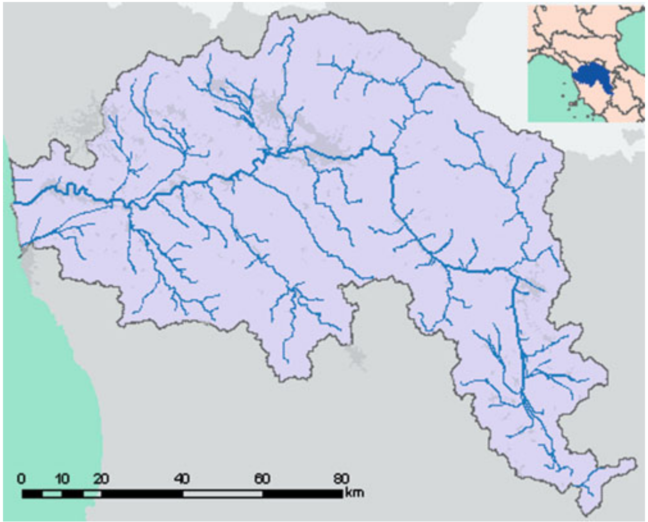

Fig. 1 Position and extension of Arno river basin

for soil conservation, protection and valorisation, and for correct water use in context of the physical and environmental characteristics of the Basin territory.

In specific terms, the Hydrogeological Management Plan (PAI) part of the Basin Plan, that was approved by the Arno River Basin Authority in 2005, faces the issues concerning landslide risk and geomorphological hazard.

Based on a broad recognition of landslide evidences, integrated with analytical evaluations of geological and geomorphological characteristics, the Plan offers a detailed map of the landslide hazard zonation.

The Arno River Basin Authority constantly updates such zonation by identifying landslide prone sites on the basis of the Italian Landslide Database Criteria (IFFI project – Inventory of Landslide Phenomena in Italy, ISPRA). Moreover, satellite-based radar interferometry detects assets at risk of landslide activity. A procedure that, not only allows the maximum level of interplay and coherence between land use planning and river basin planning, but also influences and supports decisions at the different administrative levels (i.e. municipal, local, regional) (Fig. 2) (Table 1).

The IFFI project, coordinated by ISPRA (Institute for Environmental Protection and Research) at national level, was conceived with the aim of creating an homogeneous database for landslide phenomena localization on the whole territory. It can be useful to:

- Evaluate landslide danger;
- Programme soil protection actions;
- Land use planning.

As regards to the Arno Basin territory, the Arno River Basin Authority has started cooperating, over the last years, with local authorities (Regions, Provinces, Municipalities). A cooperation aimed at homogenizing hydrological risk mitigation projects and support the administrations' planning procedures, in respect of the single competences. As regards to the Arno River Basin, the Landslide Hydrological Management Plan (included in the Basin Plan), in particular the "Maps of Landslide Prone Areas based on the Landslide Database – Scale 1:10,000" are based on the IFFI datasets and knowledge framework (Fig. 3).

Moreover, the legislation in force (article 32 of the Basin Plan regulations) foresees the adaptation of the Municipal Land Use Management Plans to the Hydrological Management Plan. This results in a continuous dynamic updating of the IFFI database. At the same time proposals that local administrations submit in order to update the Hydrological Management Plan maps are assessed on the basis of the IFFI database. Thus, the planning process implies a continuous exchange of datasets among the different administrations (Fig. 4).

The WebGIs Project

The identification of landslide prone areas, in the Arno River Basin, was integrated by important information for the assessment of the risk status, the geological characteristics and the nature/typology/activity of the ongoing displacements. Satellite based radar datasets of landslide movements were analysed (ERS satellite, 1992–2000; RADARSAT 2003–2006; ENVISAT 2003–2008). The technique used to assess landslide velocity is interferometry; in particular, advanced radar interferometry (Fig. 5).

Available displacement datasets were used first for producing statistical analyses of landslide phenomena and second for the spatial distribution of the expected landslide displacements. These results gave an important contribution to the displacements' characterisation and allowed the implementation of the WebGIS project. The WebGIS project is pivotal to planning activities and risk analyses both at local and regional scale. Moreover it supports decision makers at the different administrative levels.

Furthermore, these results allow the provisional cost-benefit assessment of landslide risk mitigation interventions and the allocation of financial resources on the basis of a priority scale with the general aim of environmental protection and efficient land management policy.

Hydro-Geological Risk Mitigation Actions – Financial Framework

In accordance with the national law for financial resources allocation regarding actions to be implemented in areas at hydro-geological risk (Art 2,(240) of Law n.191 of 23

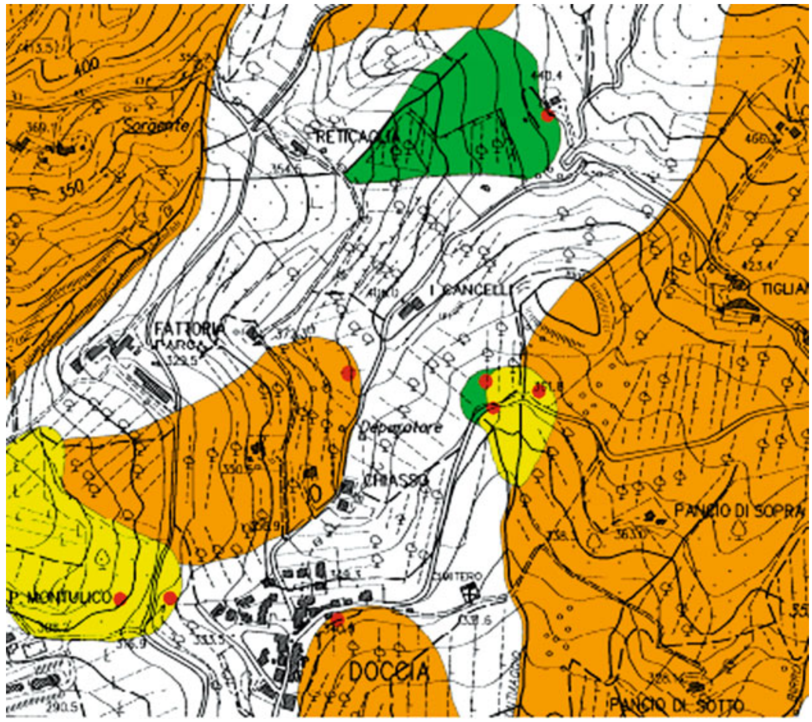

Fig. 2 Detail of maps of landslide prone areas based on the landslide database – scale 1:10,000″. Pontassieve (FI). The *yellow* areas are related to the highest hazard (PF4), followed from the *orange* areas (PF3) and the *green* areas (PF2). The *red dots* are the top points of landslides areas

Table 1 List of municipalities of Arno river basin affected from landslides events, and percentage of surface involved

N.	Municipality	% of surface
1	Pontassieve (FI)	41
2	San Casciano V. di Pesa (FI)	36
3	Castel San Niccolò (AR)	34
4	Lajatico (PI)	33
5	Montespertoli (FI)	32
6	Tavarnelle V. Pesa (FI)	31
7	Chiusi della Verna (AR)	31
8	Ortignano (AR)	30
9	San Piero a Sieve (FI)	29
10	Firenzuola (FI)	27

Fig. 3 Landslide near Loro Ciuffenna (AR), in the eastern side of Arno river basin

December 2009 – National Budget Law 2010), the Arno River Basin Authority approved an Act containing the outline of priority actions and their costs' detail.

The Act, approved by the Institutional Committee (the Authority's political body) in March 2010, formed the fundamental basis for the State-Regions Agreement that outlined the actions to be implemented on the basis of the allocated resources.

The Act is being constantly updated by the Authority with the help of an ongoing monitoring activity. This allows the identification of the funding requirements for the entire basin emanating from planning activities. Therefore, planned actions and their expenditure forecasts derive from the updated and tested knowledge of slope displacements.

Under the European Legislation that foresees the integrated management of the different basins belonging to each District, National Basin Authorities are assigned a coordination role as regards to the updating procedure of the River Basin District Management Plan, under Directive 2000/60/EC and the drafting of the Food Management Plan under Directive 2007/60/EC. This active role envisages the updating of the knowledge framework and data concerning slope displacements and the connected landslide risk. It will result in the consequent updating of the Landslide Hydrological Management Plan which is included, like the above mentioned plans, in the River Basin District Management Plan.

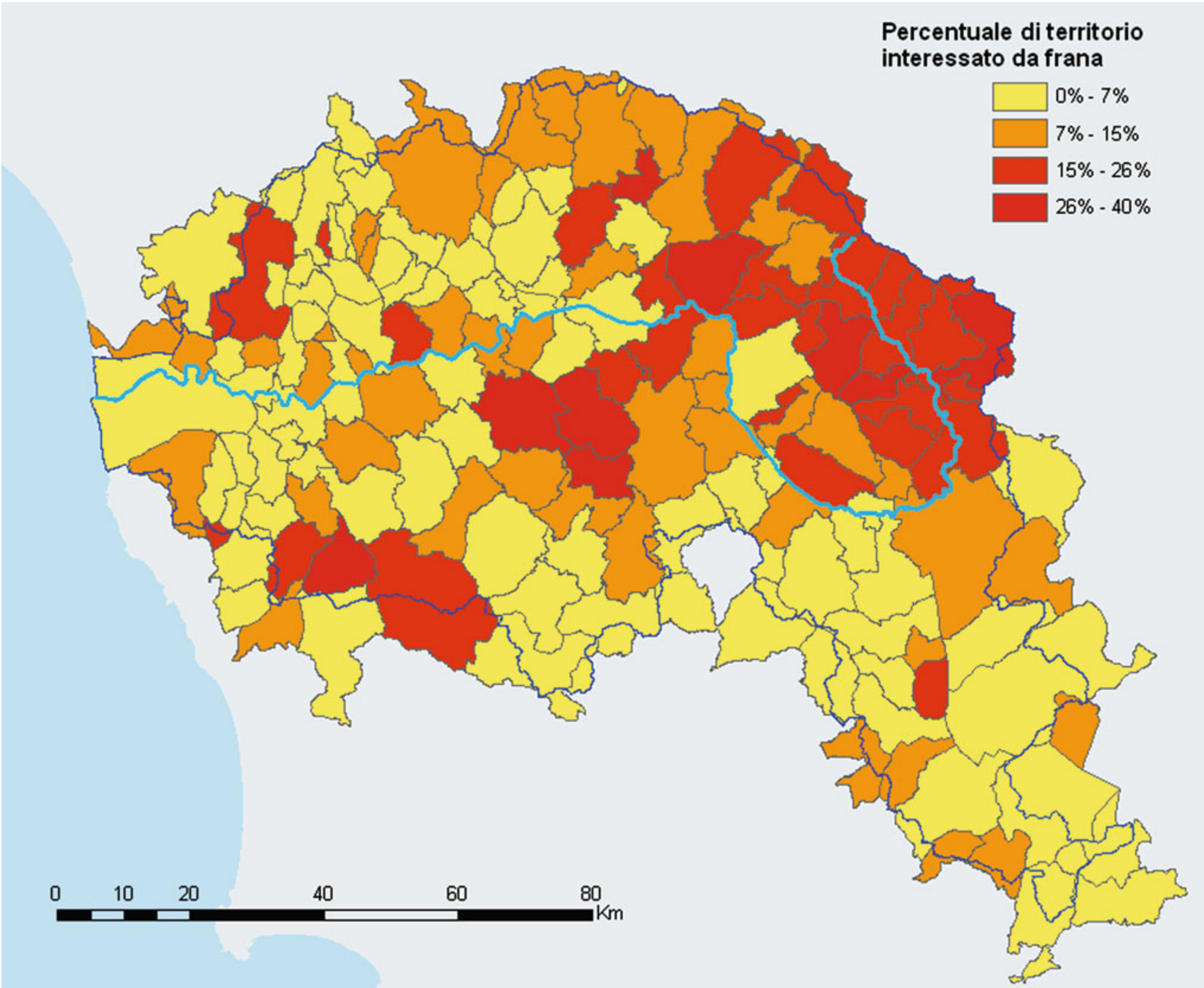

Fig. 4 Percentage of area interested from landslide events, spatially aggregated on the administrative boundaries of the 166 municipalities of the Arno river basin

At this regard the Arno River Basin Authority is carrying out stakeholders' involvement actions as regards to the IFFI project and the financial requirements of the Basin Plan. These actions are implemented in accordance with EU Directives and the Italian legislation regulation for the drafting, adoption and approval of the River Basin District Management Plan and its sub-plans.

Conclusions

The necessity to constantly update the landslide management framework led the Arno River Basin Authority to promote and facilitate (with the participation to the IFFI project) a continuous interplay among planning activities at the different administrative scales. In the meantime the Authority, on the basis of the acquired datasets, outlined the financial requirements for the planning activities and the related priority list. Thus, it was possible to influence the programming activities and the funding for interventions on the basis of the allocated resources.

The updating of the landslide database and consequently the identification of the expenditure needs for landslide mitigation are useful both for the Authority and the Regions that have competence on the territory. These data will be the basis for the drafting of the Landslide Management Plan that will be part of the River Basin Management Plan. The drafting of the Landslide Management Plan is one of the possible future actions that will be implemented, in accordance with the European Directives, with the aim of simplifying sectoral and land use plans that are in force today.

Fig. 5 Example of the web-gis representation

In accordance with the law provisions as regards to the Basin Plan, the new planning phase will imply an updating of the use regulations and general directions of the Hydrological Management Plans. These regulations, that aim at soil conservation and protection on the basis of the environmental and physical characteristics of the territory, will undergo an homogenization at territorial scale that will automatically lead to a simplification of the Plans.

The Policy Issue of Landslides in Romania

Raluca-Mihaela Maftei, Elena Tudor, George Vina,
and Constantina Porumbescu

Abstract

National policy in disaster risk reduction field is expressed through various legislative documents for the hole field and different risk types, administrative authorities, public institutions and specialized institutions with responsibilities in disaster prevention and response management.

Romania is one of the Eastern European countries more severely affected by natural hazards (floods, landslides and earthquakes), all with strong economic and social impact. Landslides comprise all the failure and movement mechanisms, e.g. slides, lateral spreading, flows and falls etc… Mountains, hills and tablelands, which cover two-thirds of the country's area, are particularly susceptible to landsliding, especially the hills and tablelands. Numerous historical documents from the fifteenth to nineteeth centuries contain information on landslide related damage, but it is only since the early twentieth century that scientific inventorying and appropriate mapping exist.

In Romania, the interests in achieving a legislative base regarding natural disasters and prevention measures/countermeasures occurred before 1960. The most important natural hazards are: strong earthquakes, major floods, landslides, soil erosion and drought.

The surface exposed to the landslide risk is 800,000 ha, where are located 50,000 households in which live 250,000 people. Area with the highest risk to landslides is located in southern and southwestern Carpathian arc. For registration and statistics highlight to the main natural hazards exist standardized evaluation sheets for damage caused by landslides and floods (Official Gazette, X 354/16.09.1998).

Keywords

Landslide • Legislation • Hazard assessment • Romania

Introduction

If before 1989, during the centralized regime, the Romanian Government was solely responsible for rehabilitation, in the current day aims at the reorganization of disaster management.

Also, as a EU country, Romania has to create andimplement an institutional and legal framework harmonized with EU requirements, to address the assembly and solve problems related to risk management. This paper proposes a brief spatial analysis of landslides in Romania, completed by a landslide susceptibility model. Landslides constitute a very common geomorphic hazard in this country, mainly in the hilly regions which occupy around 30 % of Romania's territory. The landslide susceptibility assessment at national level was accomplished using a Landslide Susceptibility Index (LSI) computed in GIS, which considers and weights the main factors that control landslide activity: lithology, slope gradient, maximum rainfall in 24 h, land use, seismicity and local relief Nunes de Lima (2005).

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Terminology

(according to the International Standard Terms Glossary for disater management, edited by the Umanitary Business Departament Geneva 1992, 1993, 1996 under ONU aegis and endorsed by the UE members legislation).

Natural disasters are distructive natural phenomena, which have as a result human and material losses (plentful rain, floods, landslides, earthquakes, massive deposits of ice and snow).

A natural hazard *is* a threat of a naturally occurring event that will have a negative effect on people or the environment. The measure for natural hazard represents the probability of exceeding the characteristically size of one phenomenon in a restricted area and in a given period of time.

The anthropic hazard refers to a certain phenomena, usually natural disasters, which state was affected by the human activities. This phenomenon has a large scale of development; it grows from climate changes, regarding the modification of the rainfall regime (slightly influenced by human actions), to nuclear explosions (total anthropic influence)

The areas that are exposed to natural hazard are geographical limited. In this regions the intensity of the values that feature the natural phenomenon is highly raised, however the risk to produce excesive damages is small.

The areas exposed to landslides are regions with high values to slide probability.

The areas exposed to natural risk **or** ***natural risk zone*** are geografical delimited regions in which the intensity of the values, that characterize the naturals distructive phenomena, is high, leading to material and human lives losses.

The elements that run a risk to natural hazard represent all the material and persons that can be affeced by the natural phenomenon that can occur.

The elements that run a risk to landslides represent all the material goods and persons that can be affeced by the landslide that can occur.

The destructive features of a natural phenomenon that engender losses is represented by that specific magnitude of the phenomenon witch produces losses when interacting with the constructions structures.

The destructive features of a landslide represents that specific magnitude of the phenomenon witch produces losses when interacting with the constructions structures: the distinctiv field movemnet for landslides that develop slowly, subsidence shift for regressive development, the kinetics energy of the sliding masses for fast landslide.

The vulnerability represents the damage degree (from 0 % to 100 %) caused by a susceptible phenomenon that generates human and material losses.

The vulnerability of the elements exposed to different destructive features represents the amount of elements affected by the natural phenomenon that causes damage. Vulnerability is a sub-unit value, noted with 0 if the elements are unaffected or with 1 if the elements are entirely amaged (lost lives and ruined constructions).

The vulnerability to landslide represents the degree of affected elements exposed to landslide action.

The risk represents the mathematical estimation of the probability to produce human and material loss for a given region and period of time lied to a certain desaster. The definition of the risk applied to a certain phenomenom is the product between the probability to cause human and material losses and the value of those losses.

The associated risk to landslides represents both the material and potential human loss caused by the appearance of these natural phenomena.

The natural risk **maps** represents isolines regarding the geographical plane distribution of the probability values to produce human and material losses caused by the appearance of natural phenomena which generate loss, value specific to each natural phenomena and each destructive characteristics.

The hazard landslide maps represents isolines regarding the geographical plane distribution of the probability sliding values or the probability to outrun the specific destructive characteristics, generating losses.

The landslide associated risk maps represents the plane distribution of the the potential annual values of material and human losses, caused by the landslides.

Methodological Approach

The methodological requirements referring to elaboration and the content of landslides natural risk maps (No.447 from 10/04/2003)

In order to establish the potential and the probability of an area to be affected by soil instability phenomenon (caused by natural or anthropic factors), in accordance with the COM 232/2006, Chap. 2, Sect. 1, Article 6, the first step that has to be made in this direction is to identify and classify the risk areas in the pruned region. The region will then be surveyed every 10 years and the investigation program will then be made public and revised every 5 years.

Presently, there is no coherence and cohesion in decisions and actions taken by the research institutes and government institutions involved, at local or regional scale in systematic investigation, or a strategy for inventorying and monitoring of landslide affected areas, at national scale.

Within the Geological Survey of Romania studies were elaborated regarding the assessment of landslide hazard, triggering factors and their effect on slope stability in site territories, were detailed geophysical and geological engineering investigations (seismic, geo-electric, bio-geo-physic) were performed (Gorj, Valcea, Prahova, Arges, Buzau and Dambovita counties).

The methodology used for the elaboration of landslide hazard maps is based on the following principles:

– The analysis criteria are based on eight factors or criteria (see Table 1);
– Three degrees of landslides occurrence potential are considered (low, medium, high) and the corresponding probabilities of landslides to occur (from practically zero to very high);
– The risk coefficient (K) is calculated depending on the potential and the probability of landslide occurrence;
– Among the factors which control the occurrence of landslides, lithology and geomorphology are considered the most important;
– In order to delimitate an area of the slope, with a specific landslide potential, the average risk coefficient „Km" is calculated using the following relation:

$$Km = \sqrt{\frac{K(a) * K(b)}{6} * \sum_{h}^{c} K} \quad (1)$$

– The territory for which the hazard map is elaborated is divided into polygonal areas as homogeneous as possible with respect to the factors used for the landslide risk assessment;
– For each polygonal area the risk coefficient (K) is evaluated, according to the criteria adopted for analyses;
– Finally, using relation (1) the average risk coefficient of the polygonal area is determined, and the landslide risk map is drawn.

Legislation and Management

National policy in disaster risk reduction field is expressed through various legislative documents for the hole field and different risk types, administrative authorities, public institutions and specialized institutions with responsibilities in disaster prevention and response management.

The relevant laws regarding the national policy for disaster management are Government Ordinance (GO) no. 47/1994, regarding the defense against disasters, approved by Law no.124/15.12.1995, Law no.106/25.09.1996 – Civil Protection Law, modified by G.O. no. 21/15.04.2004 regarding the National System for Emergency Situations Management.

At national level the system for emergency situations management is under reorganization and redefinition of all responsibilities for national and local institutions with responsibilities in this field. According to the new laws which are in full process of development, new institutions and operational structures will be organized, which will ensure people protection, infrastructure and environmental protection during an emergency situation, in a coordinated and professional manner.

According the Emergency Ordinance no.21/2004, the National System for Emergency Situations Management is composed by:

(a) Emergency Situations Committees;
(b) General Inspectorate for Emergency Situations;
(c) Professional Emergency Services;
(d) Operative centres for emergency situations;
(e) Action commander.

The committees for emergency situations will be organized on levels, as follows:

(a) National Committee for Emergency Situations;
(b) Ministerial committees and other central public institution's committees for emergency situations;
(c) Bucharest Municipal committee for emergency situations;
(d) County committees for emergency situations;
(e) Local committees for emergency situations.

The National Committee for Emergency Situations, organized under the Ministry of Administration and Interior, and the ministerial committees for emergency situations are responsible for application of the disaster risk reduction policy at national level.

The national strategy for civil protection drafted, discussed and approved by the Supreme Council for Country Defense through the Decision no. 92 from 15.04.2004, outlines the strategic direction in order to fulfill the fundamental objective established by the National security strategy and the Government's White Book.

The strategy includes the fundamental objectives and options regarding the accomplishment through protection forces specific ways and actions of the national security policy in the field of protection of people, materials goods, patrimonial values and environment in case of disaster, as well as in the field of preparedness and relief actions, in order to reduce the disaster consequences.

International conventions and other ratified accords and agreements are components of Romanian legislative system and are part of the national policy for disaster risk reduction management.

The main priorities concerning the risk reduction are the floods, earthquakes, dangerous meteorological phenomena and technological disasters.

The disaster risk reduction for floods, meteorological phenomena and hydro technical works accidents is part of the National policy and strategy for water management, which have been elaborated by the Ministry of Environment and Water Management.

In the regard of the strategy for earthquake and landslides risk reduction, the main directions are:

Table 1 Criteria used to estimate the potential and probability of landslides occurrence

Current issue	Symbol	Criteria	Landslide occurrence potential (p)					
			Low		Medium		High	
			Landslide probability occurrence and the corresponding risk coefficient (K)					
			Practically zero	Low	Medium	Medium–High	High	Very high
			0.00 ÷ 0.30	0.31 ÷ 0.40	0.41 ÷ 0.50	0.51 ÷ 0.60	0.61 ÷ 0.80	0.81 ÷ 1.00
0	1	2	3	4	5	6	7	8
1	K_a	Lithological	Hard rocks, massive, compact or cracked, unaltered		Mostly sedimentary rocks rocks category (laminated pelite rocks such as argillaceous shale, marl and marl-limestones, chalks etc.) metamorphic rocks schists highly altered igneous rocks		Sedimentary rocks (detritus) unconsolidated, clay strongly expansive, small and medium loose dust and sand, underwater, brecia salt, etc.	
2	K_b	Geo-Morphological	Relief horizontally affected by insignificant erosion processes, valleys which are bodies of water are in an advanced stage of maturity		Hilly relief type, characteristic for the piedmont and the plateau areas, broken by river valleys network reached a certain stage of maturity, lined slopes with average height and tilt generally up to 45°		Relief characteristic hilly and mountainou arias, heavily affected by a dense network of young valleys with tall and strong inclined slopes. Valleys are most consequential (parallel to the layers direction)	
3	K_c	STRUCTURAL	Massive hard rocky bodies the igneous origin, sedimentary rocks stratified at horizontal layers, metamorphic rocks with schistosity surfaces arranged horizontally		Most fault and pleated geological structures affected by cleavage and fissuration, structures, areas which indicated drifted nape head		Geological structures characteristic geosyncline areas in flysch facies and the molasse formations of marginal depressions, geological structures layered, highly folded and dislocated	
4	K_d	Hydrological and climatical	Generally dry areas with average annual precipitation reduced. The gravel beds are dominated by sedimentary processes, erosion affects the banks (sideways) only during floods		Moderate amounts of precipitation. Main valleys from hydrographic network have reached maturity while their tributaries are at the stage of youth. Important transportation and deposition of solid flow rates		Precipitation slow long-term high possibilities of water infiltration in rocks. At rapid rains, high velocity flow drain with solid debitflow rates. Prevail vertical erosion processes	
5	K_e	HYDRO-GEOLOGICAL	Filtrate forces are negligible. The phreatic free level is found at great depth		Groundwater flow occurs at moderate gradients Filtrate forces have values that can considerably affect the slopes equilibrium state		Groundwater flow occurs under high hydraulic gradients . There is flow of indide slopes to develop filtration forces that can contribute to the triggering landslides	
6	K_f	SEISMIC	Seismic intensity at Mercalli scale (MM) less than grade 6		Seismic intensity at 6–7 grade		Seismic intensity is greater than 7 Grade	
7	K_g	FORESTer	Coverage degree by arboreal vegetation exceeding 80 %. Broadleaf		Coverage degree by arboreal vegetation between 20 % and 80 %		Coverage degree by arboreal vegetation less than 20 %	
8	K_h	ANThROPic	Constructions on slopes are not made, significant accumulation of water missing		At slopes are executed a series of works (roads and rail platforms, coastal channels, careers, etc.) with limited extension and for these are executed the relevant works to protect slopes		Slopes affected by a dense network of pipelines for water supply and sewerage, roads, railways, canals coastal, quarries. Overloading the upper slopes by dump deposits, heavy construction, etc. Accumulation lakes whom wet the lower side of the slopes	

- Completion of legislative and organizational framework in order to reduce the consequences of earthquakes and to put in safe the building stock;
- Improvement of legal framework and technical tools (software, handbooks, guides, equipment) for technical expertise, development of projects and buildings consolidation works;
- Setting up the technical and organizational condition needed for the collection, stocking and automatic processing of information regarding the buildings with high seismic risk;
- Diversification of resources and financing condition to continue the design and execution activities for the consolidation of dwellings;
- Improvement of earthquakes insurance system for buildings;
- Improvement of disaster management, particularly in case of earthquake, taking into account the main aspects of prevention, protection and intervention, as well as the public education regarding the earthquakes.

A first priority field for the Romanian Government is the implementation of communitarian aquis, especially the chapters regarding the environment and civil protection. In this way, our country is passing now through a large process to fit in the national legislation with the European legal framework, in order to reduce the disasters risks. A part of European directives are already implemented through normative acts regarding the air quality, waste management, water quality, environmental protection etc.

An important component of "National Strategy for Sustainable Development" is the Strategy for Environment Protection, which includes short-term objectives (until 2004), medium term objectives (until 2010) and long-term objectives (until 2020).

To implement the objectives of Environment Protection Strategy was elaborated the "Environment Protection National Action Plan".

The Role of National, Regional and Local Authorities

Providing assistance for endangered population, in case of natural or technological disaster is an humanitarian activity in which are involved many NGO's, universities, academies, schools, mass-media, private sector, trade unions, syndicates, and in general civil society, based on coordination of all these above mentioned by Civil Protection Command.

In Romania at the national level act a complex system of NGO's, which recognizes the necessity of coordination and collaboration with central and local structures from Romania in disaster management area.

The civil society and NGO's participate in different organized activities on risk disaster mitigation, like theoretical issues (seminars, scientific symposiums, exhibitions for presenting the intervention technical means) organized by the specialized research institutes, and also in practical issues (civil protection exercises and applications, alarming and evacuations exercises, demonstrative intervention activities, etc.) organized by the Civil Protection Command.

From all NGO's the most active is National Red Cross Society who was founded at 11th of June 1876, and from 1919 was affiliated to International Federation of Red Cross and Red Crescent Societies. The frequency and amplitude of the last decade disasters conducted to elaboration of the Romanian Red Cross Program regarding prevention, operative intervention and mitigation of disaster effects on the population. The Program objective is assistance of10,000 people, possible victims of a disaster.

The Mountaineering, Mountain Rescuers and Marine Rescuers Associations are organized especially in the mountain and seaside areas and they are participating at the searchand-rescue actions in case of disasters.

The Radio amateur Associations was used at exercises, as well as in many real intervention actions in less developed economic areas.

The Dogs Associations from Bucharest, Craiova, Ploiesti, Sibiu and Cluj-Napoca have leaders and dogs very well trained for search-and-rescue operations, who participated at international contests and missions.

Medical Associations and Foundations have a diversified chemical and toxicological laboratory network, the personal is very well trained, the medical equipment and the technical means for intervention are moderns (SMURD – Emergency Medical and Extrication Service) and they are points of contact for abroad similar organizations (Medicine sans Frontier, Pharmaceutics sans Frontier, CARITAS INTERNATIONAL, etc.).

The Ecological Associations have a good endowment and training, and act especially for prevention and fighting against accidental pollution. Some of these associations were used to finalize more educational programmes (Baia Mare) for preventive control of environmental elements (Bucharest) or in international co-operative actions in disaster management area (Craiova, Pitesti and Targu Jiu).

The Charity Associations and Foundations were engaged in supporting victims of calamities in floods cases from the last years, as well as for fitting out camps for evacuated population suffering from disaster affected area.

The Romanian Orthodox Church, Romanian Catholic Church and other churches establishments contributed, under the co-ordination of Romanian Patriarchy or independently, to philanthropic and religious assistance actions for the population in a disaster case. Also, nongovernmental religious organizations with international support, participated at philanthropic actions. Romanian Civil Protection received an important support from The Ecumenical International Council in the field of disaster's management.

The Romanian Civil Federation of Fire Fighters is an well developed body, especially in traditionally areas from TRANSILVANIA and BANAT regions, and contributed to prevention and fighting against fires at forests in 2000.

Some associations bio-speo, especially from ARAD and BIHOR counties, have participated in cooperation with Civil Protection at rescue people's life on floods, snowing-up or avalanches.

Civil Protection Inspectorate Counties made the coordination between NGO's and governmental institutions, especially on local and regional area. The NGO's were involved in training and real intervention activities in case of disasters, with financial support provided by local administration authorities or from abroad, under the coordination on Civil Protection Inspectorate Counties.

Major difficulties are related to the financial and logistical support necessary for these NGO's in practical activities, as well as for setting up a data base and a national level coordination of all NGO's from disaster's risk reduction area, taking into account the large number of this.

Specialized universities (Geology and Geophysics from Bucharest, University Technical University of Civil Engineering from Bucharest, Technical University from Timisoara, Technical University "Gh. Asachi" from Iasi, Town-Planning and Architecture University "Ion Mincu" from Bucharest, University "Babes Bolyai" from Cluj-Napoca, Polytechnic University from Bucharest) and specialized research and designing institutes (The Geographical Institute of Romanian Academy, The National Institute for Building Research – INCERC from Bucharest, The National Centre for Seismic Risk).

Reduction – CNRRS, The National Research and Development for Earth Physics Institute from Bucharest, The Studies and Designing Institute for Land Improvement – ISPIF from Bucharest, The Regional Centre for Prevention and Industrial Accidents Management from Cluj-Napoca, The Environment Research and Engineering Institute, etc.) contribute to elaboration of studies, normative and guides related to "disaster risk reduction" area.

In IT area that sustain disaster risk reduction measures, The IT Research Institute together with specialists from Civil Protection Command and Romanian Academy – Geographical Institute, made up a professional collaboration protocol (no.564/25.03.2002) further applied in different unwinding projects.

For putting into practice the management water national policy and strategy, the leading part is taken by Basin Committee, who assures main factors participation (public administration, private sector, NGO's) in taken decisions for achievement of draw-ups part, which are part of defence against floods and public information process regarding every aspect recommended for approval.

Local Risk Management

A natural hazard only becomes a disaster when it affects a population which is exposed and vulnerable (Van Western et al. 2006). The risk of natural disaster has increased worldwide in recent decades as a consequence of rapid population growth, urbanization and the expansion of human activities in unstable and hazardous areas (Corominas et al. 2003).

As a result, the last 10 years witnessed a significant evolution of scientific analyses and assessments of risk due to environmental change (Micu 2008). The occurrence and extent of natural risk depends on three basic variables: hazard (natural phenomena such as landslides), exposure (entities at risk) and vulnerability (Aleotti and Chowdhury 1999).

Landslides are frequently responsible for losses in the Prahova Subcarpathians sector, and the problem is becoming more alarming with the change in land use.

Any measure used to remedy the situation (correction of an existing landslide, prevention of a pending landslide etc.) must be based on the acceptance and cooperation of the local population. As a consequence, testing human perception and the capacity to cope with, resist to and recover from the impact of natural disaster is also a major task in disaster management research.

National Laws on Reduction and Prevention of Disasters

General Laws

- Governmental Urgency Ordinance no. 21/15.04.2004 regarding National System of Emergency Management;
- Law of civil protection no. 106/25.09.1996;
- Law no. 124/1995 of approval Governmental Ordinance no. 47 from 12 August 1994, regarding defense against disasters;
- Governmental Decision no. 209 from 19.05.1997 regarding approval of Organizational and Functioning Regulation of Governmental Commission for Defense Against Disasters;
- Governmental Decision no. 635 from 18.08.1995 regarding intelligence and decision transmitting of information for defense against disasters;
- Governmental Urgency Ordinance no. 179/26.10.2000 regarding passing of civil protection military units from MoD. to Ministry of Interior, and modification of civil protection law no. 106/1996, of Governmental

- Ordinance no. 47/1994 regarding defense against disasters and of Governmental Urgency Ordinance no. 14/2000 regarding constitution
- Law no. 448/18 July 2001 for approval of Governmental Urgency Ordinance no. 14 from 2000 regarding constitution of civil protection detachments for intervention in case of disasters;
- Governmental Urgency Ordinance no. 88/2001 regarding constitution, organization and functioning of the public communitarian services for emergencies, approved, by Law no.363/2002;
- Ordinance no. 88/2001 regarding constitution, organization and functioning of the public communitarian services for emergencies;
- Governmental Urgency Ordinance no. 63/2003 regarding organization and functioning of Ministry of Administration and Interior;
- Governmental Urgency Ordinance no. 64/2003 for establish of some measures regarding constitution, organization and reorganization or functioning of structures from government, ministries and other specialty organisms from central public administration and some public institution;
- Governmental Decision no. 725/2003 regarding organizational structure of Ministry of Administration and Interior;
- Decision 57 from 30.03.1998 Instructions regarding organization and logistics of civil protection inspectorates, commissions and detachments;
- Governmental Decision no. 371 from 1993 regarding giving of humanitarian relief to displaced population in case of emergencies; Governmental Decision no. 222 from 19.05.1997 regarding organization and conduct of evacuation of population;
- Law of environmental protection no. 137/1995 – republished in 17.02 2000;
- Governmental Urgency Ordinance 1 from 21 January 1999 regarding siege and emergency status regime;
- Decree no. 224/11 May 1990 for ratification of the additional protocols I and II to the Geneva Conventions, from 12 August 1949;
- Law 22 from 22.02.2001 regarding ratification of the Espoo Convention from 25.02.1991 – evaluation of the impact on environment in the trans-boundary context;
- Law 153 from 11 October 1999 regarding approval of the Governmental Ordinance no.8/1999 for ratification of the Agreement between governs of the states participating to the Economical Cooperation of Black Sea for collaboration in intervention and emergency response in case of natural or man-made disasters, signed to Soci on 15 April 1998;
- Law 61 from 24 April 2000 Agreement between North Atlantic Treaty states and the other states participating to Partnership for Peace regarding status of their forces, signed to Bruxelles on 19 June 1995;

Laws Regarding Natural Disaster

- Governmental Decision no. 447 from 10 April 2003 for approval of the methodological norms regarding elaboration mode and content of the floods and landslides risk maps;
- Law no. 381 from 13 June 2002 regarding giving of compensations in case of natural calamities in agriculture;
- Governmental Decision no. 1036 from 18 October 2001 for approval of the Protocol between Ministry of Interior from Romania and FEMA/USA regarding cooperation for prevention and intervention in natural or technological emergencies, signed at Bucharest on 22 January 2001;
- Law no. 575 from 22.10.2001 regarding approval of national territory arrange plan;
- Governmental Ordinance regarding reduction of the seismic risk of the existing buildings, no. 20/1994, last revue 1999 and Application Methodology;
- Governmental Decision no. 638 from 5 August 1999 regarding approval of the Regulation for defense against floods, dangerous meteorological phenomena and of the accidents to the dams and of the frame norm on endowment with materials and means for defense against floods and water ice;
- Common Order of the Govern General Secretary and Ministry of Public Works and Arrange of the Territory no. 770/26.09.1997 and no. 6173/NN/26.09.1997 regarding stocktaking of the existent building status;
- Governmental Decision no. 210 from 10 May 1997 regarding approval of the Regulation on organization and functioning of the central commission for defense against floods, dangerous meteorological phenomena and of the accidents to the dams;
- Law no. 107/1996 – Law of waters;
- Governmental Decision no. 438/1996, regarding approval of the Regulation on organization and functioning of the central commission for prevention and defense against seismic effects and landslides;
- Law no. 10/1995 regarding quality in building;
- Governmental Decision no. 486/1993 regarding rising of the exploitation safety of the buildings and installations which represent a risk source;
- Law no. 75 from 14 December 1991 regarding sanitary – vet Law;

- Governmental Decision no. 1364/2001 for application of the Governmental Ordinance regarding reduction of the seismic risk of the existing buildings, no. 20/1994, last revue 1999;
- Governmental Decision no. 372/2004 for approval of the National Program for Seismic Risk Management;
- Governmental Decision no. 382/2003 for approval of the methodological norms regarding minimal demanding in content for territory arrange and urbanism documentation for natural risk areas.

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Landslide Risk and Mitigation Policies in Campania Region (Italy)

Italo Giulivo, Fiorella Galluccio, Fabio Matano, Lucia Monti, and Carlo Terranova

Abstract

The paper describes policies and procedures by which Campania Region (Italy) manages the severe landslide risk which affects its territory. The Campania Region has developed a complex strategy built on the integration of structural and non-structural measures for the mitigation of landslide risk. During 1989–2011 years about 755 millions euro have been funded in structural actions to restore landslide damages and mitigate landslide risk in Campania Region territory. In 2007–2013 years about 374 millions euro are available for structural and non-structural actions, despite of an overall need of over 2.7 billion euro for interventions to mitigate hydraulic and landslide instabilities in Campania as showed by the planning schemes developed by the River Basin Authorities. Given this condition, the knowledge of the real distribution of landslide phenomena and risks is a crucial point and represents a major goal that can be achieved also by using new technologies (spatial database, web-GIS and remote sensing) of monitoring and data management. Non-structural measures such as several study project on landslides highly improved the knowledge of landslide distribution, activity and geology. The SISTEMA Project aims to develop and systematize specific acquisition procedures, treatment and consultation of remote sensing data to support regional decision-making system on the prevention of natural hazards.

Keywords

Landslide risk • Mitigation policies • Campania • Italy

Introduction

The “hydrogeological instability”, as defined by the National law DL 152/2006, is “the condition that characterizes areas where both natural and anthropogenic processes, related to slope, soil and water bodies, determine hazardous conditions on the territory”.

In Campania region (southern Italy) areas characterized by hydrogeological instability processes are widespread due to various combination of phenomena as well as slump, sliding, debris avalanches, earth or mud flows, mass transport along alluvial fans in mountainous and hilly areas, hyper-concentrated flows, flooding and subsidence in plains.

Exposure to geological and hydraulic risks is an issue of great social importance, both for the number of casualties,

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deaths and injuries, and for damage to buildings, industries, transport infrastructure and areas of high economic value. In addition, the landslide risk in Campania has been strongly influenced by continuous changes of land-use that increase the probability of occurrence of negative phenomena. Dismission of agricultural land in mountain areas, deforestation by wild fires (D'Argenio et al. 2008), uncontrolled groundwater exploitation, urban expansion with soil sealing, illegal building and waste dumping in the river beds are the main contributing factors for increasing of hydrogeological instability in the region. Moreover, an heavy and disordered development of the urban areas, even in landslide-prone or landslide-affected sectors, make the Campania Region one of the European areas with higher landslides risks and related costs.

The paper aims to describe policies, analyses and procedures by which Campania Region manages this severe landslide risk.

Landslide Phenomena and Related Risk in Campania

The Campania Region territory extends 13,580 km^2 and presents several predisposing factors to landslides due to a complex geological setting, such as the cropping out of pelitic and complex geological units, strongly deformed by tectonics, or the presence of pyroclastic deposits above carbonate units, the recent tectonic uplifting causing deepening of valley and steep slopes, seismic and volcanic activities. There developed wide urbanized areas with a dense network of major infrastructures (railways, highways, roads, etc.) and broad areas of high natural, historic and artistic value are present giving very high values exposed to landslide phenomena.

The territory has been affected by a great number of landslide (23,430 after IFFI Project, Table 1), directly involving about 973 km^2 (Fig. 1) equal to about 7 % of the total territory (Monti et al. 2007), and by several critical areas of active ground deformation due to volcanic, seismotectonic and anthropogenic processes (Vilardo et al. 2009).

Broad, frequently reactivated by earthquakes, earth flows or complex slide-flows, having volumes up to 10^7 m^3 of deposits, are present in the eastern and southern sectors of the region, where affect cities and/or important infrastructures (e.g. Senerchia, Calitri and Montaguto flows).

Several rapid landslides occurred in Campania in the last 60 years causing 559 fatalities (Table 2), a greater number of injured and incalculable costs for damages.

About 29 % of the regional territory is exposed to the landslide risk as defined by the Basin Authorities (National Law 183/1989), which regulates the land-use within the

Table 1 Landslide type distribution in the IFFI database

Type	Number	Percentage (%)
Falls – Topples	907	4.17
Rotational – Translational slides	4.719	21.71
Slow flows	8.636	39.73
Rapid flows	3.637	16.73
Complex landslides	3.245	14.93
Other types	593	2.73

areas at landslide risk. On the whole, areas extending 3,995 km^2 are mapped with different grades from moderate (R1) to very high (R4) landslide risk. An aggregate area extending 2,136 km^2 is characterized by high to very high hazard or susceptibility (rating P3/A3 to P4/A4) or by high to very high risk (rating R3 to R4) to landslide phenomena (Fig. 2). These areas are considered as critical situations with regard to the landslide risk and have a priority in the appropriation for mitigation structural actions.

The Regional Approach to Landslide Risk Mitigation Policy

A suitable landslide risk mitigation policy should be based both on prevention planning and efficient investments of available funds.

The hydro-geological risk prevention includes activities to avoid or minimize the possible damage occurrence due to hydro-geological events. In general, there are two possible prevention strategies for risk mitigation:

(a) ***Structural measures*** to reduce hazard and vulnerability, which generally involve engineering works or infrastructure reinforcements having high cost and very local effects;
(b) **Non-structural measures** to reduce potential damage, such as evacuation plans, land use monitoring, early warning and alarm systems, restrictions on natural resources exploitation, territorial protection and warning facilities, etc., having greater flexibility and relatively lower cost.

The mitigation of landslide risk in Campania region can not be based only on "structural" actions because financial resources are limited in relation to the large extension of the territory affected by hydrogeological instability. Therefore non-structural measures are necessary to ensure proper land use planning and control of urban expansion avoiding the exploitation of landslide hazardous areas for new residential settlements, infrastructures and industrial plants.

This approach is strongly encouraged by the Regional Law n. 16/2004, providing that the Local Authorities in charge of the government of the territory in terms of development and protection must take into account both

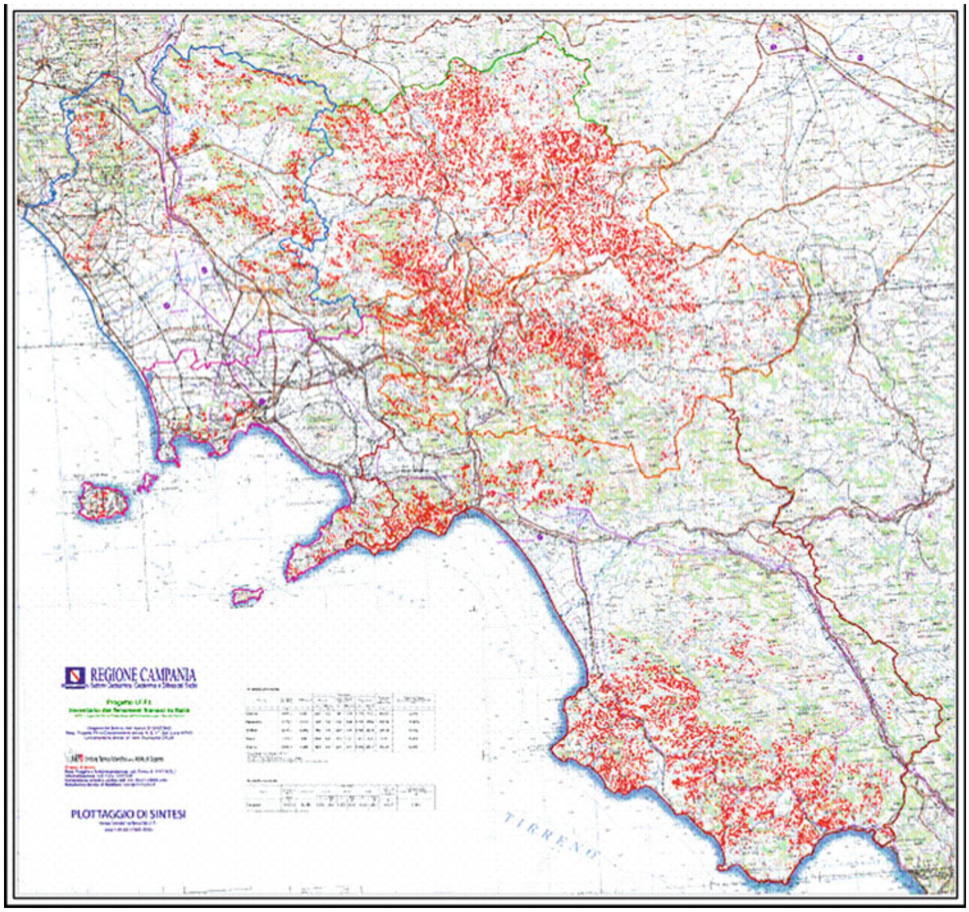

Fig. 1 Landslide inventory map of Regione Campania by IFFI Project

existing hydrogeological instability and strategic directions, identified by the Regional Territorial Plan, approved with the Regional Law n. 13/2008.

Non Structural Actions for Monitoring Landslide Risk and Planning Mitigation Measures

Non-structural measures correspond both to the enactment of regional laws and regulations and to the development of territorial studies and research project in order to upgrade the scientific level of the landslide and geologic database used as base knowledge to landslide risk-oriented territorial planning and management.

Referring to the first item, within the Campania Regional Territorial Plan (Regional Law No. 13, Oct.13, 2008) both geologic map than landslide inventory and landslide susceptibility maps have been considered as reference layers in the regional territory planning, whose main purposes are the protection of landscape and environmental resources, physical integrity and cultural identity of the regional territory and the protection of security of human settlements from the hydrogeological risks.

A proper landslide mitigation risk policy is based on a deep and upgraded knowledge of the spatial distribution, state of activity and type of landslides so as to support decision makers in land use planning and allow a correct planning.

The Campania Region has partly funded and developed several technical and scientific projects of geological study and analysis of its territory with both European and national financial support.

The **CARG Project** involved in National Geological Map production at 1:50,000 scale provides upgraded geological, tectonic and morphological data, also in a digital INSPIRE compliant database (ISPRA-Servizio Geologico Nazionale 2010). The new 1:50,000 geological map represents a valuable tool for knowledge and valorization of the territory and its resources, and has also enabled more appropriate territorial planning intended to mitigate natural risks, first and foremost hydrogeological risks.

The **IFFI project** (Inventory of Landslide Phenomena in Italy), carried out by ISPRA and the Italian Regions, supplies a detailed picture of the distribution of landslide phenomena. The main product produced by the IFFI project is an online cartography service (ISPRA-Servizio Geologico Nazionale 2006), where it's possible to visualize landslide

Table 2 Rapid (fall and flow) landslides major events with fatalities in Campania in the last 60 years (Data by Cascini et al. 1998 and Campania region landslide database)

Year/Date	Municipality (Locality)	Fatalities
1954, 26 Oct.	Cava dei Tirreni, Maiori, Minori, Salerno, Tramonti, Vietri	316
1955, 4 Feb.	San Sebastiano al Vesuvio	1
1956, 1 Feb.	Vietri	2
1963, 17 Feb.	Pimonte	4
1963, 27 Feb.	Cava dei Tirreni	5
1966	Giffoni Sei Casali	2
1966, 21 Nov.	Napoli (Colli Aminei)	3
1966, 23 Nov.	Vico Equense (Scrajo)	3
1968, 9 Jan.	Sarno	1
1970, 8 Apr.	Salerno	2
1971, 2 Jan.	Gragnano	6
1972, 6 Mar.	Angri, Pagani	1
1973, 16 Feb.	Massa Lubrense (Mitigliano, Monte San Costanzo)	10
1974, 21 Feb.	Capri (Marina Grande)	2
1976, 19 Oct.	Torre del Greco	1
1978, 3 Jun.	Barano d'Ischia (spiaggia Maronti)	5
1982, Jul.	Castellammare (Pozzano), Pagani	2
1985, 31 Oct.	Ercolano	1
1986, 22 Feb.	Palma Campania	8
1987, Mar.	Casamicciola Terme	1
1994, 26 May	Sarno	1
1997, 10 Jan.	Castellammare (Pozzano)	4
1997, 1 Nov.	Lauro	1
1993, 20 Aug.	Serino, Solofra	2
1998, 5 May	Bracigliano, Quindici, Sarno, San Felice a Cancello, Siano	160
1999, 16 Dec.	Cervinara, San Martino Valle Caudina	4
2005, 4 Mar.	Nocera inferiore	3
2006, 30 Apr.	Ischia (Monte li Vezzi)	4
2009, 10 Nov.	Casamicciola	1
2010, 2 Jan.	Atrani	1
2010, 9 Sept.	Atrani	2

bodies and query the main parameters involved, and the Report on landslides in Italy, which supplies a summary of data on landslides on both regional (Monti et al. 2007) and national scale.

At a regional scale, the **GECAI Project** (Geologia dei Centri Abitati Instabili) provides geological and landslide map at 1:5,000 scale of 189 selected critical cities, from ERDF based National Operative Project of Technical Assistance for less prosperous European regions (Objective 1) (Regione Campania – Podis 2005). The result of GECAI project is the availability of digital data, organized in a GIS environment, about geological (CARG standard) and landslide (IFFI standard) conditions in densely populated settlements.

The **TELLUS Project**, a high complexity project developed in the framework of Progetto Operativo Difesa Suolo PODIS PON ATAS 2000–2006 and carried out in cooperation with the Italian Ministry of the Environment, provided optical and radar satellite observation of regional territory starting from 1992 to 2008 and their processing and analyses (Terranova et al. 2008).

The TELLUS Project used a point target differential interferometric (PSinSAR) approach for landslide and subsidence monitoring at regional scale, coupled with the interpretation of optical satellite images, aerial orthophoto, traditional in situ monitoring and geological and geomorphological field surveys. The Permanent Scatterers technique – PSinSAR™ (Ferretti et al. 2001) is a powerful and fully operational tool for monitoring ground deformations on a high spatial density grid of point-wise targets.

Several radar images from European satellites ERS 1 and ERS 2, from 1992 to 2001, were initially applied by means of PS-InSAR™ technique over the 180 city and village targets of GECAI Project, and then extended to entire Campania region integrating the dataset with RADARSAT 1 images SAR, from 2003 to 2007.

The processing of optical satellite and aerial images has been useful for the extraction of features related to the

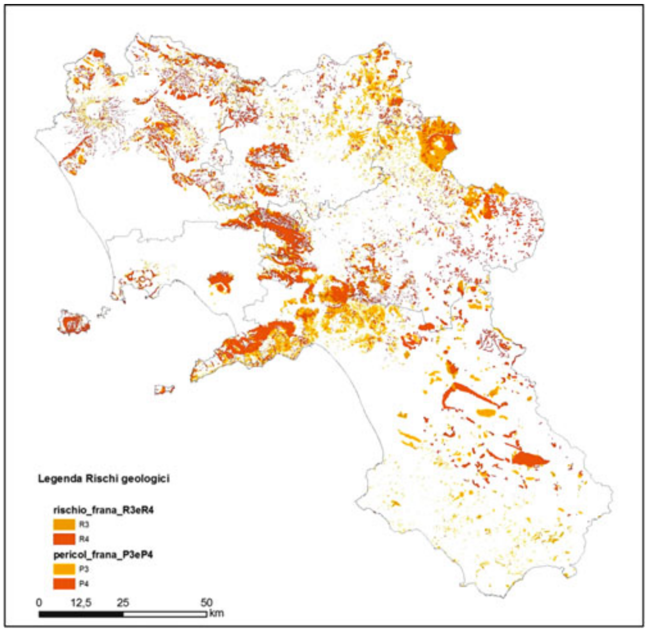

Fig. 2 Map of the critical areas to landslide hazard or risk in Campania region territory

landslides presence or susceptibility while radar data provided their time evolution, giving a spatial meaning of local point target information from PS (Matano et al. 2008). The PS analysis has been coupled with geological study and results achieved by the previous GECAI Project.

The satellite radar processing was applied both as support for regional ground deformation analyses, landslide inventory mapping and for the monitoring of single slope movements (Terranova et al. 2008) as well as volcanic, tectonic and anthropogenic subsidence (Vilardo et al. 2009), sinkholes (Calcaterra et al. 2010) and faults reactivation in active volcanic areas (Vilardo et al. 2010).

All data were stored and organized in a Geographic Information System and made available through thematic Web-Gis into the Regional Soil Defense Sector web page (www.regione.campania.difesa.suolo.it).

The main benefits of PS analysis relate to a better definition of boundaries of already detected mass movements or of their state of activity, and to the detection of previously unknown unstable areas. In particular, PS analysis has been used to obtain a better definition of the landslide spatial distribution and assessment of landslide state of activity of landslide inventory maps available for the Campania territory, such as IFFI and GECAI, at least where a few strong reflectors are available within the landslide body.

As a matter of fact, to assess the landslide state of activity can be problematic, as many difficulties are present for detecting dormant landslides mostly covered by vegetation and characterized by topographic features not clearly related to slope instabilities. In this case, the relationship between PS velocities and the state of activity of the mapped landslide, as recognized in the field, is not linear. As a matter of fact several dormant landslides present high values of PS velocity in both orbits.

These data, implemented in a GIS environment, have been used to integrate and update the current regional landslide inventory map, which is a fundamental step in the evaluation of the related hazard. This approach makes it possible, where PS are available, to identify, within landslide areas, zones with different type and/or amount of deformation, to detect unknown unstable sectors in the urban areas, and to determine the landslide state of activity.

Further Developmente of Non-structural Actions for Regional Scale Monitoring of Landslide Risk

The SISTEMA Project, approved by Regional Government on November 2009, represents a 3-years extension of TELLUS Project.

SISTEMA is a project designed as an inter-Sector and non-structural action developed in the context of Campania Region Operative Plan ERDF 2007–2013.

The project goal is to support, through both satellite and aerial remote sensing techniques and ancillary data, the activities of regional technical branches involved in mitigation of natural and man induced risks (Soil Defence Sector, Regional Geological Service and Civil Protection Sector).

The development of SISTEMA will enhance the knowledge about hazardous geo-environmental phenomena for homeland security and for the exposed economic resources in Campania. The strategic objectives are:

1. Development and application of satellite and aerial monitoring activities on areas with high exposure to geological and geomorphological risks (landslides, natural and induced subsidence, floods, earthquakes, volcanic activity) finalizing these activities to the precise identification of the existing risks and to the evaluation of possible preventive measures, as well as early detection of misuse of land resources (e.g. illegal buildings on landslide bodies, unauthorized works on rivers and shorelines, etc.) which may increase risk for the resident population. (Operational Objective 1.5 of Campania Region Operative Plan ERDF 2007–2013 "*Safety of the territories which are exposed to natural hazards*");
2. Contributing to the strengthening of the multi-hazard functional Center of Regional Civil Protection through the development of specific satellite and aerial remote sensing applications for damage prevention and possible precursors prediction, increasing the safety levels of most exposed infrastructures and settlements to natural risks (Operational Objective 1.6 of Campania Region

Operative Plan ERDF 2007–2013; "*Prevention of natural and anthropic risks*")

3. Exploration the use of a multi-parameter approach, using the contribution of radar remote sensing techniques (DinSAR, PSinSAR and CRinSAR) for monitoring and evaluation of the static conditions of main public buildings and strategic transport infrastructure (main roads, viaducts and bridges) exposed to earthquake shaking as well as seismo-volcanic tremors (Operational objective 1.7 of Campania Region Operative Plan ERDF 2007–2013 "*Security of public buildings*");

The three main actions of the SISTEMA Project are:

(a) Planning and implementation of a Remote Sensing Program for the acquisition of optical and radar images over the whole Campania region from satellite operational missions and flight missions implementation with advanced airborne digital sensors (LiDAR, Multi- and Hyper-spectral cameras, Thermal IR scanner) only over critical areas.
(b) Development of a centralized ICT infrastructure, consisting of technological and human resources with appropriate Sw and Hw tools for processing and analysis of optical and radar data, dedicated to pre-processing of remotely sensed data and integration with ancillary data, such as geological, vegetation, human activities informations (often called "ground truth") as well as to the dissemination of information to local authorities and citizens.
(c) Development of a distributed ICT infrastructure located at the three regional technical branches premises (Soil Defence Sector, Regional Geological Service Civil and Protection Sector) connected to the previous centralized ICT infrastructure, but with an independent processing competency as direct support to specific ERDF 2007–2013 Operational objectives 1.5, 1.6 and 1.7.

The results achieved by the implementation of remote sensing monitoring actions are able to improve the planning and design of structural works required for reducing existing landslide risk factors and increasing the safety levels of most vulnerable infrastructure and settlements in the region.

The SISTEMA Project is compliant to the national and European policy on scientific research and technological development since the implementation of planned action guarantees for the next years a technological and methodological tool for understanding the fundamental processes related to climate change and environmental sustainability.

Moreover the project has a high degree of consistency with the latest policies of encouraging innovation and sustainable development, declined from Lisbon and Gothenburg strategy, promoting the knowledge economy through the development of technological innovation.

The knowledge economy, especially in Campania Region context, is an indispensable driving force for regional development and an essential tool for face up the complex environmental issues as the management and prevention of natural disasters produced by landslide and flooding phenomena.

The SISTEMA objectives are closely related to the resolutions of the Council of Europe on sustainable development and global governance as required by the GMES Program (Global Monitoring for Environment and Security) which aims to establish in the European countries an independent capability for monitoring the environment and increasing security of both citizens and economic resources.

Structural Action for Risk Mitigation

The structural works for landslide risk mitigation and restoration have a cost that have to be paid entirely by the State, according to art. 25 of Law No. 183/89 and to art. 58 Legislative Decree no. 152/06. The corresponding activities of funding that concerned the Campania region territory modified during the last two decades. The State financing progressively changed by an "ordinary" type to an "extraordinary" type (Table 3).

The State ordinary financing of Soil Defense actions and works has been planned after Law 183/1989 till year 2001, when the last fund allocation was made with the DPR 331/2001. The State extraordinary financing, usually following up the occurrence of a great landslide event, have started after the Decree Law 180/98 (Decree Sarno) converted into Law 267/1998, and subsequently after the Article 16 of the Law No. 179/2002. This law provides for financing after the definition and activation of emergency programs with reference to the areas for which the state of emergency is declared, under Article 5, paragraph 1, of Law 225/1992.

The Campania region – particularly hit by adverse weather conditions and landslides – since 1999, has provided additional funds to finance their "urgent" measures on the territory for a total of about 20 million euro (Table 3).

Since 2002, EU POR funds 2000–2006 and APQ national funds (Framework Program Agreements) represented, in fact, the only resources available for the Campania Region to continue the policy of elimination/reduction of hydrogeological hazard situations in its territory.

The APQ – Framework Program Agreement, started in 2005, defined a complex planning operation, which identified and implemented programs of common interest between the Italian State and the Campania Region. In the APQ context, a special study commission identified 220 strategic actions, for a total of about 1.55 billion euro,

Table 3 Financings for mitigation of landslide risk in Campania Region

Financing	Years	Amount
State ordinary funds (national law L. 183/89)	1989–2001	187,283,000.00
State extraordinary funds (national laws D.L. 180/98, L. 267/1998, art.16 L. 179/2002	1998–2006	79,930,000.00
State (ordinary + extraordinary) funds	1989–2006	267,213,000.00
MATTM funds	1999–2008	73,511,881.45
Regional funds	1999–2004	19,998,715.35
POR 2000–2006 (Misura 1.5) funds	2002–2008	131,379,855.85
APQ Difesa Suolo + I e II Atto integrativo funds	2005–2011	283,950,028.09
Total spent or committed funds	**1989–2011**	**755,877,168.92**
POR 2007–2013 funds	2007–2013	153,682,006.92
Extraordinary plan for high hydraulic and geologic risk (Legge Finanziaria 2010)	2011	220,000,000.00
Total provided or committed funds	**2007–2013**	**373,682,006.92**

Table 4 APQ funds strategic distribution

Type of action/measurement	Amount
Mitigation of landslide risk with reference to towns and infrastructures	115,228,000.00
Risk reducing of flooding in large river systems	36,000,000.00
Coastal protection and beach nourishment	58,300,000.00
Hydrogeological protection in large urban areas	56,700,000.00
Studies, investigations and surveys	1,000,000.00

among these, 87 were identified as priorities (laws D.G.R. n. 1001/2005 and D.G.R. n. 706/2007) shared as in Table 4.

The only official result index of the effectiveness of funds employment for mitigation of landslide risk is published in the POR Campania 2000–2006 Performance Final Report (REF). Despite of allocation of 268 million euro for interventions to mitigate hydraulic and landslide risk in Campania by POR 2000–2006 funds, the mitigation became effective for 24 km^2 equal to 1.5 % of the regional territory with critical situations with regard to the landslide risk.

Discussion and Conclusive Remarks

Landslides cause very negative economic and social impacts in the regional territory. The planning schemes developed by the River Basin Authorities (National Law 183/1989) show an overall need of over 2.7 billion euro for interventions to mitigate hydraulic and landslide instabilities in Campania, with reference to the risk conditions dated to years 2001–2007. Anyway, in confirmation of this financial requirement extent to mitigate landslide risk, municipalities and other local authority belonging to Campania Region territory required in 2003 year an aggregate sum of 1.08 billion euro (Invitation to Bid of Measure 1.5 – POR Campania 2000–2006) for stabilization and mitigation works to be made only with reference to high to very high landslide risk and hazard areas. Besides, a special study commission of the Framework Program Agreements (APQ) identified 220 strategic actions for a total of about 1.55 billion euro in 2005.

The Campania Region has to face a problem of mitigation of landslide risk both geographically widespread and important in terms of financial resources. So a complex strategy built on the integration of structural and non-structural measures for the mitigation of landslide risk has been developed, also taking into account the limited financial resources available.

During 1990–2011 about 755 millions euro (Table 3) have been funded in structural actions to restore landslide damages and mitigate landslide risk in Campania Region territory. But very large efforts have been made for upgrading the knowledge framework with the involvement in national and regional study and research projects, such as CARG, IFFI, GECAI, TELLUS projects, which highly improved the knowledge of landslide distribution, activity and geology.

The knowledge of the real distribution of landslide phenomena and risks and the dissemination of these informations and data to Local Authorities and technicians (engineers, geologists, etc.) are considered a crucial point in the landslide risk mitigation regional policies. The use of new technologies, such as spatial database, remote sensing and open web-GIS, are highly considered and applied in this approach to handle the landslide problem in Campania territory and merge in the SISTEMA Project, which aims to develop and systematize specific acquisition procedures, treatment and consultation of remote sensing data to support regional decision-making system on the prevention of natural hazards.

Following the described strategy of integration of structural and non-structural measures for the mitigation of landslide risk, the Campania Region has allocated from 2007 to 2013 funds (Table 3) further 374 million euro for structural and non-structural actions in the areas exposed to very critical landslide. Given the scarcity of available financial resources, it is necessary to identify the real priorities between different needs in the territory and the various critical issues therein.

The knowledge framework about all aspects related to landslide risk mitigation is the basic tool for the risk prevention and territorial and urban planning. The implementation of new regional legislation (i.e. Regional Territorial Plan; Regional Law 13/2008) must result in the updating of the urban development plans and a new awareness of technicians and local authorities.

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NEMETON: Decision Support System for Rockfall and Rock Slide Hazard Mitigation

Jan Klimeš, Stanislav Štábl, Josef Stemberk, and Dušan Dufka

Abstract

Rockfalls and rock slides belong among the most dangerous slope processes since even small magnitude events involving single boulders may cause high damage to infrastructure or may lead to serious injuries or even fatalities. In the environment of the Czech Republic or other Middle European countries, this phenomenon is often highly localized, involving single rock slopes. Solving such a problem usually requires direct involvement of local authorities, where are rarely found people with experiences in solving rock slope stability problems. This fact along with high costs of almost any structural mitigation measures possibly applied on rock slopes makes mitigation process subject to many political and economic interests which not always result in the most effective slope stability solution. In such situations, the NEMETON decision support system should offer help and guide through the whole process of rock slope hazard mitigation. It is designed to provide complete information to three groups of involved actors. The first are investors (e.g. local authorities, private companies), second are civil engineers and designers responsible for finding and designing specific technical solution of the slope stability problem and the last group are construction companies, whose precise work affects directly the quality of the mitigation structures.

Keywords

Rockfall • Mitigation measures • Decision support system • Czech Republic

Introduction

Landslides (rock slides and rockfalls) on rock slopes occur every year in the Czech Republic, causing damages and transportation interruption. Some of the rock slopes are monitored and investigated for years (Záruba 1939) looking for the effective mitigation measures to ensure roads operation. In other places (e.g. city of Hřensko, North Bohemia, Fig. 1), manual or permanent monitoring has been set up since the potential rockfalls threaten inhabited houses and important international road to Germany (Zvelebil et al. 2005, 2008). For example, in October 2009 rockfall with accumulation of volume of the 9 m^3 blocked the main road to Germany for several days.

Magnitude of the rock slides and rockfalls in the Czech Republic, ranges from as little as few stones up to 2,700 m^3 (Zvelebil 1989) of rock damaging more than 100 m of the international road and partly blocking the main river watercourse. The volume and kinetic energy of the involved material is important assessing potential damage to the buildings and transportation infrastructure. Nevertheless, with respect to the potential human injuries even the smallest

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Fig. 1 Monitoring of the rock movement of the sandstone tower near the city of Děčín, Czech Republic. The photo shows also elements endangered by possible rock fall – road and parking lot (Photo by Strix Chomutov, a.s.)

events (involving single boulders) may cause fatalities. Example of such an unfortunate event is the case of young woman killed in car by single boulder fall on the road in 2007 in the Slovak Republic. The boulder has size of approximately 0.3 m.

Due to the economic situation, there has been observed increasing pressure from investors to minimize necessary expenses on the slope stability measures. One possible way how to find the most effective technical solution is to compare variety of possible mitigation technologies. It is intrinsically difficult task due to large number of independent technology producers and large number of technical specifications of their products. The theoretical economic efficiency of mitigation solutions combining different technologies in comparison to one typical but costly technology showed Štábl et al. (2011). They concluded that combination of technologies is capable of saving about 75 % of the costs when maintaining similar safety level as the traditional solution using one technology.

Mitigation of landslide hazard originating on rock slopes is also difficult due to involvement of variety of stake holders into the whole process. They include official authorities ranging from community administration to highway and railway authorities, as well as citizens and private companies interested in developing areas in landslide prone regions. Also due to this, the process of detailed engineering-geological investigations, planning the mitigation measures and the final project design lack of common guidelines of “the best practice” solutions. Thus in many cases inadequate and costly structural measures are proposed to mitigate rock slide or rockfall of low to intermediate hazard while in others, improper and ineffective mitigation measures are performed to secure highly dangerous landslides. Design companies without adequate experiences in the slope stability solutions are due to economic reasons force to accept such a type of work and their resulting plans may include outdated mitigation technologies applied without proper geological understanding of the problem. Application of “the best practice” solutions is further limited due to involvement of large number of people of different education and expertise who are involved in the process of preparation, design and construction of mitigation measures. The proposed decision support system provides highly professional, reliable and accurate guidance appropriate to all involved stake holders.

Main Features of the NEMETON Decision Support System

The aim of the NEMETON decision support system is to provide “the best practice” approach guidelines for rock slope hazard mitigation in all aspects of the problem solution. Those aspects include engineering-geological site investigation and hazard assessment, related legal and environmental issues, technology specifications as well as economic issues. These aspects are addressed from the point of view of the investors, designers of the mitigation measures and construction companies. Wide range of experts has been gathered to fulfill these tasks including representatives of civil engineers, designers, technology producers and construction companies which are otherwise competing on the market. Resulting decision support system will be freely available on the internet providing step by step guidance to the three different groups of end users involved in the rock slope stability solution.

Due to the complex nature of the solved problem, the decision support system includes partly independent modules with prepare results for three main end user groups. The first group are investors, namely officials, private companies and persons who have to solve rock slope stability problem on their properties. End users of this group may deal with rock slope stability problem for the first time (e.g. representatives of local governments) or may have extensive experiences in securing the rock slopes like highway and railroad managements who are solving the slope stability problems every year.

The system will simplify administrative tasks related with all legal, financial and administrative requirements related to the landslide mitigation. Moreover, preliminary assessment of the landslide hazard and list of suggested future steps will be provided by the decision support system after describing the basic characteristics of the slope stability problem. Three input forms were compiled to gather basic information necessary for further problem solution (Table 1). Thus the investor will have from the very beginning available relevant and accurate information about the proper principles of the problem solution. Further, based on more specific information, detailed list of necessary geotechnical works, legal

Table 1 Preliminary input forms used to collect basic information needed for the further processing of the NEMETON decision support system. Left column lists the main characteristics; right column specifies possible answers

Description of the event	
What happened?	Short text
Type of slope failure	Rockfall, rock slide, toppling
Size of moved material	Tennis, football or gymnastic ball, table, car
Shape of the mobilized rock blocks	Irregular, quadratic, spherical, flat shape
Description of slope failure accumulation	Short text
Height of the rock slope	In [m]
Dip of the rock slope	Selection from pup up menu
Length and dip of the slope bellow rock wall	In [m]
Did similar event occur before?	Short text
Description of destroyed, damaged and endangered objects	Short text
Basic geotechnical description of the slope	
Description of the artificial slope	Quarry, cut slope
Type of the material	Hard rock, soft rock, soils, combination
Rock type	Selection refined based on the general rock stability zones
Water action on the rock slope	Erosion, streams, springs
Fissures on the rock slope	Density of fissures, attitude of fissures and slope, fissure characteristics
Conditions affecting construction works	
Previous mitigation works?	Yes/no – description
Vegetation conditions on rock slope	Vegetation density, type of vegetation
Vegetation conditions on slope below the rock slope	Vegetation density, type of vegetation
Spatial relation to the protected areas	Short text
Ownership	Short text
Character of the construction works	Emergency works, mitigation works
Life time of constructions	Short text
Acceptable risk	Short text
Accessibility	Short text
Existing available geotechnical information	List of reports

steps and price comparison of the possible mitigation solutions will be available.

Second module is dedicated to the designers of the mitigation measures, who will get the guidelines regarding requirements of the necessary geotechnical site investigations and suggestions of appropriate mitigation technologies for the specific cases. This information includes list of recommended mitigation technologies (ranked according the degree of their applicability), technological specifications, price indications and legal and environmental issues related to selected mitigation technologies. To provide this information, detailed database with more than 160 case studies describing technologies already applied to stabilize rock slopes was compiled. The database specifies also basic geotechnical and socioeconomic conditions of the mitigation project. All the cases were evaluated by independent experts to assess their reliability and relevancy. Moreover, technological options which have not been used in the Czech Republic are being included into the decision support system. All these technologies will be ranked based on expert knowledge according their usability for certain types of rock slope stability solutions. Each technology will be also described in detail with respect to the technical norms and environmental issues. The system will then facilitate easy way to compare wide range of landslide mitigation solutions. This will ideally lower the costs of the works and increase the quality of the landslide hazard mitigation.

Construction companies are the last, but not the least group of the involved actors. Their performance directly affects functionality of proposed technological solutions and thus the effective reduction of landslide hazard. The NEMETON system will provide the companies with complex information about technological requirements of the performed mitigation measures and related legal aspects including work safety procedures and environmental issues. The provided results will contain not only guidelines and references to necessary legal norms, but also final documentation required by the majority of the investors. Such outcomes will largely reduce costs of the construction companies and increase quality of the performed works.

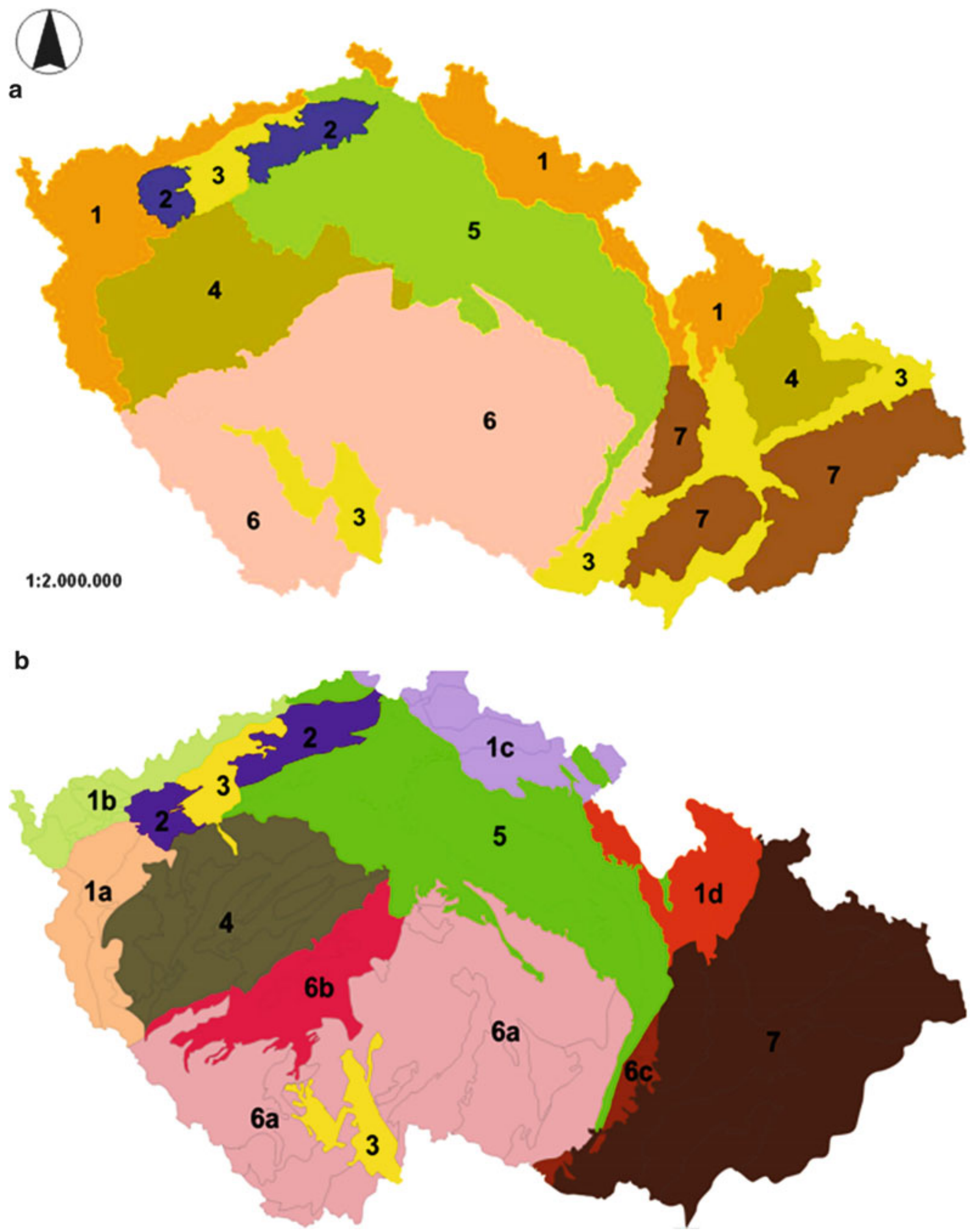

Fig. 2 Zones defined with respect to the main geological conditions affecting the rock slope stability in the Czech Republic. *1* – highly metamorphosed rocks of mountains, *2* – the Tertiary volcanic rocks of highlands, *3* – sedimentary rocks of the Tertiary basins on low land, *4* – low metamorphosed and sedimentary rocks of highlands, *5* – sedimentary rocks of the Cretaceous age of hilly land (massive sandstones, claystones), *6* – magmatic and paleovolcanic rocks of highlands, *7* – sedimentary rocks (mainly flysch rocks)

Spatial Distribution of Rock Slides and Rock Falls in the Czech Republic

The rock slide and rockfall occurrence in the Czech Republic is constrained to slopes where the base rocks are reaching near the surface or are outcropping on their surface. Favorable geological conditions for such a slope settings are restricted to several geological units within the territory of the Czech Republic. On the other hand, human activity related to road and rail constructions (e.g. slope undercutting) may prepare highly susceptible areas for rock slides and rockfalls also in other parts of the Czech Republic.

For the use of the decision support system, the area of the Czech Republic was divided with respect to rock slides and rockfalls occurrence into semi-homogenous zones based on the main rock type and morphology (Fig. 2a). These regions were further subdivided or generalized based on frequency and type of landslide occurrence. These very general zones are considered to be homogenous with respect to the main geological and geotechnical conditions affecting slope stability and most frequent type and magnitude of rock slides and rockfalls (Fig. 2b). They were defined by expert knowledge. These zones are used in the decision support system to limit possible answers by the system users regarding rock type and their geotechnical characteristics.

Historical rockfall inventory (Špůrek 1972) indicates that the most susceptible areas for rockfall occurrence are sedimentary and magmatic rocks of highlands (4 on Fig. 2b) and sedimentary rocks of the Cretaceous age of hilly land (5 on Fig. 2b). The first region is typical by highly fractured sedimentary and magmatic rocks where fractures define possible sliding and detachment planes. Slopes susceptible to rock slides and rock falls evolve usually along deeply incised river valleys. The later region is formed by massive sandstones under laid mostly by clay stone strata. The rockfalls and rock slides occur on often nearly vertical rock faces of the sandstones forming deep canons and rock towns.

Concluding Remarks

The decision support system integrates knowledge and experience from variety of fields to provide comprehensive, up to date information and guidance for the rock slope stability solutions. It aims on geologic professionals, civil engineers and stake holders who needs to cooperate to prepare safe and cost effective slope stability solution.

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Identifying Needs and Areas for Future Landslide Hazard Mapping in Norway

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Abstract

The Norwegian Water Resources and Energy Directorate (NVE) in collaboration with the Norwegian Geological Survey (NGU) has worked to produce a national mapping plan to identify future needs and priorities for landslide and snow avalanche susceptibility and hazard mapping in Norway. Preliminary results are herein presented. The plan will help the national and local authorities to direct efforts and economical resources for the realization of future hazard maps.

Keywords

Hazard maps • Landslide mapping plan

Introduction

Norway is a country with extreme relief contrasts. In addition, soft marine clays today lie onshore due to the isostatic rebound of Scandinavia after Pleistocene glaciations. For its position at the edge of the Atlantic Ocean, Norway is also exposed to strong precipitations which fall also in winter times in the form of snow. It results in multiple types of slope movements such as rock falls, rock avalanches, quick-clays slides, debris flows and snow avalanches.

As the Norwegian population is strongly distributed over the entire country, slope processes have produced damages to infrastructures and buildings and 2,000 victims in the past 150 years. This became evident in the rock slope failure in Ålesund in 2008 were five people lost their lives and the Namsos quick-clays slide in 2009 in which ten houses disappeared into the fjord. To reduce their negative impacts on society, the Norwegian government has decided to strengthen the effort to analyse and map the hazard.

Since 2009, the Norwegian Water Resources and Energy Directorate (NVE) is responsible at government level to assist municipalities in the prevention of disasters posed by landslides and snow avalanches. This assistance is performed through implementation of digital inventories, methodologies for susceptibility and hazard mapping, production of susceptibility maps and the economical support for the production of hazard maps, supervision of land-use plans and preparation of guidelines, monitoring and early warning systems, realization of mitigation measures and assistance during emergencies. These activities are realized in strong collaboration with existing scientific governmental agencies and private consultant companies.

The *Plan for landslides and snow avalanches hazard mapping* was the first tasks that NVE was asked to perform under the new responsibility (St.meld nr 22 2007–2008; and St.prp.nr. 1 2008–2009). The plan's results will guide national and local authorities to identify highly populated areas exposed to landslides and snow avalanches where hazard maps are needed, as well as important activities and methodologies that should be performed and developed in order to produce reliable hazard maps.

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Table 1 Classification used in Norway for landslides and snow avalanches

Type of material			
Rocks	Debris	Clays	Snow
Rock falls (steinsprang; steinskred)			
Rock slides (ustabile fjellparti)	Debris slides (jordskred)	Clay slides (leirskred)	Snow avalanches (snøskred)
Rock avalanche (fjellskred)	Debris avalanches (jordskred)	Quick clays slides (kvikkleireskred)	
	Debris flows (flomskred)		

Landslides and Snow Avalanches

In Norway, slope mass movements are commonly classified based on the type of material (Table 1). The word "*skred*" is commonly used as a general term to indicate both landslide processes and snow avalanches.

Available Data and Maps

The most important sources of landslides and snow avalanches data in Norway are: the national landslide database; maps of quaternary deposits; few susceptibility and hazard maps and technical reports.

National Landslide Databases

The national landslide database was started in 2003 by collecting historical landslide data from several sources, such as technical reports, old chronicles, newspapers, church registers and annals events (Jaedicke et al., 2009).

Landslide and snow avalanche events are systematically registered by the National Road Authority (SVV), the National Railway Authority (JBV), the Norwegian Geological Survey (NGU), the Norwegian Geothecnical Institute (NGI) and NVE. The data are systematically updated and presented through a web portal www.skrednett.no. Landslides and snow avalanches events are represented as points placed where the events have hit the road or the railway or where have produced damages on objects or killed people. The location, type of landslides and date and time of the event, volume and damages are also provided, when available.

Besides this database NGU is developing a database recording unstable deforming slopes that could be potential source areas of future large rock avalanches. At the moment the database provides data on three counties (Møre & Romsdal, Sogn & Fjordane and Troms).

Technical Reports

Technical reports are prepared by governmental authorities, private consultants and Universities for different purposes like regional mapping, areal planning, design of mitigation measures, and within research projects. The quality of data and maps provided by these reports is largely variable.

Maps of Quaternary Deposits, Susceptibility and Hazard Maps

The mapping of landslide processes and snow avalanches is under working since 1980 and realized by two main instances, NGU and NGI, and economically supported by different governmental institutions (Statens Naturskadefond until 1995; Statens Kartverk between 1996 and 2003; NGU between 2004 and 2008, and NVE from 2009).

The maps of quaternary deposits are systematically prepared by NGU and show the distribution, structure, genesis and properties of Quaternary deposits at or near the ground surface (www.ngu.no). Information about type, thickness and depth characteristics of deposits is presented. The maps represent important sources of landslide information because they show the distribution of: landslide deposits, marine clays, moraine deposits and other unconsolidated deposits that under excessive rainfalls can be remobilized in form of shallow rotational or translational slides, quick clays slides, or debris avalanches. If in proximity of a channel, unconsolidated deposits can be easily eroded and entrained by debris flow processes. Mapping is mainly based on aerial photo interpretation and field reconnaissance. The maps cover 2/3 of Norway with a scale of 1:125,000, 1:250,000 or 1:310,000. In many areas new and more detailed maps are also available with a scale of 1:50,000; 1:20,000 and 1:10,000.

The identification and mapping of marine clays deposits potentially sensitive or quick started in 1980 by NGU and NGI, after the Rissa slide event in 1978. Since 2000 the potentially quick clays sliding areas were classified based on their degree of hazard and consequences in order to estimate the potential risk. The risk classification is based on theoretical consideration and empirical data from historical quick clays slides (Gregersen 1983; NGI 2008). The maps cover only some parts of the country (areas with the most extensive clays deposits) at the scale 1:50,000.

The systematic mapping of rockslide areas is performed since 1990 by NGU and starting in the counties of Møre & Romsdal, Sogn & Fjordane and Troms. Previous identification of rockslides areas was done by NGU and NGI after the Tafjord disaster in 1934.

Susceptibility maps are available only for some types of slope movements. Some of them cover the entire territory others were made only in some areas of the country.

Two different versions of susceptibility maps are available for rock falls and snow avalanches. The old version of a combined susceptibility map for rock falls and snow avalanches was elaborated by NGI during the last two decades. Terrain analyses and field surveys were used to identify potentially source areas and statistical-topographic methods were used to estimate the run out distance. The maps cover just the western and northern areas of Norway and were elaborated at scale 1:50,000. These maps were prepared by request of local authorities and used for areal planning purposes. These maps have been called hazard maps because they include a qualitative estimation of the temporal probability.

The new version of susceptibility maps for rock falls and snow avalanches were produced in 2009 by NGU covering the entire country and showing both source areas and run out areas (Derrón 2008a, b). The maps are based on a physical "shadow angle" model which combines a slope analysis method for the estimation of the source area and a shadow angle model for the estimation of the propagation zone. The method for the propagation zone is an adaptation of the statistical alpha/beta model developed by Lied and Bakkehøi (1980) and considers that the value of the angle of propagation (alpha) changes according to the shape of the slope. The source areas are automatically identified from slope angles and terrain elevation model. From the source areas the run out distance is calculated automatically. Method is not calibrated with field surveys.

Few hazard maps are available providing a quantitative temporal probability. The available maps show multi-hazards areas and a total maximum run out distances for rock falls, snow avalanches, debris slides and debris flows. Often the hazard is represented by a cumulative line for all type of landslides. In addition, hundreds of reports have been prepared in the last 30–40 years by private consultants for areal planning purposes or for the construction of mitigation measures that include the preliminary hazard analysis of a certain area. The maps show hazard limits of 1/100, 1/1,000 and 1/5,000 frequency intervals as required by the building code. The methods and mapping of the hazard used in these reports are different among them and difficult to compare.

The National Plan for Landslide and Snow Avalanche Hazard Mapping

Objective

The national mapping plan had the general objective to identify landslide and snow avalanche susceptible areas with high concentration of population where hazard maps are needed.

Specific objectives were:

– To analyze and define the current knowledge, quality of available data and map products for each type of landslides and for snow avalanches;
– To identify the main needs in what it concerns: new data acquisitions, improvements in the data collection, quality of susceptibility maps, and maps of quaternary deposits; improvements of methods for the elaboration of susceptibility maps, improvements and establishments of methods for hazard analysis and mapping;
– To set priorities and identify inhabited areas potentially at risk, based on the available data, where future landslides and snow avalanches hazard mapping should be performed.

Organization

The project started in 2009 and was divided in four subprojects, based on the main types of landslide processes:

1. Rockfalls and rock avalanches,
2. Debris slides and debris avalanches,
3. Quick-clays slides,
4. Snow avalanches.

Each subproject was performed by a group composed of specialists from the Norwegian Water Resources and Energy Directorate and from the Norwegian Geological Survey. Each group worked separately and produced separated analysis and separated documents (NVE 2011a, b, c, d). The results obtained were later synthesized in a final document (NVE 2011).

Methodology

The common methodology included a literature research, analyses of quality of available data and maps, identification of needs in terms of maps and hazard mapping methodologies and, identification of potential endangered areas.

The methodology for the identification of potentially endangered zones adopted by the different groups was quite similar, however criteria and sources of data used were different from one type of landslide to the other. The methodology consisted in using GIS tools to combine population data, type of buildings (like hospitals, schools, etc.) with available maps for quaternary deposits, susceptibility maps and historical events from the database to identify "conflict zones". Depending on the type of slope movement the conflict zone can be defined as the highly populated area:

- Within an area with a larger areal of potentially quick clay deposits
- In proximity of a potentially source areas of debris slides/ debris avalanches (Fig. 1)
- Within rock fall or snow avalanche run out areas

The analysis was done at site-specific scale for all type of slope processes except for quick clays slides, where a scale 1:50,000 was used (~topographic quadrangles) and rock avalanches, where a county scale analysis was performed. Expert judgement, orthophotos verifications, and weighting scheme were used to set priorities. Additional data received from municipalities and regional authorities in form of questionnaires were take into account, but not used directly in the analyses. Table 2 presents a synthesis of the methods and source data used in the different subprojects. The analysis was based only on available data during the realization of the project.

Results

The main results of the national mapping plan were:

(a) The identification of future needs in what it concerns new data acquisitions, improvements in the data collection and the methodological developments that are necessary under hazard mapping tasks;
(b) Lists of inhabited areas potentially at risk, where future landslide and snow avalanche hazard mapping should be performed.

Future Needs

High resolution topographical data and terrain models are necessary for detailed mapping and hazard analysis. INSAR and ground based radar, bathymetry and seismic measures in lakes and fjords are necessary to identify, characterize and monitoring rock avalanches areas.

The database is a very valuable source of information on historic landslides although it presents several limitations in what it concerns the completeness and quality of information, lack of spatial extent, improper terminology on landslide types. Improvements in the national landslide database are strongly needed. In particular, the registration of new events should be performed systematically also in uninhabited areas; the different landslide types of landslide should be better distinguished in the database; the time of occurrence should be registered regularly. Mapping the extent of scars, travel path and deposits for new and historic and prehistoric events is extremely important to identify the intensity, areal extension and runout distance of the different types of processes. Information on quick clays should be collected in a common source.

The regional mapping for rock avalanches should be continued especially in the counties not mapped yet, identifying and mapping the extension of potential rockslide areas and past rock avalanches.

The mapping of quaternary deposits should be continued at a more detailed scale in the areas not yet mapped and should provide more detailed geomorphologic landslide features, like deposits and source areas and differentiate the different types of landslide deposits. They should also represent better the extension of altered and weathered rocks, landslide path, colluvial fans and presence of rock outcrops.

The susceptibility maps available for rock falls and snow avalanches should be improved taken into account respectively a higher resolution digital elevation models, forest coverage; improvements of the run-out model by limiting the run-out distance, especially on flat terrain; field observations.

Methodologies for analyse and map the susceptibility should be developed and improved for debris slides, debris avalanches and debris flows and rock avalanches.

Methods for analysing and mapping the hazard posed by rock falls, snow avalanches, debris flows and debris slides should be established as well as methods to classify the hazard and risk posed by rock avalanches.

The quality of available quick-clays slides maps should be improved and maps should be updated. The method used until now to analyze and map quick-clays slides hazard should be re-evaluated and eventually improved.

Once methods for hazard mapping are defined or existing methods improved, hazard maps should be produced in the areas with high priority as identified in the national plan.

Areas that Should Be Prioritized for Hazard Mapping

Population data were combined with available susceptible areas (rock falls and snow avalanches) or with newly susceptibility analyses (debris slides and for quick-clays slides) to obtain the number of persons located in a potentially endangered zones.

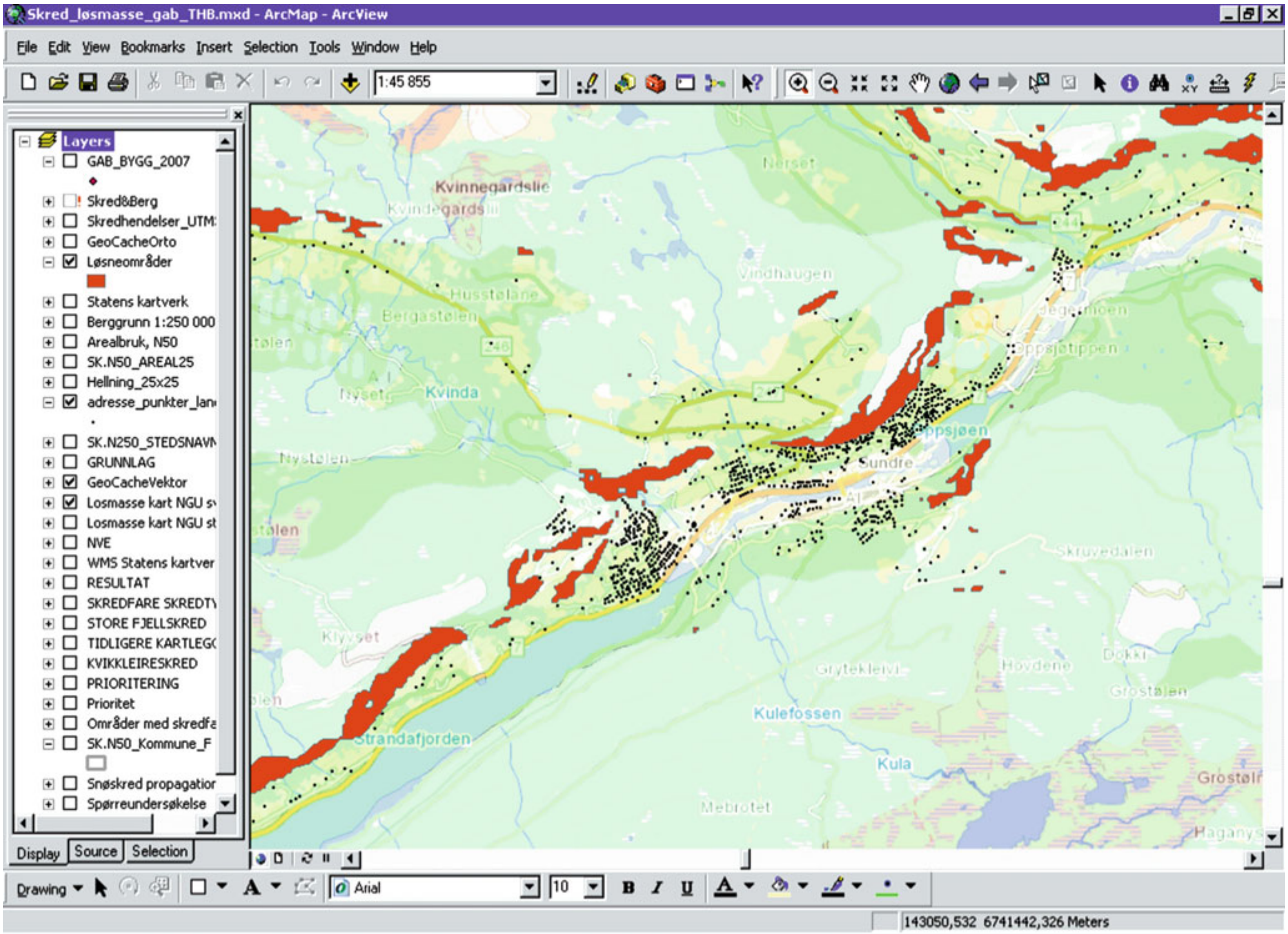


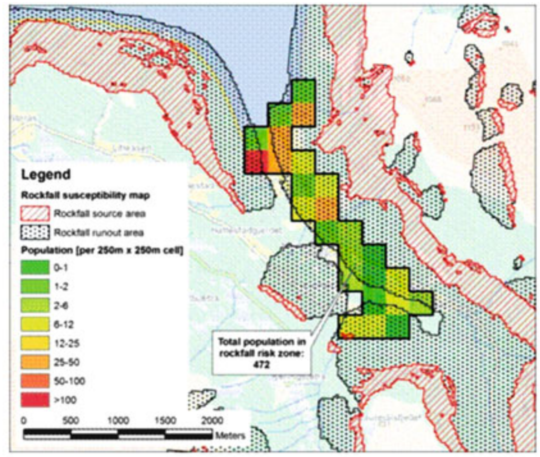
Fig. 1 Example of conflict zones for debris slides and debris avalanches. *Red zones* are potential source areas and *black dots* show the location of buildings

Table 2 Synthesis of methodology used for the different types of landslides and snow avalanches

	Rockfalls	Rock avalanches	Debris slides, debris avalanches	Quick-clays slides	Snow avalanches
GIS analysis	New version of susceptibility map		DTM	Marine clays limits model	New and old version of susceptibility map
			Slope angle map	Maps of quaternary deposits (marine clays deposits)	
			Maps of quaternary deposits (moraine, landslide deposits)		
	Population data		Population data	Population data	Population data
Ortofoto analysis	x	x	x		
Expert judgment	x	x	x	x	x
Historical events from the database	x	x	x	(x)	
Weighting scheme	x	x	x		
Klimascenarios			x		
Results from the questionnarie	(x)	(x)	(x)	(x)	x

The symbol (x) indicates that data were taken into account but not directly used in the prioritization

Fig. 2 Example of conflict zone for rock falls and weighting criteria used



Total population	Weighting	Count
≤ 10	1	224
11 – 100	2	609
101 – 1000	3	275
> 1000	4	15

Presence of rockfall sources & signs of rockfall activity	Weighting (with forested run-out area *)	Count (with forested run-out area)
No cliffs or rock outcrops	eliminatory → priority = 0	178
Cliffs or rock outcrops	1	551
Cliffs + historical events	3 (2)	134 (31)
Cliffs + scree slopes	3 (2)	188 (17)
Cliffs + historical events + scree slopes	4 (3)	72 (39)

* Weighting reduced by 1 if run-out area covered by dense forest.

Rock Falls

Using the new version of the rock fall susceptibility maps and existing settlements, the analyses highlights 1,123 sites (conflict zones) potentially exposed to rock fall hazards. Based on the total number of persons potentially present in the conflict zone and several criteria testifying to rock fall activity (presence of cliffs, scree slopes, historic rockfall events, forest cover in the run-out area), different priority levels (from low to very high) have been attributed to the sites. Combining the orthophoto analysis with the historical rock fall events enabled the creation of the criterion "presence of potential rock fall sources along with signs of rock fall activity". This criterion can be combined with the total number of persons exposed in a rock fall risk zone by summing the weightings (Fig. 2). Finally, the prioritization leads to values ranging from low to very high. For areas with high and very high priority values a second orthophoto analysis with comprehensive expert judgment was performed with the focus on densely forest in the rock fall run-out area that generally reduce the rock fall hazard at this site. In case of dense forest cover the weighting for the rock fall activity was reduced by 1. Out of 1,123 conflict zones, 115 sites have a medium-high to very high priority.

Debris Slides/Debris Avalanches

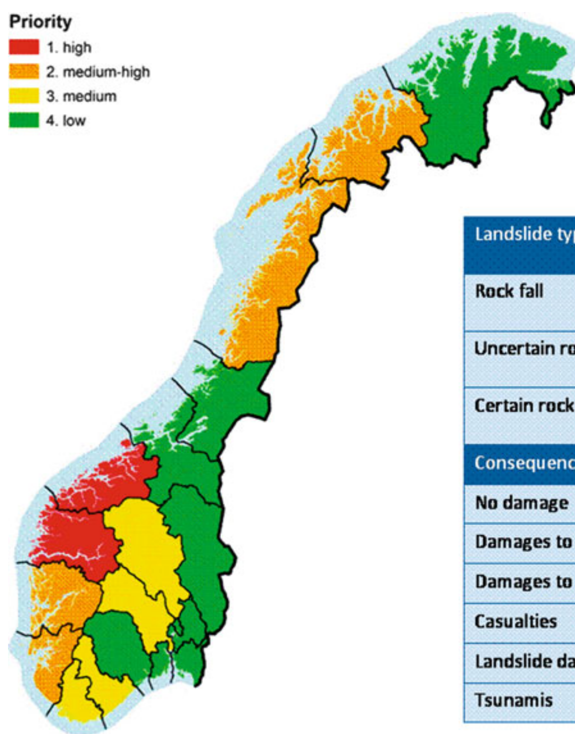
Since susceptibility maps for these types of landslides are not available yet, a susceptibility analysis was done using slope angle maps, maps of quaternary deposits (in particular moraine deposits, old landslide deposits) to identified potentially source areas (Fig. 1). A buffer zone of 300 m was added around these zones to identify possible runout areas based on expert judgement and experience from field observations. About 30,000 potentially sites were identified. Later, only those areas with the highest density of population were considered for future prioritization. A weighting scheme was proposed to set priority values, using population and type of infrastructure; occurrence of historical events; presence of forest; density of forest; thickness of loose quaternary deposits; presence of rock outcrops; extension of watershed; presence of concavities in the slopes. The priority ranges from 1 (high) to 4 (low). About 170 sites were identified potentially exposed to debris slides or debris avalanches and 100 of them have very high and high or medium-high priority.

Snow Avalanches

The new version of snow avalanche susceptibility maps and information on existing settlements was used to identify the conflict zones. In order to set a priority these zones were analyzed using expert judgment and ortophotos analyses (like concavities in the slope or absence of a dense forest), information on previous events, and compared with data from the municipalities and from the old version of the susceptibility map, where available. The analysis shows that about 350,000 people are leaving in potentially snow avalanches prone areas. Table 3 presents an example of list

Table 3 Priority list for snow avalanches for Nordland county

Municipality	Type of process	Priority	Locality
Vefsn	Snow avalanche	2	Mosjøen vest
Meløy	Snow avalanche	2	Mosvoll, Neverdalen, Glomfjord, Vassdalsvik
Fauske	Snow avalanche	1	Bursimarka – Sulitjelma
Sørfold	Snow avalanche	2	Elenjorda, Mørsry, Leirfjorden
Moskenes	Snow avalanche	2	Deler av Moskenes, Tind og Reinevågen
Flakstad	Snow avalanche	2	Ramberg, østside av Skjellfjord, Nappsvågen
Vestvågøy	Snow avalanche	2	Ballstad, Stamsund, Mærvoll, Straumnes
Sortland	Snow avalanche	2	Sigerfjord, Strand, Maurnes, Hognfjord
Narvik	Snow avalanche	2	Fagernes-Kvitsandøra, Beisfjord, Fagerjorda-Strømsnes



Landslide type	Weighting
Rock fall	1
Uncertain rock avalanche	6
Certain rock avalanche	12
Consequences	**Weighting**
No damage	0
Damages to forest, arable land or cattle	0.5
Damages to buildings	1
Casualties	2
Landslide dam	3
Tsunamis	4

Fig. 3 Priority map and weighting scheme for mapping and investigating unstable slopes and rock avalanches in Norway

for Nordland county. Only the very high (1) and high priority (2) is presented. Some areas were excluded if dense forest was observed or lack of landslide events.

Quick Clays Slides

The quick clays slide subproject focused on identify and classify new areas where hazard mapping has not been performed yet. Based on the model of marine clays limits, the maps of quaternary deposits likely to include or overlie quick clay deposits and, information of the population, it was possible to quantify the areas with the larger potential risk for future quick clay slides. Because the previous hazard mapping was done following the existing topographic quadrangles also this analysis was done at scale 1:50,000 and not at site-specific scale like for the previous landslide types. It was identified that 83 quadrangles have large areas (more than 3 km^2) of potentially quick-clays areas. The areas are mainly distributed along the Norwegian shoreline. Some of the prioritized areas were recognized as areas with known quick clay deposits, and for others such local knowledge was lacking. Thus there will always be a need for collecting more detailed information before ranking and the final prioritizing of the next area to map.

Unstable Slopes and Rock Avalanches

For this type of landslide processes was performed an analysis at county level and the priority was assigned to the county instead to a specific site. Since no rock avalanches susceptibility map is available, the priority list for unstable slopes with the potential to form large rock avalanches was based on the historic inventory of rock avalanches of the past centuries and large rock falls that killed people and/or triggered tsunamis. Orthophotos analyses were used to investigate visible criteria such as visible rock avalanche deposits and/or scars, large volumes and excessive run-out distance. Due to the limited number of historic rock avalanches, uncertain events and small rock avalanches (~100,000 m^3) events are also included in the priority list of counties. To account for the different processes and the consequences of each historic event recorded in the database, a weighting scheme was introduced. Different weightings are attributed to rockfalls, uncertain rock avalanches and certain rock avalanches and to the various consequences of an event (Fig. 3). The weighting of the consequences are summed for each event and then multiplied by the weighting of the landslide type. Finally the scores of each rock avalanche event were summed up per county. Four priority classes were obtained and two counties, Møre og Romsdal and Sogn og Fjordane, have the highest priority with several certain and uncertain fjellskred events.

Final Results

Each group provided separated lists for the different types of landslides and for snow avalanches. However, in the final document the lists were combined in a common list, one for each county and ordered by municipalities.

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Stortingsmelding nr 22 (2007–2008)

THE SECOND WORLD LANDSLIDE FORUM

Landslide Management in Austria with Particular Attention to Hazard Mapping and Land Use Planning

Margarete Wöhrer-Alge

Abstract

The assessment of landslide hazards and the planning and construction of protection measures in Austria is carried out by the Austrian Service for Torrent and Avalanche Control (a federal agency) in close cooperation with the provincial Geological Services.

As the feasibility of technical measures is often very limited in the case of landslides, a combination of measures targeting all parts of the risk cycle is necessary to limit the damage caused by catastrophic landslide events. In the last years special attention has been paid to avoid building activities in heavily endangered areas. In Vorarlberg (the westernmost province of Austria) the systematic incorporation of landslide hazards into the Hazard Zone Maps was launched in 2004 and areas endangered by mass movements are classified into two categories:

Areas of high hazard potential (not suitable for permanent use regarding settlement and transport purposes).

Areas of medium to low hazard potential (the permanent use regarding settlement and transport purposes is impaired).

Keywords

Landslide management • Land use planning • Hazard mapping

Introduction

According to the definition of the Alpine Convention, Austria has the largest share of the Alps. 65 % of the country's territory are situated in that geographical unit, and thus in an area with high relief energy.

Owing primarily to the high intensity of relief, the geological situation and the high to very high precipitation rates in some areas, landslides occur frequently in Austria. The effects of climate change may also modify the stability of slopes and reactivate dormant landslides. Due to the increasing settlement pressure and the growing vulnerability of human facilities, as well as the growing importance of the Alps as an economic area, the risk of damages caused by mass movements becomes more significant. Knowledge concerning the location of vulnerable areas, the frequency and intensity of events, the triggering factors as well as the possibility of prediction and early warning, of prevention and minimization of damages becomes increasingly important.

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Geology of Austria

The geological diversity of Austria is a result of its evolutionary history. Across a maximum distance of 300 km (Vorarlberg, 70 km) from north to south several geological units occur. Predisposing factors for landslides are poor consolidation of sediments, tectonic strain during the orogenic phase and glaciation during the glacial period.

C. Margottini et al. (eds.), *Landslide Science and Practice*, Vol. 7,
DOI 10.1007/978-3-642-31313-4_30,

Table 1 Legal bases and competences in natural hazard management in Austria (Rudolf-Miklau 2009)

Measures	Legal basis	Competence
Development planning	Development Planning Acts	Provinces
		Community (Building authority)
Protection of settlement areas	Forestry Act	Federal State (Austrian service for torrent and avalanche control)
Protection of roads and railroads	Road Construction Act	Provinces
	Railroad Act	Federal Motorway Co.
Protection of cableways	Cableway Act	Federal State (Legislation and Permission)
Protection forest	Forest Act	Federal State and Provinces, Owner
Road closures	Road Traffic Act	Provinces and Communities
	Civil code	
Evacuation	Safety Police Act	Mayor of the Community
	Catastrophe Acts	Director of District Adm.

Table 2 Measures of natural hazard management (Source: Rudolf-Miklau 2009)

Measures of natural hazard management		
Preventing risks	Prevention	Legal norms, investigation of NH, monitoring of NH, preventive planning, technical protection measures, management of protection forest, building protection
	Precautions	Information (awareness), financial precautions (insurance), catastrophe management planning, emergency planning, prognosis, early warning, alarm
	Preparation	Clearing, closure, evacuation
Coping with risks	Rescue operations	Self help, rescue operations, salvage
	Assistance (Emergency measures)	Medical first aid, psycho-social first aid, humanitarian assistance, emergency measures, clearing-up operation, repair, disaster documentation
	Reconstruction (Improvement)	Reconstruction, resettlement (translocation), financial compensation of damages, analysis and reflection

The Alps were almost entirely covered by ice during Quaternary glaciation. The glaciation had immense influence on geomorphology by reshaping valleys, creating post-glacial slope instabilities and leaving behind moraines and lake deposits, mostly of clay (Neubauer and Hock 2000).

In Vorarlberg, the poorly consolidated sediments of the Folded Subalpine Molasse and the Flysch Zone (in Swiss German "Flysch" means "to flow") are particularly susceptible to landslides.

Landslide Management and Competences in Austria

Competences

In Austria several public organisations are involved in Natural Hazard Management (see Table 1). According to §102 of the Forestry Act 1975 the Austrian Service for Torrent and Avalanche Control is responsible for the protection against torrents and avalanches. Mass movements as part of the catchment area of torrents are included implicitly (Table 2).

The Forest Act details the tasks and duties of the Austrian Service for Torrent and Avalanche Control. These include inter alia the development of hazard zoning maps, planning and implementation of technical and biological control measures, consulting services and expert activities, and acting in the public's interests with respect to the protection against alpine natural hazards.

Measures of Landslide Management

As the feasibility of technical measures is often very limited in the case of mass movements, a combination of measures (see Table 2) targeting all parts of the risk cycle is necessary to limit the damages caused by catastrophic landslide events.

Due to heavy losses caused by landslides in 1999 and 2005 and constantly increasing damages from rock fall events in recent years in the western part of Austria, special attention has been paid to limit human activity in endangered areas.

Effective prevention against natural hazards requires a better understanding of the processes occurring in nature. The primary aim of hazard assessment is to gain a deep and comprehensive knowledge of these processes in order to provide accurate prognosis of the expected magnitude of hazardous events and the corresponding damaging effects (Rudolf-Miklau 2011).

Assessment of rapid gravitational mass movements such as rock falls and landslides is carried out by several public organizations in Austria. Inventories of such events are

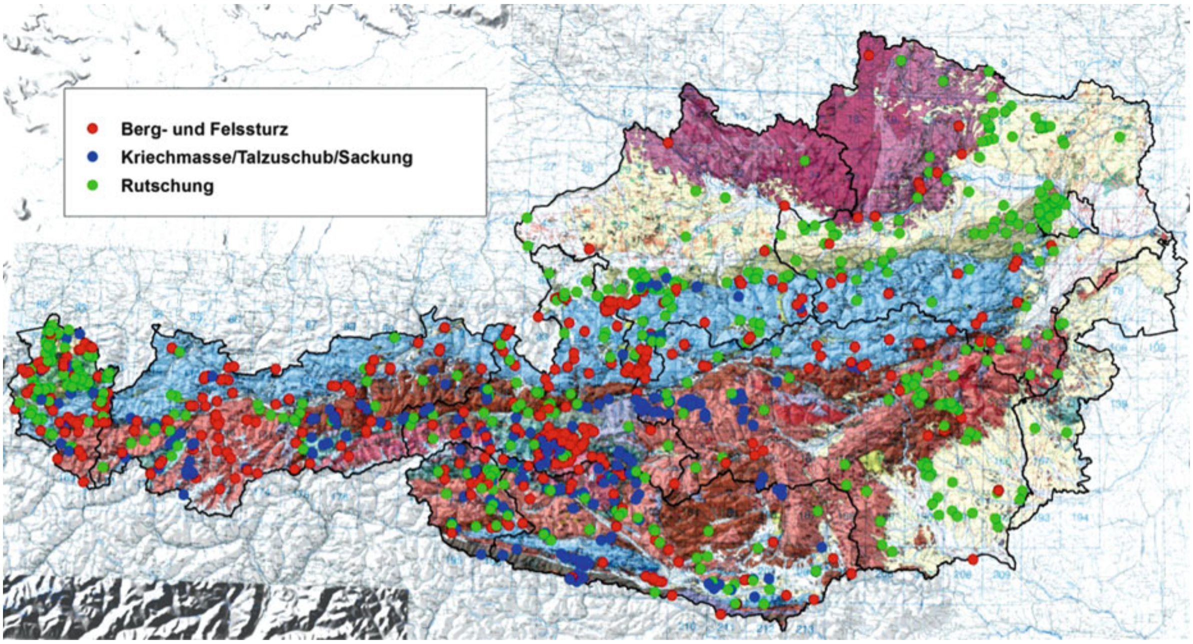

Fig. 1 Inventory of mass movements in Austria (Source: GBA: www.geologie.ac.at)

maintained by the Austrian Torrent and Avalanche Control (WLV) and the Geological Survey of Austria (GBA), apart from independent assessments done by the national railway and road administrations (Mölk et al. 2011).

Since 1978 the GBA has been gathering and displaying information about gravitational mass movements and other hazardous processes (see Fig. 1) and has developed a complex data management system called GEORIOS.

The Austrian Service for Torrent and Avalanche Control carries out the assessment of landslide hazards and the planning and construction of protection measures in close cooperation with the Geological Services of the provinces.

Hazard Mapping and Spatial Planning

As spatial planning and building in Austria falls under the competencies of the provinces, nine different legislative regulations exist, but provisions regarding natural hazards are very similar.

The regulations of Spatial Planning Laws and Building Codes hold an important preventive position in the integrative nature of risk management in Austria, since specific building and zoning restrictions avoid increasing risk potential within natural hazard areas. The restriction possibilities apply to geographically delineated natural risks in general and mass movements in particular. In the context of mass movements, the Spatial Planning Laws and Building Codes contain only limited specific regulations. In many cases the general building and utilization regulations for natural risks are used without specification: limited obligation to identify natural hazard areas in spatial plans on regional and local levels, extensive utilization restriction, especially for building land (with exceptions) in the context of land-use planning and building prohibition within the building procedures according to the assessment of the building plots. In the spatial planning and building processes with reference to mass movements, municipalities always tend to fall back upon specific expert opinions, especially on the content of Hazard Zone Maps (Kanonier 2011).

The creation of Hazard Zone Maps for torrents and avalanches became compulsory in Austria with the Forest Act of 1975. Hazard Zone Maps are primarily the basis for the planning of protective measures and the estimation of their priority, but they are also important for building and spatial planning as well as for civil protection authorities. Hazard Zone Maps are based on expert opinions and, therefore, have no legislative effect. In Austria, however, non-compliance will result in an impediment in the allocation of public funds for the implementation of protective measures in the relevant risk zone.

Additional hazard zones other than those relating to torrents and avalanches (e.g. rock fall and slide areas) may be defined in the Hazard Zone Maps as information for the planning and building authorities, but this is not mandatory. These so-called reference areas outline areas of possible mass movements, but are rarely available for the whole settlement area, and magnitude and the intensity data are largely missing for these areas. Here, case-specific interpretations have to be made for zoning and building proceedings.

The identification of hazard zones is based on state-of-the-art methods. It considers up-to-date knowledge, personal experience, documentation of historical disaster events (records of the Torrent and Avalanche Control) and presentation of possible damage events (scenarios), which are described with a probability of occurrence (recurrence probability) of 1 in 150 years. They are presented on a 1:2,000 scale, mostly for a specific region of a municipality on the basis of the digital land registry. Every Hazard Zone Map is subject to a comprehensive control and approval procedure which ensures a broad consensus at the technical level and a high planning quality on the one hand, and aims on the other hand at achieving a high level of public acceptance of this important instrument of land-use planning, as well as of the building and security sectors. The first phase of hazard mapping was finished in Vorarlberg (the westernmost province of Austria) in 2004. Hazard Zone Maps for 82 communities are available.

Heavy rain falls in 1999 and 2005 triggered numerous debris flows and landslides and highlighted the importance and necessity of a consistent (standardized) designation of hazard zones. Problems with rockfall also became increasingly important in recent years.

With the start of the second phase (the revision phase) of hazard mapping in Vorarlberg in 2004, the systematic incorporation of landslide hazards into the Hazard Zone Maps was launched and the reference areas have since been classified into two categories (see Fig. 2):

Areas of high hazard potential (darkbrown areas in Fig. 2): areas that, due to the expected damaging effects are not suitable for permanent use regarding settlement and transport purposes, or the construction of protective measures involves disproportionate effort.

Areas of medium to low hazard potential (light brown areas in Fig. 2): the permanent use regarding settlement and transport purposes is impaired. Destruction of buildings is not to be expected if special requirements are met.

The identification and classification of the two categories mentioned above result from the expert opinion of geologists, which is based on:

- Geological and tectonic maps of the geological survey of Austria (GBA)
- Personal experience
- Documentation of historical events (chronicles) and eyewitness interviews
- Field investigation (silent witnesses, morphology)
- Analysis of aerial photographs and DTMs
- Simulation programs (rock fall)

Areas classified as critically endangered should be kept free from future construction work as much as possible. In areas with moderate or low risk, the permission for future construction work is only given if geological expertise has defined additional object-specific protection measures. If buildings or infrastructure already exist in the endangered areas, investigations should clarify if protection measures can be erected at a reasonable cost. If this is not possible or only possible to a limited extent, the implementation of an early warning system may reduce the risk. The creation of disaster management plans based on the Hazard Zone Maps and the training of emergency personnel will help to reduce the danger to an acceptable level for persons and reduce the cost of damages in the event of a disaster.

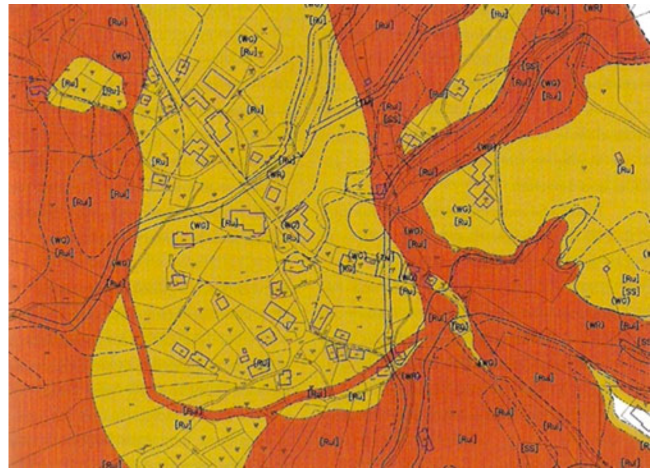

Fig. 2 Section of the hazard zone map of the community Sibratsgfäll in Vorarlberg, with depiction of the brown reference areas

Example Cases of Landslide Management

Landslide Rindberg/Sibratsgfäll

One of the largest landslides in Austria in recent years occurred near Sibratsgfäll in the federal state of Vorarlberg (Austria), where about 70 million cubic m of soft rocks on an area of 1.6 square km was involved in a hazardous mass movement, destroying 17 buildings (Fig. 3), the entire infrastructure and the drainage system of this area completely (Jaritz et al. 2004). A short period of heavy precipitation and the rapid melting of snow in the spring of 1999 initiated this catastrophic landslide. The landslide area of Rindberg is situated at the orographic right flank of the Rubach valley, east of the community Sibratsgfäll. The whole flank of the valley downwards to the river Rubach (840 m above sea level) was affected by the movement of 1999. The 1.6 km large slide area ranged from 830 to 1,500 m above sea level, the average slope angle measured 12°–20°. The movement rates of rock- and debris bodies involved exceeded up to

Fig. 3 Damaged houses in the village Rindberg (WLV GBL Bregenz)

10 m per day. Historic records report the destruction of buildings caused by catastrophic landslides in 1540 and 1732. Tree trunks which were discovered in the sliding masses showed an age (determination by radio carbon dating) of approx. 4,500, 2,000, 1,200 and 700 years.

The landslide area is entirely located in the Feuerstätter nappe, which is part of the North Penninic Flysch unit. This geological unit is characterized by extensive rock disruption. The landslide area itself is mainly composed of rocks of the Junghansen and Schelpen series. These sub-units consist of marl and schist with highly variable stability as a result of tectonic fracturing. Due to their low resistance against weathering, rocks degrade under the influence of water into deeply weathered granular soils. All primary scarps are located within these areas (Jaritz et al. 2004).

During the main movement phase (from May to October 1999), the aim of undertaken measures was the maintenance of a safe discharge of the runoff. After the landslide event the drainage system was reconstructed, springs were tapped and crevices in the soil were closed in order to avoid a significant moisture penetration of the sensible soil.

The first Hazard Zone Map of this area was elaborated in 1991 and the whole landslide area was depicted as reference area landslides. After the landslide event the Hazard Zone Map was revised and the reference areas classified as described above. The main settlement area of Sibratsgfäll west of the landslide Rindberg is located on a creeping mass of glacial lake deposits which also accelerated during spring and summer 1999. In the following years three houses were totally destroyed. Comprehensive interdisciplinary studies were carried out to assess the hazard level of the settlement area. The participation of stakeholders and local people in the planning process of the Hazard Zone Map and the subsequent integrated risk management project was a precondition for the acceptance of the Hazard Zone Map (Jaritz et al. 2011).

Fig. 4 Aerial photo of the landslide Gschliefgraben in May 2008. The *red line* marks the red hazard zone and the *red arrow* the main hazard area with five buildings and the local road (WLV GBL Bad Ischl)

Landslide Gschliefgraben/Gmunden

The "Gschliefgraben" is located in Upper Austria, on the east-banks of the lake "Traunsee" (Pürstinger 2009; Marschallinger et al. 2009). The catchment area of the Gschliefgraben drains a huge, geologically-caused landslide system. Generally, the Gschliefgraben is a torrent which has a high potential for debris flows with an associated risk exposure for the populated debris fan.

A tectonic window of ultrahelvetic rocks over thrusted by the Flysch Nappe is exposed in front of the border of the Calcareous Alps (Mt. Traunstein) in the Gschliefgraben. The widely distributed Northern Ultrahelvetic series mainly consist of dark grey, partly variegated marls, which are highly susceptible to water saturation, forming huge streams of earth-, mud– and debris-flows down the valley and resulting in a sub-aquatic fan, 900 m wide and 120 m deep. These glacier-like mass movements have destroyed forests, cultivated land and farm houses for centuries (known in the years 1660, 1734, 1825 and 1910). Debris flows along the main Gschlief- and Lidring river, as well as torrents within the Gschliefgraben, have caused serious problems during thunderstorm events up to present times, especially in the years 1897, 1899, 1920, 1947, 1955, 1958, 1977 and 1987 (Pürstinger 2009).

In late November 2007, presumably triggered by a rock fall in April 2006, an earth flow amounting to approximately 3.8 million cubic m of accumulated solids was set in motion. Dislocation velocity was up to 4.7 m/day at the beginning, and as a result the earth masses threatened to damage 37 estates with 55 buildings and to shift parts of these into the lake.

The dimension of the mass movement were well known to the experts of the torrent and avalanche control, giving

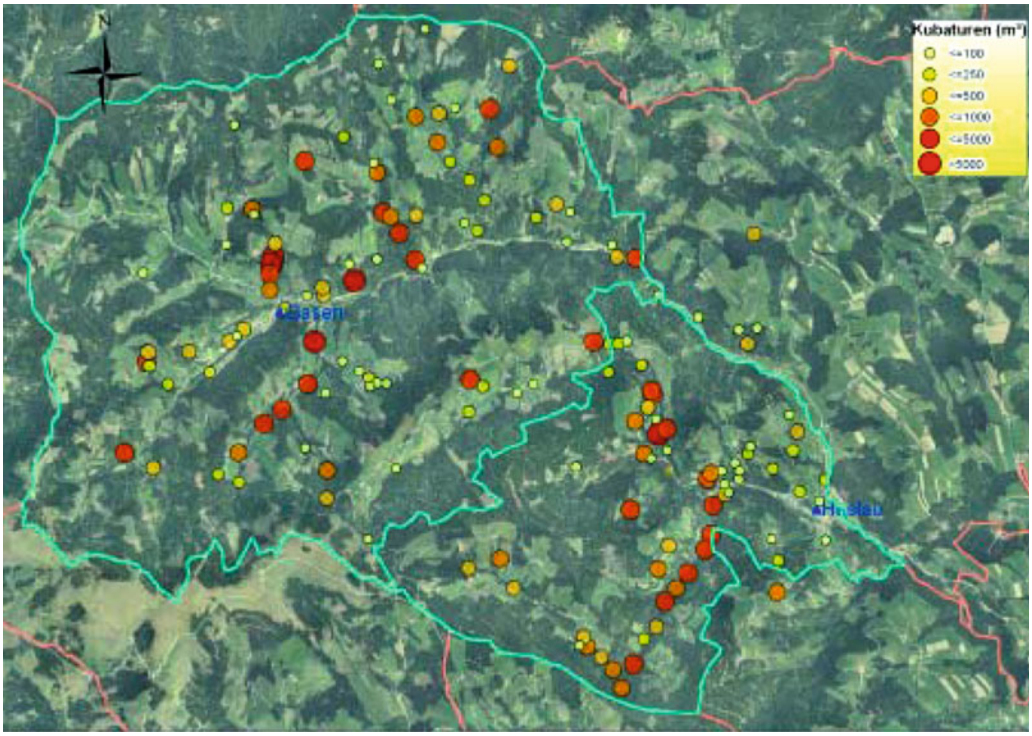

Fig. 5 Location and volume of the landslides in Styria 2005 (Source: Andrecs et al. 2007)

rise to a Hazard Zone Map for the Gschliefgraben in 1974, Which was included in the first legally binding land-use plan in 1978. Today, there are 74 objects within the red hazard zone (Fig. 4). The location is in high demand; however, since 1978, a construction halt for buildings has been in place. Besides endangering the adjoining buildings, the landslide threatens local infrastructure like rural roads, water-, electricity- and communication conduits. Due to the reactivation of the landslide in December 2007, 55 houses had to be evacuated. As a result of the engineering works (drainage structures, piping, wells, torrential structures, afforestation and erosion protection) and a comprehensive monitoring system, implemented and coordinated by the Torrent and Avalanche Control, 40 houses could be reoccupied. By end of August 2008, the evacuation was suspended in consideration of requirements.

Landslides of Gasen, Haslau and Feldbach in Styria

During the night between the 21st and 22nd of August 2005 heavy rainfall (up to 210 mm/36 h) triggered more than 1,000 shallow landslides of different size in the three communities Gasen, Haslau and Feldbach (Fig. 5) (Eastern Styria, Austria). These landslides caused high economic losses as well as two fatalities.

The geology of the bedrock (Austroalpine) can be assigned to the Paleozoic of Graz and the "Angerkristallin". The Paleozoic of Graz represents an overthrust plate lying over the Crystalline Nappe and is complexly fragmented into several parts. Due to the absence of glaciation, thick layers (up to 10 m) of unconsolidated material resulting from the decomposition of tertiary rock were accumulated. In combination with the superficial weathering crust of the solid rock (0.5–1.5 m), this material constitutes the aquifer for percolation water, secondary springs, etc (Tilch et al. 2009).

As spontaneous slope failures have caused considerable damage, these processes were considered to be of crucial importance for a realistic estimation of hazards and for the delineation of hazard zones. The crisis management team and the Austrian Service for Torrent and Avalanche Control therefore commissioned experts to carry out a comprehensive assessment and documentation of the landslides in parallel to the clearing-up operations, the restoration works and the construction of protective measures. On the basis of the findings obtained by analysing those data and with the help of further geological and geomorphological data, areas prone to landslides were identified and subdivided into:

- Areas where landslides with a high hazard potential can occur. The use for building purposes is only possible with disproportionate costs.
- Areas where landslides with a medium to small hazard potential can occur. The use for building purposes is possible at a reasonable cost (Schmid 2011).

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Landslides and Quarries in Italy: Reflections on Census and Safety

Nando Ferranti, Giovanni De Caterini, Gabriele Leoni, and Quintilio Napoleoni

Abstract

A quarry geotechnical project consists mainly in the calculation of the inclination of the excavation faces and of environmental recovery profiles. Quarry fronts are treated in the Eurocodes as generic excavation fronts equalizing the mining to civil engineering.

A quarry face is designed to ensure production and safety, in harmonious balance. In order to evaluate the efficacy of the design, according to more restrictive rules, it was decided to use as a diagnostic tool, the incidence of landslides in the mining yards, assuming that they are pathological signs of design errors.

The ANIM (National Association of Mining Engineers) has promoted a census of the landslides in the mining sites in co-operation with the offices of Mining Police. The project has provided, already in the start, interesting directions.

Keywords

Landslides • Quarries • Mines • Laws

Standards and Quarry Fronts in Italy

The *Technical Laws for Construction* (NTC 08) inspired on Eurocodes 7 and 8, entered into force in Italy in July 2009. Italian and European regulatory framework in the mining issues is bound to specific national regulations that frequently do not exist or they are very old. In Italy the referring law dates back to 1959 ("*Law D.P.R.* 128/59"). It is very general and it imposes as the only constraint to design the prohibition to leave the vertical edges (Fig. 1).

This legislation is too much vague and generic comparing to the current state of knowledge. As a matter of fact, it predates the birth of the science that studies the Mechanics of Rock: the International Society for Rock Mechanics (ISRM) was founded just in 1962.

Afterwards, the law decree 624 in 1996, which was done after EEC intructions 92/91 and 92/104, says that it is compulsory for the employer to present a report about quarry face before the starting of the yard. This report should be brought up-to-date every year, but it still does not give any guiding line about method to adopt.

After a big effort done in Europe to standardize the principles and design techniques, the mining sector remains in the same condition, this means orphan once again of specific addresses and specific inspiration, with no rule to refer to.

As a consequence, designers of mines and quarries have to refer to *Technical Laws of Civil Engineering* in force nowadays, as for example NTC 08 (A.L.I. 2009; Eurocodice 7;

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Fig. 1 Example of a large abandoned quarry face for many years in extremely critical condition. The stratigraphy consists of tuffs, sands and gravels with a horizon of clay at the base that supports the aquifer (Rome, Ponte Galeria)

De Caterini et al. 2011). In this way they have to face supplementary problems, that is to adapt the civil field to that of mining.

These problems have been underlined by Ferranti et al. (2011).

The entry into force of the NTC 08 in Italy has been accelerated after the earthquake that struck the city of L'Aquila. They improve significantly, in terms of safety, the design approach regarding the evaluation of seismic hazard.

Which are basically the points of novelty of the new legislation?

(a) It gathers in a single law text the leading lines of geotechnical and structural engineering;
(b) It introduces the semi-probabilistic approach to limit estate for security checks of geotechnical works;
(c) It introduces a new method for seismic hazard evaluation;
(d) It introduces specific standards for the design and verification of works and of geotechnical systems subjected to seismic actions.

Which are the aspects that are not clear about geotechnical problems regarding mining?

- Generic sides of excavation and mining are considered as the same thing. They are different for kind of work and timing in yard and above all for areal and volume extent.
- The concept of provisory face, on which demolition and cultivation techniques depends, is not taken into consideration unifying this approach to that of the final front.
- In order to determine the geotechnical parameters the law requires partial coefficients to be applied to those characteristic not specifically calibrated for the rock masses.
- For the verification of stability it requires a return period of 35 years for earthquake and provisory face;
- It does not require, for mining yards, security and performance checks and monitoring and control plans.

Why a Census of Landslides?

It is well known that Italy has a high level of hydrogeological hazard on a surface which is predominantly mountainous, with intense active tectonics, and a high seismic activity A.A.V.V. Inventario dei fenomeni franosi in Italia. The quarries are placed in a really complex framework from a geological point of view. The environment has a very high population density which imposes a necessary and proper land use within an economic development project. It is important to know the relationship between quarries and damages both for the land management and for the validation of design techniques.

In order to show a design methodology that covers such a big field we believe it is important to have a diagnostic picture of the major diseases of quarry fronts and of the management of mining yards. To know the series of landslides involving quarry fronts means, in essence, to have an estimate of the efficacy of the designs on the territory, it also helps to suggest possible modifications of the legislation in this specific sector.

Italian literature does not have specific data on landslides occurring in mining yards, even if, in some cases, they are of such a size that geologists call "regional".

One has also to consider that, since the activity is delegated to Regions and Provinces (see Fig. 2), we do not have an accurate and updated national census of the number of quarries and of the production of mining. In addition to this, data acquired by Regions are not uniform and sometimes yet lacking because they do not have the precise number of disused or abandoned quarries. Not even an available database which is uniform in the GIS, exists.

In order to fill this gap, ANIM used to publish periodically its own statistic using all those data taken from various Italian Regions. The last survey was published in A.A.V.V 2006.

However, a new survey has been done by our group. We have assembled data which were extrapolated from Regional and Provincial plans of mining referring to active and abandoned quarries. See Table 1 and Fig. 2.

Census has been done thank to the cooperation of regional and provincial offices of Mining Police. The questionnaire has been filled up by qualified and competent people such as geologists, engineers and mine experts.

The Questionnaire and Study Methodology

In Italy there are about 6,166 and 11,313 active quarrying sites, including recovered or abandoned ones. The Mining Police is the responsible institution for the control, the

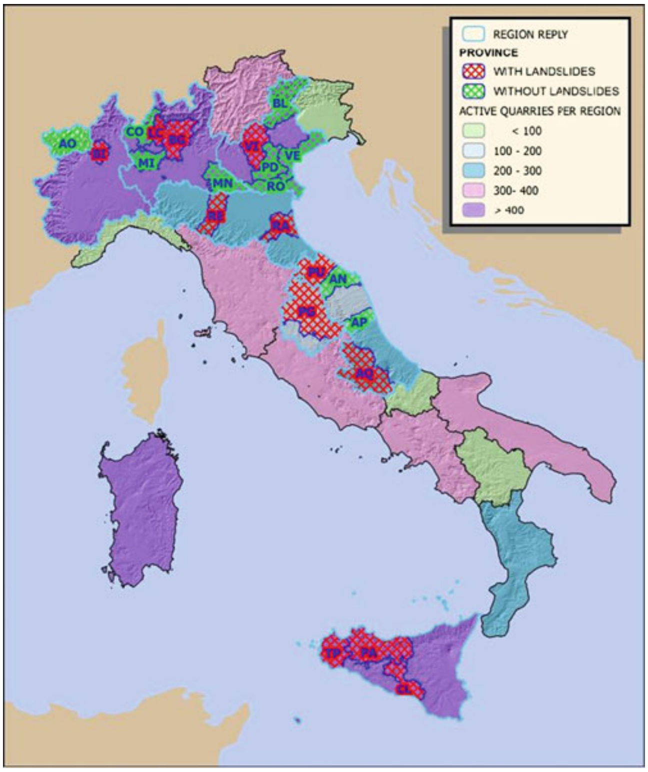

Fig. 2 Scheme of the density of active quarries in Italy. Only the provinces and regions that on July 2011 responded to the census are reported

granting of licence and the vigilance of the Quarries and Minings and is organized in 20 regions and 110 provinces.

The census campaign began in spring 2011 and is still having an unexpected success thanks to the efficiency in the response of the offices. We are still collecting questionnaires by writing this article and we hope to receive all answers by the end of the year.

The topics of the questionnaire are the following:

- Data of mining office;
- Features of the layer (sort of rock, loose or cohesive soil);
- Site where the failure occurred whether internal or external to the mining site;
- Cultivation method;
- Morphometric features of the front (height, tilt and extension of the front and terrace);
- Classification of the collapse (according to Varnes), type of release area (entire excavation face or front are equal, edge of slope, terrace), type accumulation area, storage area (limited fraction, terrace, pit, areas outside the site);
- Phenomenon recurrence;
- Features of the rock mass and/or soil (rock mass, rock land insertions, etc., fracture status);
- Bedding and fracture joints features;
- Presence of water;
- Triggering factor of the landslide (heavy rains, freeze/thaw cycles, earthquakes, etc.);

Table 1 Number of active and abandoned mining in Italy. Results comprehend both mining and quarries data

	Quarries		
Region	Active	Abandoned	Total
Abruzzo	239	–	239
Basilicata	51	32	83
Calabria	216	–	216
Campania	374	1,328	1,702
Emilia-Romagna	296	298	594
Friuli Venezia Giulia	69	–	69
Lazio	371	607	978
Lombardia	558	2,888	3,446
Liguria	98	542	640
Marche	176	996	1,172
Molise	57	–	57
Piemonte	581	340	921
Puglia	339	550	889
Sardegna	674	675	1,349
Sicilia	557	691	1,248
Toscana	380	993	1,373
Umbria	166	493	659
Valle d'Aosta	39	37	76
Veneto	603	783	1,386
Pr. Bolzano	162	10	172
Pr. Trento	160	50	210
Total	6.166	11,313	17,479

- Damage occurred (to persons and/or to things), internal or external to the mining area, need of front reprofiling interventions, interruption of the economic activity and damages to the viability;
- Additional documentation such as photos or technical reports.

Parallel to the census we are working to build a GIS database using the already existing data and adding new information: data of the existing quarries, stratigraphy and structural pattern and census of landslides reported in the IFFI Project (Fig. 3). The database is updated with the new information and those acknowledged from the census.

The First Results

From the questionnaire (survey limited only to 2 months), 23 files were collected. They referred to landslides in the mining of limestone for aggregates, limestone and lava for decorative stone, clay for bricks and pottery, limestone and marl for cement. It was also reported the collapse of a vault of an underground quarry that cultivated ornamental stone that caused the opening of a pit on the surface.

Offices of the following Regions were involved in the census: Valle d'Aosta, Piemonte (Province of Biella), Veneto (Province of Venice, Vicenza, Rovigo, Belluno, Padova), Lombardia (Provinces of Milan, Mantova, Como, Lecco, Bergamo), Emilia Romagna (Provinces of Reggio

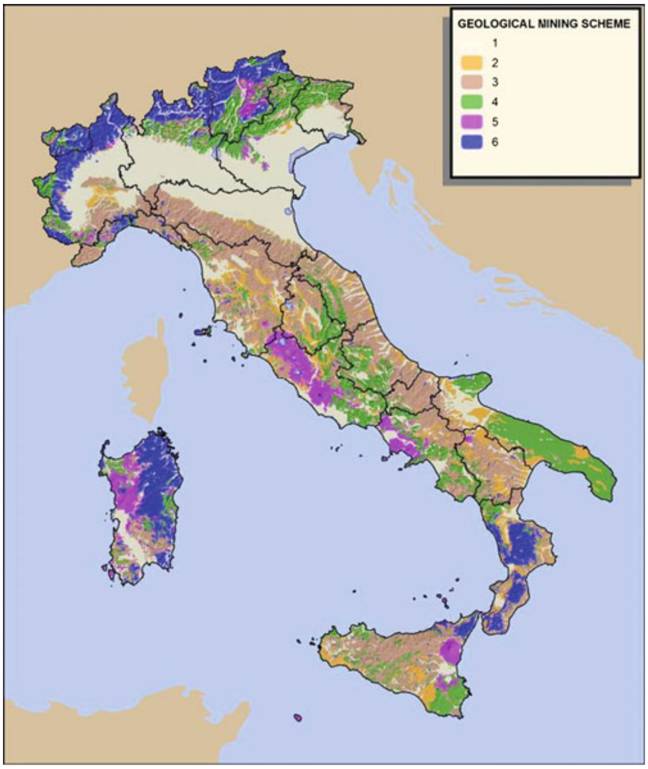

Fig. 3 Schematic geological mining of Italy. Legend: (*1*) sand clayey-conglomeratic (Pliocene-Quaternary), (*2*) clays (Pliocene-Quaternary), (*3*) marly-arenaceous rocks Flysch and Molasse – arenceous and clay stones (Pliocene-Mesozoic); (*4*) calcareous sedimentary rocks (Ordovician-Pliocene), (*5*) volcanic rocks – igneous extrusive (Triassic-Quaternary); (*6*) intrusive igneous and metamorphic crystalline rocks (Precambrian-Pliocene)

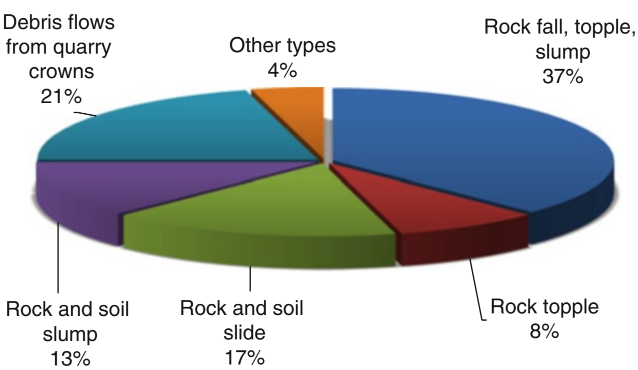

Fig. 4 Classification of the types of landslides that emerged from the census

Emilia, Ravenna), Marche (Provinces of Ascoli Piceno, Ancona, Pesaro and Urbino), Umbria (Province of Perugia), Abruzzo (Province of L'Aquila), Siciliy (Provinces of Trapani, Palermo, Caltanissetta).

The landslides reported occurred in a range of time between 1998 and 2011 and relate to important events of significant portions of the front (sometimes the whole site).

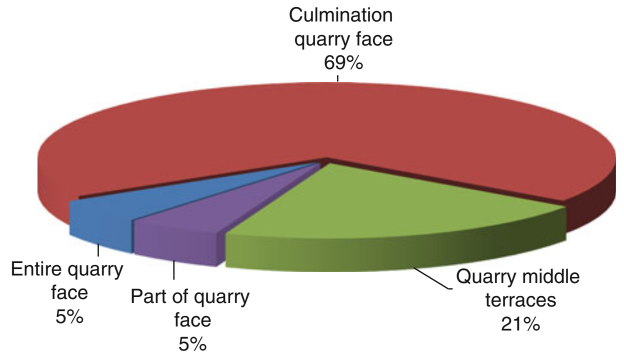

Fig. 5 Localization of damage inside the Quarry

In order to fix the damage many interventions were taken: re-profiling of the quarry or of partial steps and in one case a significant widening of the mining to secure the slope. The main damages regarded the stop of the activity, the interventions of re-profiling of the fronts were usually incorporated in the normal course of the project with modifications.

The landslides occurred mainly in those sites where ornamental rocks, clay for bricks, lava and limestone for aggregates grew.

The most common type of collapse for quarries in rock is represented by a fall of the crown of the yard with signs of detachment of wedges, of altered portions of the rock or debris flows (Fig. 4). Just in one single case a portion of an abandoned yard which had been recovered for 20 years has been involved from debris flows in an area of the natural slope.

With regard to soil or soft rock quarries, phenomena of translational slides induced by the presence of soft layers at the base have been reported, together with collapse of blocks on the side and above all a deterioration in the geotechnical characteristics in the flow of time.

In a catchment in the province of Reggio Emilia phenomena of flows and roto-translational collapse have been reported. They were regular corresponding to a stop of the yard in wintertime where heavy rain took place.

Most of the landslides regarded quarries of ornamental rock in Vicenza province, but these events are not related either to the type of field, or to the cultivation technique. They were collapses of the quarry crowning and portion of soil or rocks altered with mechanisms of rock fall, toppling, slump, wedge and debris flows and indifferent to the traditional method of cultivation of ornamental rocks, which set the yards in condition of dip slip position. However, the census has underlined that the edge of the quarry is the most frequent place for the inception of the landslide (Fig. 5).

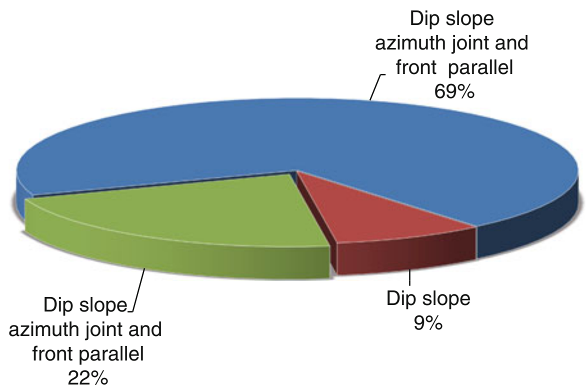

Fig. 6 Joint orientation related to strata attitude for census landslides

Compared to the size of the quarry sides, all the landslides were of modest size, all of them have involved limited areas inside the yard, while only two cases involved external areas.

The landslides occurred almost always in association with intense rains, freeze or thaw. In three cases the bases have been under excavated by river erosion or differential erosion for the presence of weaker levels at the basis of the slope. It is interesting to note that, most of the landslides occurred in conditions of unfavourable geological structure where the strata were dip-slip, rock masses were broken and in presence of faults and joint with not favourable position (Fig. 6).

The presence of water internal to the rocky ground was not relevant in the analysed cases even if this is a parameter which has to be studied.

Relevant cases are only a few. Let alone the widespread generation of different types of landslides in clay layers that were reported in the Province of Reggio Emilia and Ferrara, there are two high-profile cases we have been reporting.

The first in the Province of Pesaro and Urbino, where the entire front of the quarry collapsed exactly in the just recovered portion (Fig. 7a). As may be seen in the pictures, the geological structure showed densely layered dip slip rocks (succession of limestone and marly limestone with siliceous and marly interstrata – the Cretaceous Scaglia Rossa) and fracture joints and faults parallel to the cultivation front (see Fig. 7b).

In second case registered in the Province of Caltanissetta the entire quarry mining front made up of clays and calcarenites was affected by a rototranslational movement when the two layers got in contact (Fig. 8).

The census has provided a not yet fulfilling however very interesting outline of the landslides in the mining yards.

In Italy on about 6,166 active quarrying sites, about 23 files containing information of 28 landslides were filled. If these landslides were the only occurred in the entire national territory this would mean an incidence of 0.4 % of mine instability in a decade.

This result, however, is not relevant considering all the data that have been gathered. If we compare it with the results of the provinces that have answered at the census, it is not so far from reality.

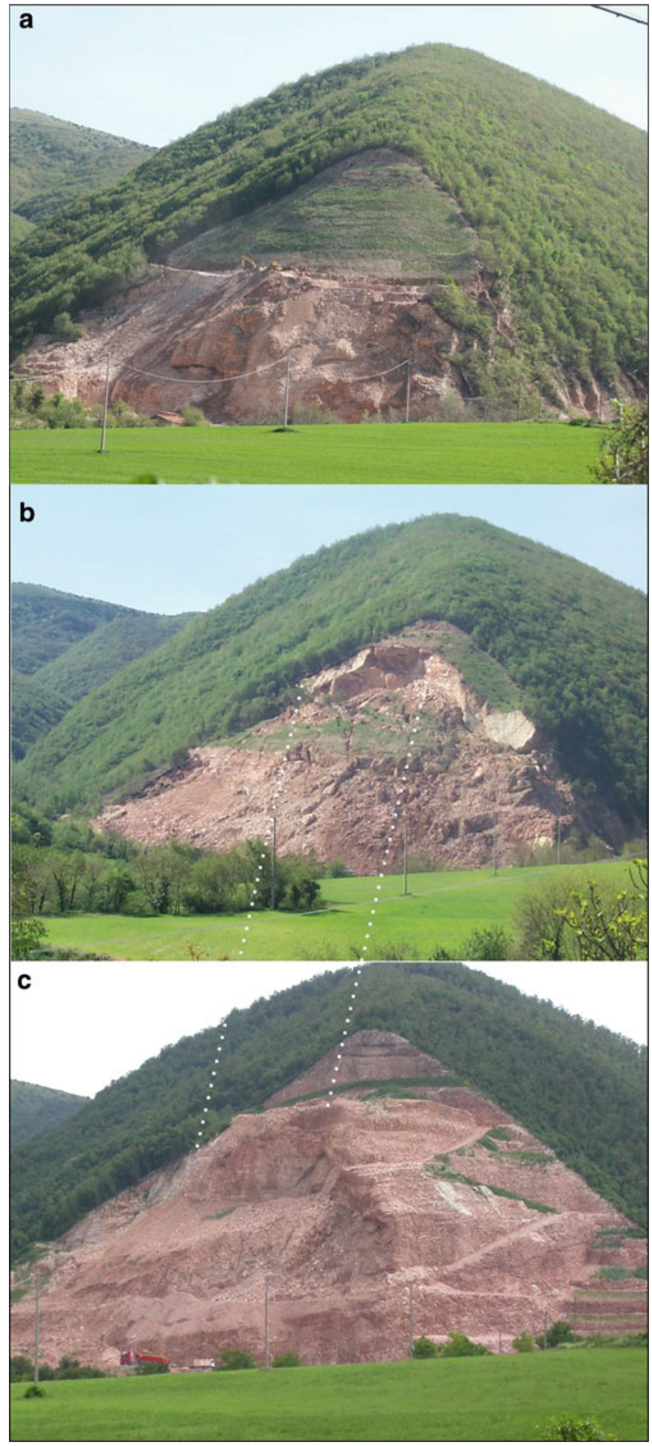

Fig. 7 Sequence of the dramatic evolution of a quarry face: (**a**) during cultivation and environmental restoration (1998); (**b**) collapse of the entire front of the quarry (2003) in which the current recovery phase has substantially broadened the area of intervention (**c**) (Photo F. Landini Police Mining Province of Pesaro and Urbino)

Fig. 8 The entire quarry face has collapsed with a shift of about 20 m (Photo M. Collalti Department of Energy – Geological and Geophysical Service IX Sicilian Region)

If we take into consideration the Province of Vicenza (Veneto Region see Fig. 1), where the concentration of quarries is very high (241 active quarries, 399 abandoned quarries), the frequency of landslides per yard is 2.9 % of active quarries, and it becomes 1.1 % if we consider also the not-active ones.

Finally, the study found that only in two cases (those shown in Figs. 7 and 8) the mining activity has caused a damage at the territory in terms of landslide.

Conclusions

The census of the landslides in the quarries has been done in order to know the efficacy of the design. If we borrow from the surgery, the concept of "success rate for type of intervention", (numbers of designs that did not have landslides in active quarries) we can have an idea about the safety of design techniques.

In the Veneto Region except for the provinces of Verona and Treviso (see Fig. 2), the efficacy of the design is 97.7 % (7 cases out of 305 active quarries). If we apply it to the province of Pesaro and Urbino, we obtain a value of 97.1 % (1 case out of 35 a.q.), to the Sicilian Region 99.3 % (4 cases out of 557 a.q.), to the province of Reggio Emilia 93.1 % (2 cases out of 29 a.q.), to that of Ferrara 93.3 % (1 case out of 15 a.q.) and 99.1 % (1 case out of 112 a.q.) to the province of Bergamo.

If we accept the statistical value of these numbers we can compare them to the percentage of success of surgery for routine work such as cataracts or an appendectomy (95–98 %). In this case we could define the designer of quarries as successful surgeons, or, more simply, that the regulations have provided an acceptable safety level.

Has the evolution of the new legislation improved the situation? Surely it is much more conservative because it gives much smaller parameters than the previous law, and also because it requires additional reductions related to the estimated seismic acceleration of the project with a return period of 35 years.

It is relevant to remember how important is to face the problem of the excavation of the quarry faces thinking more at the needs of the sector starting with the following points:

1. To calibrate the corrective factors for the deduction of the design parameters from those characteristic to the specific needs of rock masses;
2. To take into consideration that mining yards often cover large areas at the base of slopes. Focusing on safety, the design of a quarry face should cover not only the effects on the entire slope, but also those that the slope could create in that site (landslides, avalanches, etc.);
3. As far as calculation of seismic activity is concerned, the legislation requires the estimation of a minimum return period of 35 years that seems overly restrictive;
4. The legislation fails to consider, for quarry faces, the, monitoring and evaluation of the deformation at SLE. Considering the size of certain quarry faces, it would be appropriate to impose control systems during the work and for a certain period after the environmental recovery.

Through this study other interesting factors have emerged that will also contribute to other studies dedicated to the evaluation of landslide susceptibility, providing a comprehensive picture on the stability of slopes. Another contribution is given to the estimation in back analysis of the limit angle of the natural slopes.

Acknowledgments We would like to thank the Offices of Mining Police of the following Regions: Abruzzo, Emilia Romagna, Lombardia, Marche, Piemonte, Siciliy, Umbria, Valle d'Aosta, Veneto. Many thanks to Anna and Veronica Bilotta and Marco Ciardullo.

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Part IV

Landslide Education, Training and Capacity Development

Introduction by Dwikorita Karnawati[1] and Surya Prakash[2]

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Different from the earthquake, tsunami and volcanic eruption, landslide occurs in more local area and has more localized impacts but higher frequency of the events than those of the other catastrophic disasters. Therefore the societal risk of landslides eventually increases, especially in the mountainous region with high density of population and uncontrolled landuse development.

It is apparent the increasing numbers of landslide occurrence as well as the landslide risk and impacts strongly controlled by inappropriate capacity of the local community and improper existing disaster management system, to prevent and mitigate the landslide occurrence. Even though, misperception that the landslide disasters are natural, seriously sacrifices the awareness for landslide prevention and mitigation.

This chapter focuses on landslide education, training and capacity development to promote awareness and preparedness against disasters, thus reducing the risks and losses. Most of disasters occur, where the communities are not well aware, informed and prepared. Absence of awareness and preparedness results into poor implementation of landslide prevention and mitigation measures, and thereby brings down the capacity/resilience to disasters. Therefore, papers related to various efforts or programs to develop capacity of the society to make them resilient against the landslides, are presented in this chapter. Innovative approaches and methods, case studies, best practices and lesson learnt from past disasters for improving the quality and efficacy of landslide education and training, at the local, national or global levels are promoted as the strategic alternative of approach and model for capacity development program to reduce the landslide risk.

Capacity development program should be targeted to all actors in the disaster management system, which includes the practitioner, young scientist, student, government/policy maker, local people, etc. Accordingly, this chapter demonstrates various strategy and approaches to develop the capacity of all those relevant actors. It is also highlighted in this chapter the necessity to improve the interest of society by implementing attractive outreach activities. One excellent case example is a community-based landslide risk reduction activities, which have been successfully implemented in several Eastern Caribbean communities during the period 2005–2011 with the MoSSaiC – Management of Slope Stability in Communities program developed by Halcombe et al. This is such a smart strategy due to its holistic approach, which engages all stakeholders throughout implementation cycle. Similar approach is also promoted in Indonesia by Karnawati et al. through the student community service program as well as in India by Prakash et al. and in Laos by Hearn and Hunt. Moreover, to ensure the capacity of all stakeholders is raised to meet expectations, Parlan et al. introduces PASTI as an instrument used to measure community based preparedness in Indonesia that covers three basic aspects: basic human service, community development and disaster risk analysis for nine typical threats which include landslide.

It is also highlighted in this chapter the importance of public education program for landslide disaster risk reduction, such as has been conducted in Malaysia by Eriko and

Hassandi and in Germany by Wolfgang. Furthermore, Margottini attractively demonstrates the importance of a Museum to facilitate public education for landside risk reduction in Italy, and Wang et al. provides a review on the current status of landslide guideline around the world. Then, the role of anthropogenic factors on development of selected active landslides in recent history of Slovakia is reviewed by Medvedova et al., whilst Petrone and Preti presents a lesson learnt from South Africa and Ecuador which discusses the implementation of soil bioengineering measures for landslide mitigation and environmental restoration,

Learning from all of the papers in this Chapter, it is finally considered that the capacity development through landslide education, training and public outreach activities should create awareness amongst communities, but also encourage the improvement of responsibilities. By implementing a strategic capacity development program, eventually the society resilience to reduce the risk of landslide disasters can be improved, and so the sustainable development in the landslide prone area can be achieved. This has been the commitment of International Consortium on Landslides through the establishment of a special Network for Capacity Development.

Landslide Risk Reduction in Developing Countries: Perceptions, Successes and Future Risks for Capacity Building

THE SECOND WORLD LANDSLIDE FORUM

Malcolm G. Anderson

Abstract

There is widespread recognition by the international community of the significance of risk reduction measures in the context of natural disasters. However, as far as landslide risk in developing countries is concerned, evidence suggests that: (1) Risk is accumulating; (2) Relatively few ex-ante risk reduction measures are delivered on the ground; (3) Community residents often construct inappropriate risk reduction measures; (4) Peoples' perception of risk is not in accord with the likely impact of the event, or the probability of its occurrence. A community-based approach to landslide risk reduction can help to correct perceptions, deliver on the ground impact and locally arrest risk accumulation. Whilst this can be seen as a successful methodology to deploy, there remain significant future risks. Most notable are the rate of population growth, and the associated growth of poor, unregulated housing on steep vulnerable slopes adjoining urban areas.

Keywords

Landslide • Community • Capacity build • Risk perception • Future risks

Introduction: Risk Perception Is Important

Reports from the international development agencies, geoscience and engineering communities all point to an increase in the occurrence of natural hazards and their consequences, especially with respect to countries with low to medium levels of development (IFRC 2002, 2004; UNDP 2004, 2008; Alcantara-Ayala 2002; AGS 2000). A comprehensive discussion of this trend is given by the IFRC in their annual World Disasters Report. Taken overall, there is clear evidence of the increase both in the number of natural disasters over recent decades, and in the insured and uninsured losses associated with those events (Fig. 1).

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Despite that recognition, and the acknowledgement that ex-ante risk reduction is likely to be preferable from both a humanitarian and economic perspective, 90 % of bilateral and multilateral disaster-related funding is still spent on relief and recovery after the event (ex-post) (Blaikie et al. 1994).

There is thus something of a disjuncture at the international level that is seeing an increase in natural disasters, policy that is not arresting the risk accummulation, and difficulty in moving to ex-ante measures.

To gain an appreciation of the full context for risk reduction policies, to this observation must be added the perception of risk of the individual resident. Evidence suggests that most people who are potentially at risk, discount the likely impact of the event, and the proability of occurrence of the event itself:

> The bad thing is not going to happen; If the bad thing does happen, it's not going to happen to me; If the bad thing does affect me, the effects will be minimal. (FM Global 2010)

> . . . people are generally not well prepared to interpret low probabilities when reaching decisions about unlikely events . . . People underestimate both the probability of a disaster and the accompanying losses. (Kunreuther and Useem 2009)

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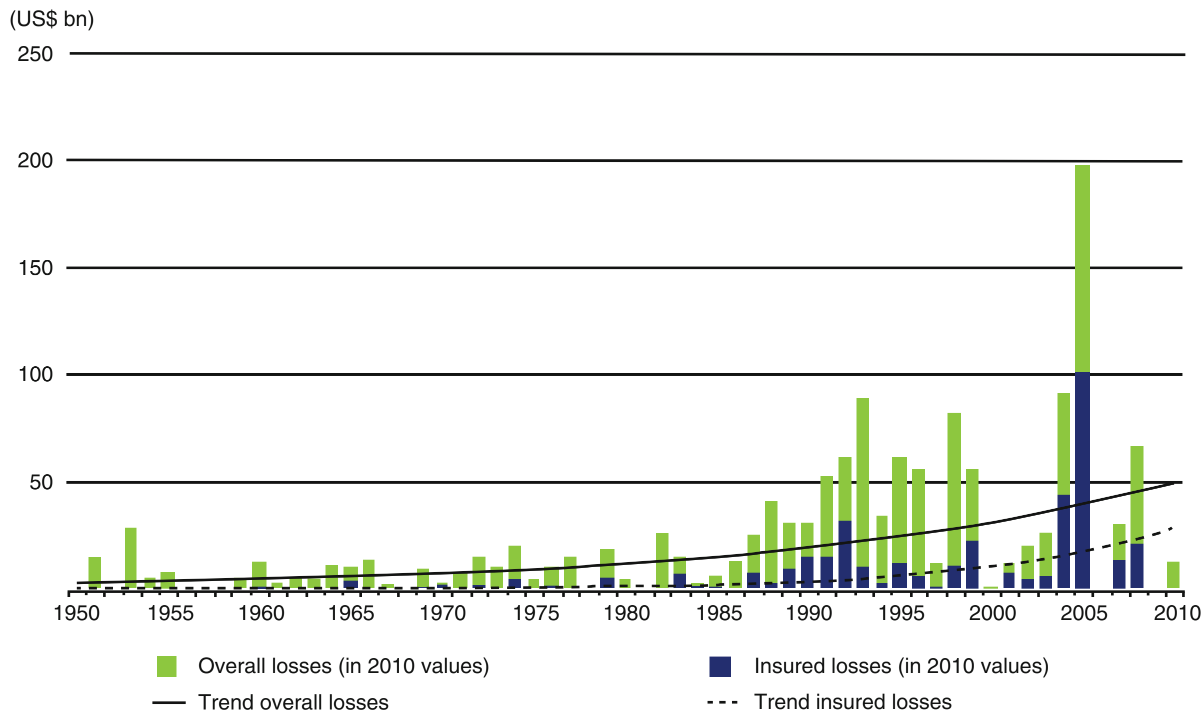

Fig. 1 Economic losses associated with natural disasters (© 2011 Münchener Rückversicherungs-Gesellschaft, Geo Risks Research, NatCatSERVICE)

The Science of Slope Instability

Whilst the perception, behaviour and response by individual residents and the international community is complex and potentially misaligned, the science of slope stabilisation and associated landslide risk reduction has a more sound evidence base.

In vulnerable communities in developing countries residents typically construct small retaining walls, perceiving that such structures will improve slope stability conditions. However, failed retaining walls are a common sight (Figs. 2 and 3); numerical simulations show such 'domestic' constructions are often structurally unsound. Such structures often result in an increase in pore pressure upslope of the wall during major rainfall events, resulting in the wall failing due to overturning forces (Anderson et al. 2008, 2011).

To assess the hazard at the scale of the triggering process is important if actual mitigation works are to be undertaken. Models that predict slope processes provide further insight into instability triggers and suitable risk mitigation approaches. For communites on steep vulnerable hillsides (Fig. 4) such models can show that effective landslide hazard reduction can often be achieved through surface water management.

To enable scientific assessment of such options, Anderson et al. (2010), authored and used the CHASM software, a physically based combined soil hydrology and slope stability

Fig. 2 Retaining wall on a landslide prone hillside, built by a resident in the belief that it would provide sufficient structural support to reduce landslide risk

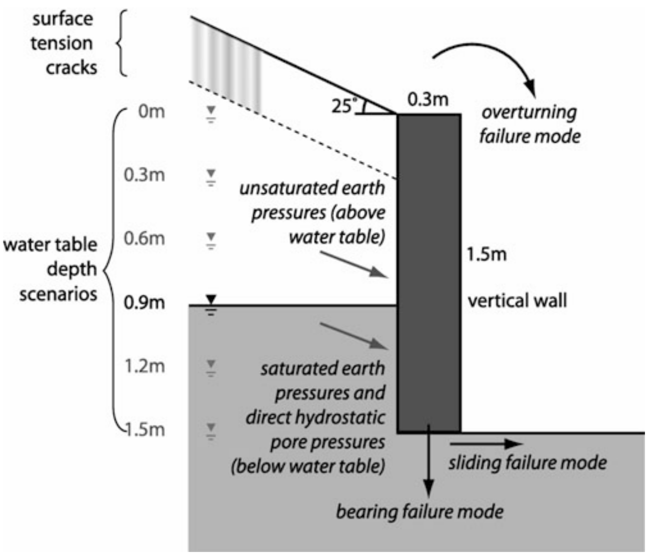

Fig. 3 Numerical analysis can be applied to retaining structures (Fig. 2) to ascertain the effectiveness of the structure in stabilising slopes at risk of instability (after Anderson et al. 2011)

Fig. 4 Houses built on deep residual soils on steep slopes are vulnerable to landslides triggered by major rainfall events

model that comprises fully integrated hydrology, surface cover (vegetation) and stability components. We have described certain of the main features of the model elsewhere (Anderson et al. 1996, 1997; Wilkinson et al. 1998, 2000). Within CHASM, rainfall infiltration is determined by hydraulic conductivity conditions, vertical flow in the unsaturated zone is computed using Richards' equation solved in explicit form inside vertical columns, and Darcy's law is used to represent saturated flows. Within the integrated model structure the hydrology scheme represents slope plan curvature (convexity and concavity) by varying the breadth of the columns. The effect of the three-dimensional topography on water fluxes can thus be investigated and its impact on stability estimated (Geotechnical Control Office 1982). The generated pore pressure field is then used as input to standard two-dimensional stability analyses where the slip surface is located within the mid-plane of the pseudo three-dimensional structure. CHASM uses Bishop's (1955) simplified circular method for estimation of the slope's factor of safety (FOS) with an automated search procedure (Wilkinson et al. 2000). Pore pressures, both negative and positive, are incorporated directly into the effective stress determination of the Mohr-Coulomb equation for soil shear strength. This allows derivation of the minimum FOS, with temporal variations arising from hydrodynamic responses and changes in the position of the critical slip surface (Wilkinson 2001).

More complex slope stability assessment is afforded by potentially progressive failures. In these circumstances, to confirm more precisely the likely causes of instability and assist in any potential future risk reduction strategy, a comprehensive simulation can be undertaken using software such as FLAC or 'Fast Lagrangian Analysis of Continua' (Itasca 2000; Anderson et al. 2010). FLAC is a two-dimensional explicit finite difference program for engineering mechanics computation. This program simulates the behaviour of structures built of soil, rock or other materials that may undergo plastic flow when their yield limits are reached. Materials are represented by elements, or zones, which form a grid that is adjusted by the user to fit the shape of the object to be modelled. Each element behaves according to a prescribed linear or non-linear stress/strain law in response to the applied forces or boundary restraints. The explicit, Lagrangian calculation scheme and the mixed-discretization zoning technique used in FLAC ensure that plastic collapse and flow are modelled very precisely. Runout can also be represented if a plane of detatchment is specified.

Slope stability models, appropriately parameterised, can therefore guide landslide risk reduction approaches, and themselves be a constituent element in a broader methdology for policy change (Fig. 5).

Can We Use Science to Encourage the Right Policy?

We have observed firstly the policy recognition of the importance of landslide risk reduction, and secondly the ability of numerical modelling to provide guidance on mitigation measures, but, for reasons we will discuss further, it is clear (Fig. 1) that the impact of current policies are falling short of what is needed: "During the past three decades policy statements by all major agencies have included risk reduction as a pre-condition and an integrated aspect of sustainable development ... but when it comes to practical

Fig. 5 Providing effective surface water management on slopes, rather than retaining structures (Fig. 2), can be an effective way of reducing landslide risk

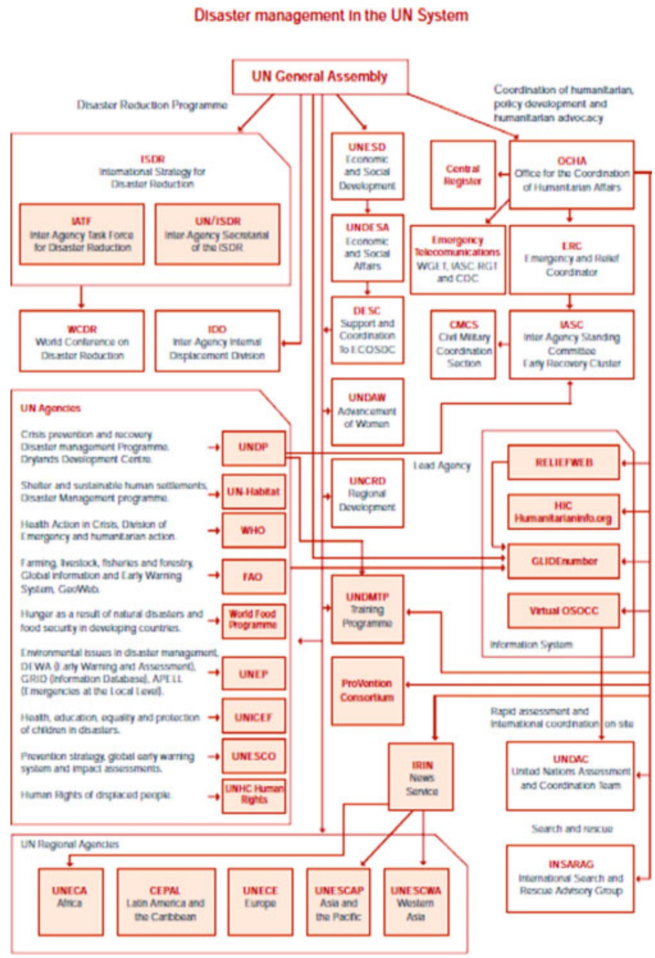

Fig. 6 The institutional complexity in the UN disaster response organisational framework (after Lloyd-Jones 2006)

implementation, comparatively little has been done" (Wamsler 2006, p 159). A contributing factor here may well lie in the complexity of the international frameworks (Fig. 6).

Whilst international governance frameworks of this form have a logic in terms of their origin, Segone (2004) notes: 'The traditional separation between the policy arena, practitioner communities and the research and evaluation community has largely proven unhelpful'.

In an attempt to make these connections between policy, communities and science to provide for on-the-ground delivery of mitigation measures, we created MoSSaiC (Management of Slope Stability in Communities). The programme sought to justify the rationale for landslide hazard reduction measures to all stakeholders – policy-makers, practitioners and communities. This is at the heart of an evidence-based process – in integrating appropriate technical capacity with the full engagement of policy makers it goes beyond simply seeking political influence (Fig. 7).

Over a period of 6 years in the Eastern Caribbean, we received funds of ~US$6 million for undertaking construction of drains and other surface water management elements in a range of unplanned communities on steep, landslide prone hillsides. The majority of funds went to residents in those communities to undertake the construction. Four principle outcomes emerged:

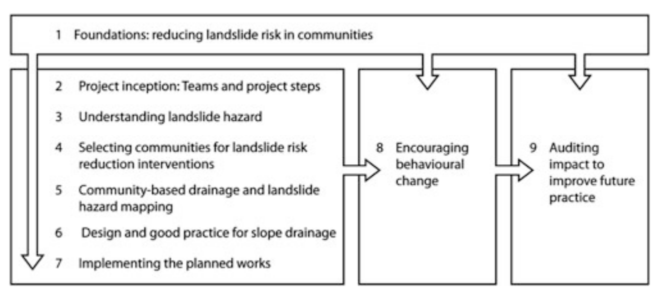

Fig. 7 The nine components of MoSSaiC: note that public awareness and audit preparation should run throughout any project

(a) The Community-based approach to landslide mitigation was approved by Governments and donors alike (Anderson and Holcombe 2006a, b). We explored with community members and other local stakeholders an approach to landslide risk reduction that was designed at the local level. In this context, using Easterly's (2006) definition, we adopted the 'searchers', rather than 'planners' approach.

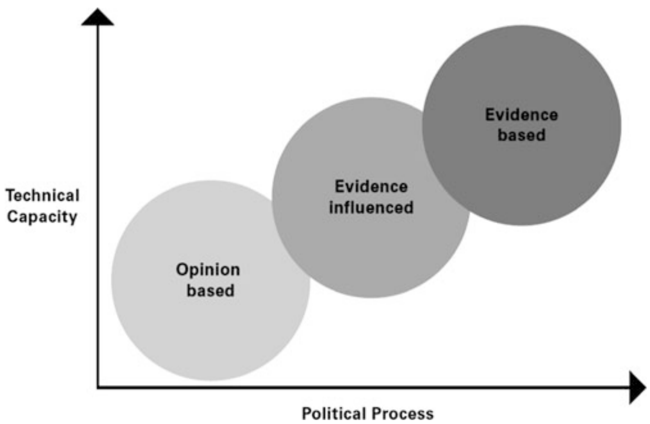

Fig. 8 Dynamics of policy making. MoSSaiC methodology seeks to deliver evidence-based policy (after Segone 2004)

(b) The mitigation measures were successful in so far as, post-intervention, the slopes remained stable even during the passage of Hurricane Tomas in St Lucia (~1 in 500 year, 24 h rainfall event, of 550 mm). Pre-intervention, such slopes had shown signs of instability for 24 h rainfall events with return periods as low as 1 in 2 years (Anderson et al. 2011).
(c) The approach has been shown to have a benefit:cost ratio of 2.7:1 (Holcombe et al. 2012).
(d) The novelty and success of implementation approach, the physical performance of the measures and the cost-effectiveness, has meant that donors are supportive of the approach being rolled-out more widely (Anderson et al. 2010; Holcombe and Anderson 2009).

Auditing outputs and outcomes is an important aspect of project delivery. The audit process should deliver technical and scientifically-based evidence of not just *what* has worked (or not worked), but *why* it has worked (or hasn't worked). If recognised in the political process, then this should position MoSSaiC as contributing 'evidence-based' policy (Fig. 8). This accords with the needs of policy makers 'who are increasingly asked to explain not just *what* policy options they propose, and *why* they consider them appropriate, but also their understanding of their likely *effectiveness*' (Segone 2004).

Why We Must Understand the Drivers of Evidence-Based Policy

A methodology like MoSSaiC can thus migrate from a starting point of a having a political champion (with an opinion that the methodology should work), to delivering evidence to the political process of the methodology having worked on the ground. This transition could be seen as migrating from opinion-based policy to evidence-based policy. It is, however, worth examining what drivers may exist in linking policy and research, and hence defining more precisely the meaning of the term 'evidence-based policy'. Young et al. (2002) define five models of research-policy connections (Table 1), which can usefully be portrayed as in Fig. 9. From these definitions, MoSSaiC is 'interactive' in terms of the connections made between research and policy.

Table 1 Conceptual models of research-policy connection that Young et al. (2002) define

Model of research policy connection	Model description
Blue sky	Research somewhat distant from immediate policy concerns. Research benefits policy somewhat indirectly
Knowledge driven	Research leads policy
Interactive	Research and policy are mutually influential
Problem solving	Research follows policy
Political/tactical	Policy is the outcome of the political process

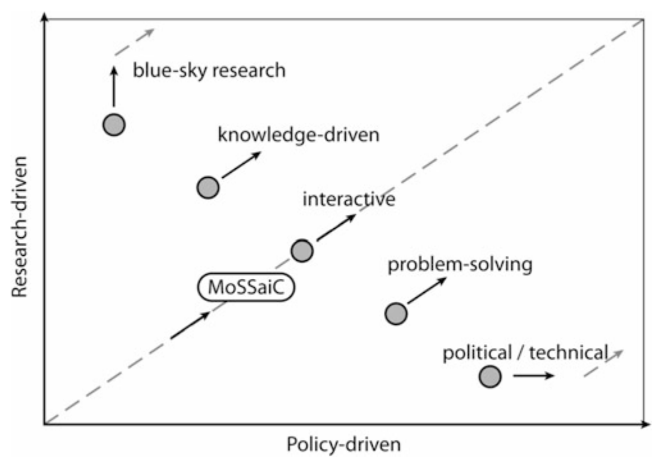

Fig. 9 Conceptual research-policy models (based on ideas in Young et al. 2002)

Means of improving the processes by which policy is made has been reviewed by Nutley et al. (2002). They include mechanisms to increase the pull for evidence and mechanisms that facilitate the use of that evidence (Table 2). In mapping the MoSSaiC approach onto the list of enabling factors summarised by Nutley et al., it would appear that MoSSaiC contains elements relevant to, and consistent with, processes aimed at improving the policy setting process. Equally, it is important that all sound evidence is presented in the policy arena and that available evidence does not go unused.

Table 2 Factors aimed at achieving a better use of evidence in policy making (Adapted from Nutley et al. 2002), onto which relevant characteristics of MoSSaiC are mapped

Increasing the pull for evidence	MoSSaiC inclusion
Require the publication of the evidence base for policy decisions	MoSSaiC seeks to justify mitigation measures
Require departmental spending bids to provide a supporting evidence base	Bids could be supported by evidence from MoSSaiC interventions
Provide open access to information – leading to more informed citizens and pressure groups	MoSSaiC is community focussed and involves a wide range of stakeholders throughout
Facilitating better evidence use	MoSSaiC inclusion
Encourage better collaboration across internal services	MoSSaiC de facto encourages collaboration
Cast external researchers more as partners than as contractors	MoSSaiC encourages this inclusion
Integrate analytical staff at all stages of the policy development process	MoSSaiC aims to simultaneously ensure existing policy awareness and create policy suggestions through the Government management and technical teams

Policy recognition is likely to occur after project performance evidence has been provided to Governments and donors, who subsequently recognise the project as being of value. In turn, policy recognition may manifest itself over time (perhaps 3–5 years) in the form of commitment to further similar initiatives.

The Strategic Incremental Approach to Policy Change

It follows that the journey from 'opinion' to 'evidence-base' policy is likely to be both strategic and incremental – a process of 'strategic incrementalism' (World Bank 2004) (Fig. 10). This recognised process is one which strengthens structures and increases the likelihood of behavioural change. This cycle of incrementalism, can be used as a platform to create behavioural change for landslide risk reduction (Fig. 10). Such a cycle was directly reflected in the MoSSaiC implementation process, starting with the establishment of the management team and ending with the evidence base.

Strategic incrementalism encapsulates a longer term view, embodying the fact that incremental activities should be used to create more favourable conditions for reform in the longer run – linking current operational actions with long-run institutional strategies and goals (World Bank 2004, p 114). The concept of "strategic incrementalism" suggests that wholesale reform is rarely achievable. What can be sought, instead, is an approach which is incremental, but which is so in a strategic way, with an eye to sustained progress over the long term (Lavergne 2004, 2005).

In contrast, incremental incrementalism (effectively a temporary work-around) cannot and should not substitute for creating the conditions for reform. The core objective has to be that of striking a sensible trade-off between comprehensive and incremental reforms, seeking early wins for stakeholders and supporting reform champions and

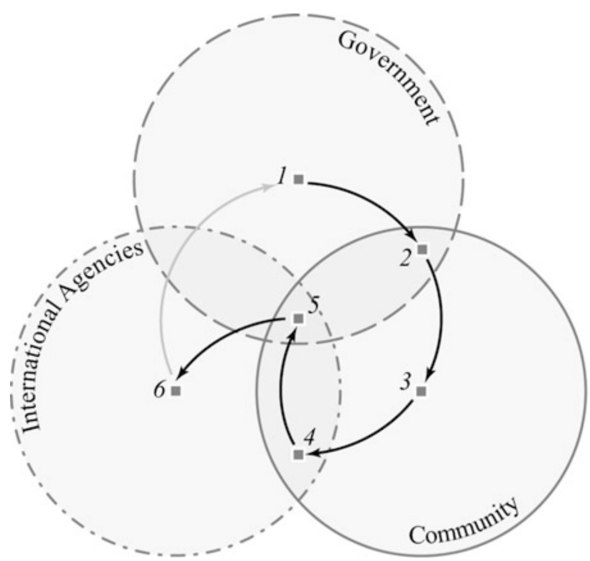

Fig. 10 The process of strategic incrementalism depicting six steps: from the formation of the local interdisciplinary management team (step 1), engaging community development agencies or organisations and communities (step 2), community-to-community knowledge transfer (step 3), to recognition of on-the-ground projects by regional/international development agencies (step 4) and the move to a wider acceptance of preventative policies and implementation at community, government and development agency levels (steps 5 and 6)

cross-agency teams that can bring along others of like mind (World Bank 2004). Stakeholders need regular reminders that all actions that take place in development projects affect peoples' motivation and psychology; it is that recognition and sensitivity that creates the best environment to identify and self motivate champions for innovative risk reduction projects.

The strategic incrementalism approach of progressive engagement (and associated shared learning), is consistent with the MoSSaiC 'interactive' model of research-policy connection. That connection can, given sufficient uptake of MoSSaiC by Governments, manifest itself in formal policy.

For example, MoSSaiC is referenced in the St Lucia Government's landslide response plan. This inclusion raises awareness, not just amongst Government officials, but potentially more widely, as practises are reviewed and shared between countries in the region. Evidence that could be recorded as policy uptake might include:

- Community-to-community knowledge transfer (Fig. 10, Step 3)
- Interest, visits and support from new donors (Step 4)
- An enlarged group of stakeholders (Government, donors, Social funds) jointly working together and submitting a new proposal for MoSSaiC interventions (Step 5)
- Evidence of donors themselves promoting and proposing MoSSaiC interventions (Step 6)

Future Risks

The arguments we have reviewed relating to the need to deliver risk mitigation on the ground, have to be placed in the context of future perceived risks if risk accumulation is to be successfully addressed. Future scenarios for local landslide risk mitigation are rarely envisioned – they are too often 'frozen' in GIS mapping of landslide susceptibility. As we have noted, such maps do not generally facilitate the selection of hazard reduction approaches, nor incorporate relevant aspects of social change. There are a number of factors that are acting to shape the form and effectiveness of future landslide mitigation strategies that need recognition and consideration. These include aspects of significant social change, and the potential continuing scarcity of analytical data to support detailed cost-benefit analysis of community-based mitigation.

Urbanisation

However, we need to recognise that society is changing faster than climate change. Urbanisation is a major contributor to landslide susceptibility. Four important drivers provide a critical context for the accumulation of landslide risk. Significant rise in the global population (Fig. 11) is accompanied by increased urbanisation, and poor housing (Fig. 12), which results in the most vulnerable having the greatest exposure to landslide risk.

The following urbanisation factors serve to increase the potential for landslide risk:

- In many locations the amount of unplanned housing (approximately 60 % in areas of the Eastern Caribbean, for example) exceeds that of planned housing. In such circumstances planning and associated zonation policies have limited impact.

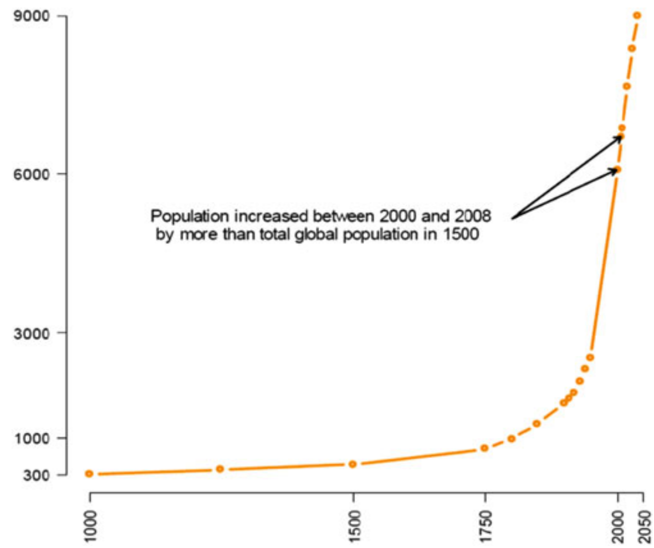

Fig. 11 Increase in the world population (after Coburn and Maynard 2010)

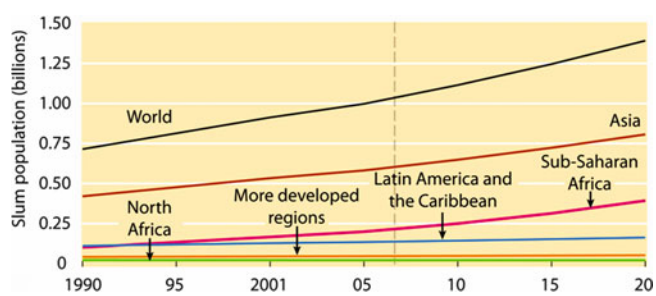

Fig. 12 Increase in the slum population accompanies population growth and urbanisation (after Bloom and Khanna 2007)

- Unplanned, or 'informal', housing often being located on already landslide-prone slopes. Whilst typical slope zoning requirements for a landslide-prone area suggest that no houses should be built on slopes that exceed 14° (Schuster and Highland 2007), informal housing settlements are invariably on hillslopes considerably steeper.
- Informal housing contributes to slope instability by:
  - Residents cutting slopes at steep angles to provide benched slopes for additional housing
  - Redirecting storm runoff so that flows are concentrated onto portions of slopes that are not prepared to receive them.
  - Adding water to slopes from septic systems.
  - Removing trees, shrubs and other woody vegetation.
- The very rapid growth in numbers of people living in unplanned housing areas in the low income "barrios" of Caracas, Venezuela, it has been estimated that about 40 % live in low income barrios that grow in population at an annual rate of about 20 % (Schuster and Highland 2007).

The response to this is that there is perhaps 'a need to focus on building responsive institutional arrangements that monitor change and maximize the flexibility of populations to respond creatively and constructively to it' (Rayner and Malone 1997). MoSSaiC, with its local multi-disciplinary management team, and focus on communities, is designed to create just such a responsive mechanism.

From a political standpoint the most pressing issues here often relate to the increasing pressure to develop on landslide prone slopes. In developing countries migration generally involves the most vulnerable moving from rural areas to these marginal urban fringe areas. This trend suggests that landslide risk will continue to increase unless effective mitigation measures are delivered on the ground. An attendant issue for Governments to consider is the degree to which they would regard the construction of landslide mitigation measures as "legitimising" unplanned (unregulated) communities in such circumstances. This is an issue that would need to be reviewed at the point any such project is considered for implementation.

Cost-Benefit Analysis

Many people in developing countries live in highly concentrated areas in structures that are susceptible to extensive damage and complete destruction in a disaster. Consequently, relatively inexpensive hazard mitigation strategies might reap substantial returns in lives saved and economic losses avoided, yet these programs are slow to evolve as these nations rely on foreign organizations to provide the resources to design and implement them. The World Bank and US Geological Survey calculated that economic losses worldwide from natural disasters in the 1990s could be reduced by $280bn if $40bn were invested in preparedness, mitigation and prevention strategies (Dilley and Heyman 1995). In risk reduction work, cost-benefit analysis is usually applied to large-scale projects, especially those involving structural mitigation, and this is reflected in the standard methodological guidance available (OAS 1991). Whilst the widespread view is that the results of cost–benefit analyses make a convincing case for risk reduction, Twigg (2004) argues that such examples should be treated with caution, however. They are few and far between, at least in the published literature, where they are usually presented as statements of fact without explanation of how the calculations were made. 'The readiness with which publications on disasters repeat such assertions should perhaps be worrying, as it suggests that little substantiated data is available' (Twigg 2004).

For these reasons, we considered it important to undertake a cost-benefit analysis of the landslide mitigation measures we implemented. For a sample community the computed benefit:cost ratio was 2.7:1 (Holcombe et al. 2012), acknowledging of course that such an analysis has to express all benefits and costs in monetary terms (Ganderton 2005). This is in line with the small number of community-based reports such as that of a World Bank team working in La Paz, Bolivia, which calculated that disaster prevention and preparedness would cost $2.50 per capita, whereas annual losses from property damage alone resulting from natural disasters were estimated at $8 per capita (Kreimer and Preece 1991).

The risk is that the presence of widely stated and held, but seemingly uncritical, assertions in relation to mitigation benefit:cost ratio, becomes enshrined within the delivery process, and fails to stimulate the real need for cost-benefit analysis which is to inform Governments, donors and residents alike of the value of the investment (does it pay?).

Political Agendas

There are four political issues that, in combination, become a risk to landslide risk reduction implementation. Firstly, the political cost – maintaining funding continuity and concept momentum is difficult since 'the political costs of redirecting priorities from visible development projects to addressing abstract long-term threats are great. It is hard to gain votes by pointing out that a disaster did not happen'. Secondly, the timeframe – the fact that for a mitigation project, from conception, through funding, to delivery, can typically take 3–4 years – that being the median period for the models which we have used. Thirdly, change of Government – since a key element in the community landslide risk approach we have taken is to involve Government and Communities alike, then a change in Government can potentially bring about significant changes in commitment. Fourthly, those stakeholders who are not supportive of mitigation (for whatever reasons) have an interest in expanding the perception of any uncertainty (Kasperson 2008).

The partial offset to this risk is the engagement of politicians and senior civil servants across the political and Government spectrum to seek to achieve a common acceptance of the mitigation need and methodology, thus enhancing the likelihood of commitment, even with Government change. This we have witnessed with an incoming Government renewing Budget funding for community-based landslide mitigation. Notwithstanding, Prater and Londell (2000) affirm the instability of political agendas over time as a substantive risk, commenting that the key to getting policies adopted is persistence, best achieved they suggest by 'policy entrepreneurs' to champion and promote the relevant approach. To have someone knowledgeable in both the technical and political spheres, who is able to enthusiastically promote the approach, is critically important to offset the risk of potential major funding breaks. It is not just a financial risk that is being offset however. Because conflict is certain and some interests are likely to be threatened by any policy change, the role of policy entrepreneur reduces the risk of mitigation measures being 'taken off the agenda' by groups having other interests which they wish to be more dominant.

Discussion

International agreement on policy regarding ex-ante risk reduction needs to be translated into more on-the-ground activity. Whilst there have been similar, generalised, assertions made previously (e.g. Kalsnes et al. 2008), the consequential questions of how should this be done? and what are the risks?, have neither been explicitly stated nor addressed.

We see this as a critical need if substantial advances are to be made in arresting landslide risk accumulation in developing countries. To directly address these issues, we have reviewed the benefits and success of a programme of landslide risk reduction that was implemented by community residents, was cost effective, physically successful, received policy uptake and is in the process of delivering behavioural change (World Bank 2010). This programme ensured that the scale of the intervention was appropriate to the triggering mechanism (rainfall infiltration), and thus that mitigation works (management of surface water) could be designed. In being a 'bottom-up' approach, it is suited to delivering policy recognition through a process of strategic incrementalism.

In implementing the methodology, our experience was that there is evidence of behavioural change, both at the scale of community residents, and of international donors (Anderson et al. 2011; World Bank 2010). Building on this methodology, and scaling up the implementation, is the next major challenge. What we have outlined is a blueprint, rather than a prescriptive approach. It will need adaptation to the local context.

Whilst a community-based methodology may be suitable in terms of effective hazard mitigation, there is every possibility of continued accumulation of landslide risk, driven by the global process of urbanisation. The poorest move to those areas that are least expensive to live, these being the most vulnerable slopes, typically surrounding urban areas. This transition coupled, with a substantial unregulated housing stock in many developing countries, presents a major challenge to numerous countries. The community-based methodology for landslide risk reduction we have outlined has the potential to impact positively on risk accumulation, but it now requires a substantial programme of dissemination and adoption, given the marked current spatial and temporal trends in population.

Malamud and Petley (2009) observe that 'Although a large percentage of existing natural disasters are in less developed countries, there is depressingly little transfer of science into practice'. Our view is that the 'transfer' is somewhat more complex and in any event, two-way. In consequence the approach adopted here has been rather more that of 'learning by doing', aligned with Easterly's 2006 definition of 'searchers' (Holcombe et al. 2012). The hope is that acceptance of the methodology can be achieved by using the blueprint (Anderson and Holcombe 2013), and through the process of adaptation to make it relevant to local conditions (political, social and physical); local (country) ownership could follow. For that to happen, there need to be 'policy entrepreneurs' and more attention paid to rigorous cost benefit analysis of landslide mitigation measures. In short, there need to be 'smart' links made between science, social science and behavioural sciences; something which the MoSSaiC methodology has sought to both encourage and establish.

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Education, Training and Capacity Development for Mainstreaming Landslides Risk Management

Surya Parkash

Abstract

The multifaceted aspects of landslide management, especially risk assessment, prevention, mitigation, preparedness and response require an inter-disciplinary cross-sectoral and multi-level action strategy. But the success of the strategy depends on education, training and capacity building of all stakeholders to make them act in an integrated manner towards a convergent holistic approach for mainstreaming landslides risk reduction and disaster management. The present paper discusses about the issues and initiatives proposed or taken in this direction, with particular reference to India.

Education and training needs analysis of different stakeholders dealing with landslides led to the view that there is dearth of adequately educated and trained human resources as well as infra-structure/resources to tackle the various issues related to risk reduction, emergency response and recovery. A scrutiny of existing landslides management practices highlighted that only ad-hoc reactive piece-meal measures have been taken in a discontinuous mode without sound scientific, systematic means which proved to be a costly affair. Thus, a revision of the existing educational, training and capacity building programmes became necessary to strengthen the nation-wide organized vibrant pro-active, systematic and scientific institutional mechanism that would replace the less recognized and poorly appreciated existing system.

Keywords

Education • Training • Capacity • Landslides • Risk • Mainstreaming

Introduction

An International Decade for Natural Disaster Reduction (IDNDR), beginning on 1 January 1990, was launched by the United Nations, following the adoption of Resolution 44/236 (22 December 1989). The Decade was intended to reduce, through concerted international action, especially in developing countries, loss of life, property damage, social and economic disruption caused by natural disasters such as earthquakes, tsunamis, floods, landslides, volcanic eruptions, droughts, locust infestations, and other disasters of natural origin. It prompted the governments in different countries as well as the UN and international organizations to initiate some actions towards study and management of natural disasters. The World Conference on Natural Disaster Reduction at Yokohama, Japan during 23–27 May 1994 assessed the status of disaster reduction midway into the Decade and proposed a strategy as well as plan of action at community and national levels, regional and sub-regional levels, and international level through bilateral and multilateral cooperation. The main aim was to build the institutional capacity for disaster management at different levels. The United Nations Development Programme initiated Disaster Risk Management Project in the year 2002–2003 in some countries to support systematic efforts for disaster management and

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develop community capacities with involvement of local governments in the programme.

This was followed by the Millennium Development Goals (2000–2015) and signing of the Millennium Declaration by 190 countries in September 2000 to effectively and speedily respond to the crisis situations and renewed interest and engagement in the issue of capacity development. A World Conference on Disaster Reduction held at Kobe, Japan during 18–22 January 2005 prompted adoption of Hyogo Framework of Action (HFA) by 168 governments to protect lives and livelihoods against disasters. The HFA 2005–2015: Building the Resilience of Nations and Communities to Disasters, has further strengthened the efforts for formulation of action plans for disaster management and capacity building in this sector. As the successor to the IDNDR, United Nations International Strategy for Disaster Reduction (UNISDR) continues enabling communities to become resilient to the effects of natural, technological and environmental hazards and reducing the compound risks they pose to social and economic vulnerabilities within modern societies. UN-ISDR is a strategic framework, adopted by United Nations Member States in 2000, aiming to guide and coordinate the efforts of a wide range of partners to achieve substantive reduction in disaster losses and build resilient nations and communities as an essential condition for sustainable development. UNISDR serves as the focal point for the implementation of the HFA.

The UN General Assembly proclaimed the 10 year period from 2005 to 2014 as UN Decade of Education for Sustainable Development (DESD 2005) to integrate education for sustainable development into their national educational strategies and action plans at all levels. Recently Global Facility for Disaster Reduction and Recovery (GFDRR) has been established in 2006, with a partnership of 36 countries and 6 international organizations committed to help developing countries reduce their vulnerability to natural hazards and adapt to climate change. The partnership's mission is to mainstream disaster risk reduction (DRR) and climate change adaptation (CCA) in country development strategies by supporting a country-led and managed implementation of the HFA. UNDP has initiated another programme on disaster risk reduction – governance and mainstreaming, in 2009 to strengthen the institutional capacity against disasters.

Specific initiatives for landslide risk reduction received an impetus with the setting up of an International Consortium on Landslides (ICL) in January 2002. It focused on the issue of landslides and their impacts on society, environment and resources. The consortium brought together several organizations from different countries as well as UN organizations and international organizations that have interest in landslides risk reduction. The ICL joined hands with UN-ISDR to launch UNITWIN programme and establish a Research Centre on Landslides at Kyoto, Japan. In 2003, an International Programme on Landslides was initiated jointly ICL and UN-ISDR to promote the activities and projects/programs related to landslides risk reduction.

National and Local Initiatives

At the national level, the governments in different countries have taken actions to establish an institutional framework and mechanism (legal, administrative and financial) for disaster management, after the Yokohoma conference in 1994. The chapter describes the initiatives taken by Government of India (GoI) in this regard.

A Centre Sector Scheme was launched in 1995 to establish disaster management cells in the States and a National Centre for Disaster Management (NCDM) at the national level to cater to the need for capacity development in disaster management in the country. Later in the year 1999, a High Power Committee (HPC) was constituted by Government of India, to suggest appropriate institutional framework and mechanism for disaster management. The HPC submitted its report in 2001 (refer HPC 2001), with recommendations for establishing disaster management authority at different levels, disaster management policy, national institute of disaster management, national disaster response force and emergency operation centres etc. The Disaster Management (DM) Act was passed by the Parliament of India and signed by the President in December 2005. With the enactment of disaster management act 2005, National Disaster Management Authority (NDMA) was created under the chairmanship of the Prime Minister of India. NCDM was upgraded as National Institute of Disaster Management (NIDM) in 2003. National Disaster Response Force was established by pooling human resources from the four para-military forces of the country. The tenth (2002–2007) and the eleventh (2007–2012) planning commission of India have also given due importance to the field of disaster management and dedicated a separate chapter to it. The planning commission indicated a commitment to mainstream or integrate disaster risk reduction into the process of development at all levels so as to achieve sustainable development. It has also envisaged specific development schemes and stand-alone projects for prevention and mitigation of disasters. The 13th Finance Commission (2010–2015) of India allocated adequate financial grants to meet the needs for capacity development in disaster management as per provisions under the DM Act 2005.

NDMA has the mandate to formulate and implement national policy, guidelines and plans for disaster management in the country. The national disaster management policy, formulated by the NDMA, was passed by the Parliament of India in October 2009. NDMA has also worked upon to prepare and release national guidelines with respect to management of specific types of disasters, specific types of disaster management related operations and preparation of disaster management plans at different levels. It released National Guidelines for Management of Landslides in June 2009. The copy of guidelines can be accessed from website http://ndma.gov.in/ndma/guidelines.htm. The guidelines have envisaged the establishment of a Centre for Landslides Research, Studies & Management at national level to cater to the needs for capacity development in landslides management sector. Presently NDMA is working for formulation and implementation of a mission mode project for landslides, known as National Landslides Mitigation Project, to set up pilot project on landslides risk management. The main objective of this project is to strengthen the structural and non-structural landslide mitigation efforts and reduce the landslide risks and vulnerability in the hilly terrains.

NIDM (www.nidm.gov.in) has the mandate for training, capacity building, documentation, dissemination of information/knowledge, networking, linkage and coordination for disaster management. It has organized about 20 training programs (both national and international) on landslides management directly and a large number of trainings on landslides are conducted at state levels by the disaster management centres in the states under its supervision and guidance. The institute is working for preparing the training design, modules and manuals for the trainers on landslides management. The trainings are conducted in different manners including face-to-face training, online training (jointly with World Bank Institute and Global Forum for Disaster Reduction & Recovery), SATCOM (Satellite based Communication) training, self study modules, radio/television communication and video-conferencing. Vigyan Prasar, an organization under Ministry of Science & Technology, Government of India is also imparting education on disaster management through EduSAT (a dedicated satellite channel for education purposes). Ministry of Science & Technology has also a mission mode project on landslides to promote research and studies for understanding and management of landslide risks.

Besides conducting trainings, NIDM organizes India Disaster Management Congress at national level. A special session dedicated to mass-movements is organized in this congress to share and exchange knowledge, information and experiences related to landslides. The institute is maintaining a web-portal called India Disaster Resource Network (www.idrn.gov.in) and is working on another portal namely India Disaster Knowledge Network (www.idkn.gov.in). In order to promote publications on disaster management, NIDM publishes a biannual Journal on Disaster & Development. It has several collaborations with UN organizations, international organizations and national level organizations working on disaster management. In India, Geological Survey of India (GSI) has been declared as a Nodal Agency for Landslides. NIDM and GSI are working together for capacity development in landslides risk reduction at the national level. In order to build the national database on landslides and other disasters, NIDM has initiated a system called National Disaster Statistical System (NDSS) to record disastrous events (Parkash and Nair 2008a) and National Hazard Statistics System (NHSS) to inform about existing/potential hazards. The data are collected by GSI from the field and published jointly with NIDM and Central Statistical Organization (CSO).

The institute has signed memorandum of cooperation with National Institute of Land and Infrastructure Management, Ministry of Land, infrastructure, Transport and Tourism, Government of Japan and Public Works Research Institute, Japan to work together in the field of Landslides Risk Management. The Institute is also a member of the ICL to seek support from international experts and organizations in its endeavours for capacity development on landslides risk reduction in India.

Ministry of Home Affairs (MHA), Government of India is the nodal ministry for disaster management in the country. It has established a Centre of Excellence on Landslides (CoEL) at Uttarakhand Academy of Administration, Nainital, Uttarakhand State to cater to capacity development needs for landslides management in a dedicated manner under the supervision and guidance of NIDM.

At the local levels, the government and non-governmental organizations have also introduced activities/projects/programs related to landslides management. The main stakeholders for capacity development on landslides risk reduction at local levels are the academic bodies like Universities, Indian Institute of Technology, National Institutes of Technology, National Institutes of Science Education and Research; research/field organizations in the States like Departments of Science & Technology, Remote Sensing, Geology and Mines, Public Works Department, Irrigation and Flood Control, Forest etc.; Non-Governmental Organizations (NGOs), Community Based Organizations (CBOs); Public/Corporate Sector Organizations like Hydel Sector, Power Sector, Communication and Transport Sector and so on. Capacity developments actions for landslides risk reduction at local levels can be broadly discussed here with focus on education and training.

Landslide Education

Education including formal education, public awareness and training, should be recognized as a process by which human beings and societies can reach their fullest potential. Education is critical for improving the capacity of the people to address issues related to environment, sustainable development and risk reduction. Education programs are now being designed, with greater focus on capacity development of students and teachers in landslides risk reduction. The knowledge institutions and universities should focus attention on landslide education through revision of syllabi, enlarging the scope of teaching earth sciences, civil engineering and allied disciplines with practical bias and through crafting of new educational programs. Landslide education plans to address the multifaceted aspects of landslide management. The development of high-quality education materials, textbooks, field training and high standard of teaching at all levels is also being given due emphasis. The landslide managers need the education that they should insist on a scientific, systematic slope investigation and that ad-hoc measures without sound investigation may prove to be a costly waste.

The education sector initiated the efforts by introducing the subject of disaster management in all streams of education at different levels, i.e. primary, secondary and higher education levels, by the knowledge institutions. Central Board of School Education and National Council of Educational Research and Technology have revised the syllabi in the school level education to include disaster management in their curriculum. Similarly the University Grants Commission, All India Council for Technical Education and Medical Council of India have also introduced the subject of disaster management in the various streams of higher education. The development of educational/training materials, textbooks, field exercises etc. is being pursued. A module for training of teachers to teach the revised curriculum and newly evolved courses is also being worked out.

There is also a need to educate professionals in damage and loss assessment due to landslides and create simple tools and uniform procedures by which objective assessment becomes possible. Technical institutes, polytechnics and universities located in vulnerable areas are developing technical expertise on the various subjects related to landslide management. The State Governments, if required, in association with the University Grants Commission (UGC), Department of Science and Technology (DST), Ministry of Human Resources Development (MHRD), All India Council for Technical Education (AICTE) etc. will introduce short term Quality Improvement Programs (QIP) for teachers and professionals engaged in teaching the subjects related to landslides. The new technical programs on the lines similar to those launched by various Central Ministries for college teachers, geoscientists, civil engineers, town planners etc. for developing the additional capacities in landslide management should also be taken up. The GoI needs to address the gap between the requirement and availability of quality teachers conversant with natural hazards, especially with the landslide assessment and mitigation techniques.

The mainstreaming of landslide management in development planning will be supplemented with the development of the requisite infrastructure in technical and professional institutions, improved laboratories and libraries in identified R&D institutions. These measures would enable these institutions to undertake research and execute pilot projects on different aspects of landslides employing latest technology and set pace setter examples that will build confidence amongst geo-scientists, geo-technical engineers and communities regarding management of landslides. The results of such studies should also help to develop and update the technical documents that may form important part of resource materials prepared for training programs.

Further the need for community education cannot be over-emphasized since it is usually the first responder to a disaster and their role in containing damage could be of prime significance. It is necessary that the government and the communities together evolve joint action plan aiming at spreading of community education and development of community leadership. Such an education will enable communities in ensuring safer constructions.

Training on Landslides Management

Another possible intervention is training of working geologists, engineers, architects, planners, administrators, volunteers and other kinds of workers to ensure that benefits of science are accrued in professional practice. It has been observed that large number of geologists and engineers presently engaged in landslide studies do not possess requisite expertise to manage this hazard and require training. Specialized trainings are needed for skill development on landslide hazard zonation techniques, risk assessment, remediation and early warning practices. These stakeholders are exposed to latest develop ments in the domain of landslide investigations and management being evolved globally on regular basis so that well trained and equipped manpower conversant with latest technological advances is available to manage the hazard effectively. The training programmes are systematically planned and executed with extensive interdisciplinary exposures for engendering an integrated holistic management of landslides. These training programmes are pilot tested, critically evaluated, upgraded, documented, and peer reviewed at regular intervals. The training modules are continuously updated based on the evaluation and feedback from participants.

The major landslide related training programmes at National Institute of Disaster Management in India include a comprehensive landslides risk management targeting a multi-stakeholder inter-disciplinary group; community based multi-hazard risk management including landslides and the target group is NGOs, CBOs, Volunteers, Communities, local bodies

Fig. 1 International collaborations for promoting capacity development on landslides

Fig. 2 Strengthening capacity through national policy and guidelines

Fig. 3 Training of trainers programmes for capacity development

Fig. 4 Field training and capacity development through multi-sectoral workshops

and representatives; specialized professional trainings like applications of geoinformatics for landslides risk management; trainings on creation of landslides database for planning, policy and decision making; training of trainers on conducting the various types of programmes related to landslides (Figs. 1, 2, 3, 4, 5 and 6). It is proposed to integrate the requirement of training programmes with the licensing criteria for professional practices as well as career growth/promotion.

Similarly other training institutions in India are now including the topics related to disaster management in their programmes. Some academic organizations are conducting quality improvement programmes for working professionals and officials. The technical and professional organizations like Geological Survey of India are also organizing training courses on landslides for capacity development of their employees. Non-governmental organizations are also organizing trainings to build the capacity of communities to assess the risks and respond to disasters effectively.

The mainstreaming of landslide management in development planning will be supplemented with the establishment of the requisite infrastructure in professional institutions, improved laboratories and libraries in related institutions. Government of India is also planning to create a Centre for Landslide Studies, Research and Management to cater to the educational, training and capacity building demand of the country. National Disaster Management Authority has made it mandatory to submit a natural disaster impact assessment report for developmental projects to promote risk reduction efforts. It is expected that this strategy will enhance and strengthen the capacities in terms of expertise, knowledge and resources for effective management of landslide hazards.

These training programs are pilot tested, critically evaluated, upgraded, documented, and peer reviewed at regular intervals. The training modules are also continuously updated based on the evaluation and feedback from

Fig. 5 Mass education through staellite communication

Fig. 6 Capacity development through community participation

participants. Ensure that they have architects and engineers with background in landslide-safe design and construction. Those who have undergone the 'Training of Trainers' programme are responsible for training the professionals through the network of professional societies. Recommended areas requiring training are:

- Geomorphological, geotechnical, hydro-geological and GIS based LHM with perception of mapping scales
- Geotechnical Investigation of landslides with particular reference to characterization of slopes, elucidation of landslide boundaries, representative undisturbed sampling from shear zones, handling of samples, simulated stress-path testing and stability analyses in terms of total and effective stresses
- Techniques of monitoring slope surface and sub slope movements and movement rates and cross linkage with rainfall record, piezometric profiles and behaviour of buildings and structures on the slope
- Slope modeling
- GIS based landslide hazard, vulnerability and risk assessments
- Slope kinetics, site effects and earthquake induced landslides in seismic micro-zonation and risk assessment
- Instrumentation of slopes, landslides and avalanches, and early warning
- Design of landslides and avalanche control measures with particular reference to choice of technologies
- Training of first responders in search, rescue and medical care
- Training of communities and local bodies
- Training for visual, print and electronic media in the science of disasters for improved and more objective reporting

Capacity Development for Landslides Risk Reduction

As outlined earlier, the capacity development was geared for achieving the goals of development efficiently and sustainably. The mandate required management of disasters like earthquakes, landslides, tsunami etc. that may affect adversely the development in the affected communities. Landslides being one of the most significant disasters in the hilly terrains have been dealt by different capacity development stakeholders at global, regional, national and local levels. The International Consortium on Landslides under the International Programme on Landslides approved a project proposal "IPL-166: Documentation, Training and Capacity Building for Landslides Risk Management" to National Institute of Disaster Management, New Delhi in November 2010.

Mechanism should be developed to identify institutions active in the field of landslides, assess their capabilities, enhance and strengthen their capacities in terms of expertise, knowledge and resources for effective management of landslide hazard. Main areas requiring capacity development in the context of landslide disaster management are as follows:

- Establishment of a nation-wide organized vibrant proactive, systematic and scientific institutional mechanism would replace the current piecemeal, ad-hoc, less recognized and poorly appreciated landslide management practices
- Enhancement of expertise and capacities of knowledge centres in different parts of the country for dependable and timely geomorphological, geotechnical and hydrogeological investigations and for scientific design and speedy and effective implementation of control measures.
- Strengthening of a few objectively identified institutions, their units and departments in all states and union territories, if willing to redefine and enlarge their respective mandates/roles to provide/support pre and post landslide routine/specialized functions.

Conclusion

It may be concluded from the discussions above that numerous capacity development initiatives for landslides risk reduction are being taken by various organizations and governments at different levels. It is envisaged that these initiatives would collectively work in a synergised manner for societal security, environmental conservation and sustainable development. It will also enhance the capacities of the societies to cope and respond to disasters more efficiently.

In India, Geological Survey of India has now dedicated landslide units under Land Hazard Information Management (LHIM) Division which are operational in the field of landslides risk reduction. The Centre of Excellence on Landslides established by Ministry of Home Affairs, Government of India is also now contributing well towards the objectives of landslides risk reduction through various actions. The implementation of National Landslides Mitigation Project under the guidance of National Disaster Management Authority, India has been approved under the Eleventh Five Year Plan (2007–2012) by the Planning Commission of India. It will help in demonstrating state-of-art practices for landslides risk reduction. NDMA has constituted a Working Committee of Experts (WCE) on Landslides for undertaking various activities related to management of landslides. The 11th Planning Commission of India has also approved plans for Information, Education and Communication Programs related to disaster risk reduction and encouraged international cooperation for providing necessary support to neighbouring countries through multilateral cooperation and involvement of regional organizations.

As part of the networking activities under the project IPL-166, NIDM has developed a good base of inter-disciplinary cross-sectoral stakeholders on landslides risk reduction in the country. It is now gearing its efforts to establish a regional landslides school network with support from neighbouring countries like Nepal, Bhutan and Srilanka. NIDM organizes >100 training programmes on various aspects of disaster management every year directly and encourages 29 disaster management centres in the 28 States of India to undertake >700 training programmes on disaster management throughout the country. The author has organized >20 training programs (national and international levels) specifically dedicated to landslides risk reduction.

It is expected that the understanding and implementation of capacity development initiatives highlighted in this paper would also serve a good purpose in reducing the incidences and impacts of landslides as well as promote sustainable development and environmental regeneration.

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Awareness and Preparedness Strategies for Community Based Disaster Risk Management with Particular Reference to Landslides

Surya Parkash

Abstract

Awareness and preparedness strategies are an essential component of community based disaster risk management. A sustained effort is required by the government, NGOs, Volunteers, electronic and print media through interactive meetings, audio-visuals, handbills/booklets/posters, competitions and quizzes, street-shows, mock drills and exercises for creating awareness among the public and preparing them to act appropriately for disaster risk reduction. Community involvement in disaster management cannot be overemphasized since it is usually the first victim as well as responder to a disaster and hence, its role in containing damage or loss is of prime significance. The community campaigns emphasize on the prevalent landslide risk and vulnerability of the exposed elements. It highlights the roles, responsibilities and standard operational procedures for risk reduction and response by the communities. Information, maps and illustrations containing status of landslide hazards, landslide indicators or precursors, precautionary measures, possible causes, suggestive remedial options and early warning signals are shared with the community in a layman's language. Communities are made aware of the likely major disasters that threaten the localities of immediate concern to them, and the projected disaster scenarios; the possible landslide hazard distribution and major known landslide spots.

However, one of the most challenging tasks in landslides awareness and preparedness is the sensitization of all stakeholders, and their involvement in landslide risk management process. If the communities recognize the importance of landslides safety vis-à-vis developmental activities, tremendous gains can be achieved in landslide risk reduction. Therefore, a comprehensive awareness and preparedness campaign should be developed and implemented for following safe practices before, during and after a landslide. Landslide risk management should be done by applying locally available knowledge, expertise and resources customized to suit site specific situations.

Keywords

Awareness • Preparedness • Risk reduction • Landslides

Awareness Programme, Principles and Methodology

Several awareness programmes for disaster risk management have been pursued by Ministry of Home Affairs, Government of India with support from UNDP-India by implementation of the Disaster Risk Management Programme (2002–2009) in 176 multi hazard prone districts in 17 States

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across the country. The programme attempted to demonstrate a sustainable model to institutionalize systems for disaster risk management at all levels (village/Gram Panchayat/Block/Ward/Urban Local Bodies/District/State) with focus on community based disaster preparedness and response.

After the successful implementation of the GoI-UNDP Disaster Risk Management Programme (2002–2009), Government of India with support from UNDP is now implementing the GoI-UNDP Disaster Risk Reduction Programme (DRR) from 2009 to 2012 with an outlay of $20 million. The GoI-UNDP DRR programme, presently being implemented in 26 States in India, is envisaged to support Central and State Government programs and initiatives by providing critical inputs that would enhance the efficiency and effectiveness of the efforts in Disaster Risk Reduction. The programme strives to strengthen the institutional structure to undertake Disaster Risk Reduction activities at various levels including risks being enhanced due to climate change and develop preparedness for recovery.

Definition and Principles of Awareness

Awareness is generally defined as knowledge created through interaction between an agent and its environment, a setting bounded in space and time. It involves states of knowledge as well as dynamic process of perception and action. It is the knowledge that must be maintained and kept updated to complete some tasks in the environment. Awareness generation is considered as core element of successful disaster risk reduction. Raising awareness among affected communities will have multiple benefits. Thus, awareness generation has to be targeted at the literate as well as illiterate community and should be pursued through all possible means including both formal as well as informal sectors. This will help in weaving the culture of disaster risk reduction among all stakeholders. The awareness generation should be based on the following broad principles.

- The strategy for generating awareness should be designed and implemented with a clear understanding of local perspectives and requirements with materials reflecting local conditions.
- The strategy should target all sections of the society including decision makers, professionals, public and individuals living in vulnerable areas.
- It postulates that different types of messages and delivery systems should be used to reach various target audiences at different locations.
- An ideal campaign has to be sustained over time to foster changes in social and behavioural norms.
- Awareness generation framework should follow the target audiences segmentation i.e. grouping by demographic, social, economical variables to create messages that are salient, effective, oriented and attractive.

Methodology for Awareness Generation

The methodology for creating awareness for disaster risk reduction amongst every member of the community should clearly identify the ways as well as channels to carry out the campaign. Some of the ways/methods to carry out various awareness programmes can be:

- Educational curriculum
- Quiz, Declamations and Debates
- Messages during Assembly
- Workshops, Seminars, Orientation programmes and Lectures
- Field visits to disaster affected/hit areas
- Notices
- Posters, leaflets, brochures etc.
- Cartoons
- Photographs
- Films, Film clips, Videos and advertisements
- Dance, Drama, folksongs and streetplays
- Games based on knowledge about disasters
- Short radio/television features
- Talks/Presentations
- Demonstrations (Shake Table)
- Handbooks/booklets
- Maps/Vulnerability atlas
- Woven into folklore of a vulnerable area
- Conducting Mock Drills
- Organizing Rallies

Some of the channels that can be used to carry out these programmes are as follows:

- Institutes of education and learning
- Places with high public visibility like hospitals, railway stations, bus terminals, airports, post offices, commercial complexes, municipality offices etc.
- Museums like amusement parks, arts/history and science museums with static and dynamic models Government stationery like postal letters, Railway tickets, Airline boarding cards, stamps etc.
- Telephone directories
- Shopping bags
- Existing government programmes/projects
- Radio/Television
- Cinema programmes (short films or clipping)
- Police information channels
- Utilizing popular events
- Print media, Computer/Web media
- Religious Missions/monuments/sites
- Voluntary organizations

Fig. 1 Interactive meeting with community for raising awareness level

Fig. 2 Posting of emergency signboards at potential disaster sites

- Fairs and community festivals
- Door to door awareness campaigns
- Internet sites
- Mascot for Disaster prevention
- Through celebrities and significant personalities
- Synchronous technologies – Web-based, Telephone, Videoconferencing, Web conferencing, Direct-broadcast satellite, Internet radio, Live streaming
- Asynchronous technologies – Audiocassette, E-mail, Message board forums, Print materials, Voice Mail/fax, Videocassette/DVD

Fig. 3 Community play for participation in awareness and preparedness activities

Awareness Strategies for Landslides Risk Reduction

As a part of awareness generation exercise of landslide hazard mitigation effort, a programme has been initiated to establish contact with various State Governments in landslide affected areas and create awareness about this natural hazard among all stakeholders. The programme included audio-visual presentation, distribution of booklets, handbills and posters for creating awareness about landslide hazards, familiarising landslide terminologies, causes, status of landslide hazards, details of landslide indicators along with precautions to be adopted and suggestive measures. The mass awareness generation programs are planned to be carried out as sustained effort (Figs. 1, 2, 3, 4, 5 and 6) through electronic and print media, interactive meets and distribution of handbills and posters in local languages. Local communities aware about disastrous effects of landslide hazard and its hazardous locales in their area, would be in a better position, both physically and psychologically to reduce and cope with the risks.

Since landslides are frequent and sudden, and cause disasters that affect localised areas resulting in segregated losses, these do not receive appropriate attention due to their transitory nature, and short-lived human memory. Hence, the level of awareness about landslides has been quite low compared to other disasters like earthquakes, floods, and cyclones. Cumulatively, losses due to landslides are much higher in India than any other disaster in hilly terrain. Thus, there is an immediate need to educate people about landslides so as to reduce the associated risk and losses.

State governments/State Disaster Management Authority (SDMA) of landslide affected areas will, in collaboration with the nodal agency and other key stakeholders, make special efforts to mobilise communities to carry out landslide mitigation efforts.

Electronic and print media will also be associated in the endeavour to create greater public awareness about the landslide hazard and the importance of land use zoning practices.

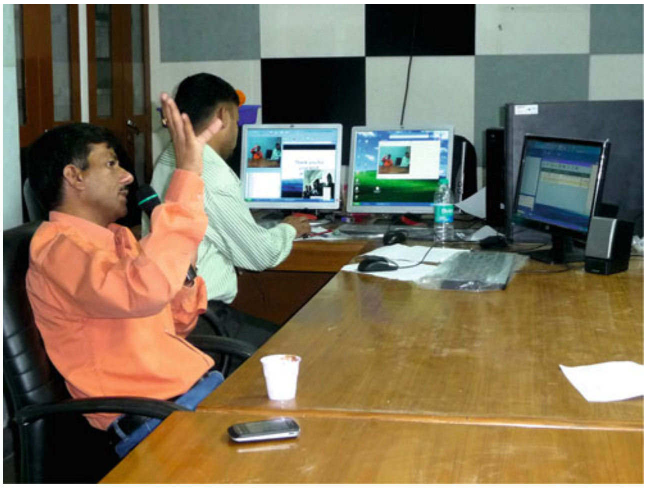

Fig. 4 Application of audio-visual media for community awareness

Fig. 5 Field exercises for on-site awareness and preparedness

Organisations and institutions like the Geological Survey of India (GSI), National Institute of Disaster Management (NIDM) and other knowledge institutions including some of the NGOs will be entrusted with the responsibility of preparing material for awareness generation campaigns pertaining to the landslide prone states in the country in a scheduled manner.

Comprehensive awareness campaigns targeting different groups of people living in landslide prone areas will be carried out systematically. These campaigns will emphasise the prevalent landslide risk and vulnerability of the areas as well as highlight the roles and responsibilities of communities and stakeholders in addressing this risk. These will also focus on the specific role that each institution/organisation or community will play in order to mitigate the effects of landslides.

Fig. 6 Involving celebrities to attract community invilvement in awareness and prepoaredness programmes

Public Awareness on Landslide Risk Reduction

Handbooks, posters, and handbills containing the status of landslide hazards will be distributed, and details of landslide indicators along with precautions to be adopted and suggestive measures will be displayed near landslide prone sites. All the above documents will be translated into local and regional languages. Short video films on the landslide risk, vulnerability, and the importance of preparedness and mitigation measures will be prepared for the general public. The electronic and print media will also be made an integral part of the campaigns. The campaign focuses on the following issues:

- What are the major disaster threat perceptions in the localities of immediate concern to them, and what are the projected likely disaster scenarios (landslides included?)
- What are the possible landslide hazard distribution scenarios and major known landslide spots and identified elements at risk in the area?
- What are the lessons to be learnt from past landslide disasters in the area, and from their (mis)management?
- What are the precursors and early indicators that can avert landslide disasters?
- What are the elements like roads, housing, schools, etc., that are exposed to landslide risk?
- What is the role and responsibility of the government and local bodies before, during, and after a disaster?
- What are the expected roles and responsibilities of communities and people at large before, during, and after a disaster? How much responsibility are the residents and communities willing to assume in choosing to live or do business in high risk areas?

- What is the role of the public sector, NGOs and other voluntary organisations?
- Do the construction materials, design, and construction conform to prevalent building codes and established engineering practices?

Awareness Drives for Specific Target Groups

One of the most challenging tasks in landslides preparedness and mitigation is the sensitisation of all the stakeholders, and educating and training them to participate in landslide preparedness and mitigation efforts.

GSI along with state governments, some selected institutions collaborating with local bodies, urban planners, and NGOs, will initiate programmes to sensitise decision makers and other important functionaries in undertaking mitigation measures in landslide affected areas. The contents and structure of the resource materials will be reviewed and revised, depending on the results of earlier programmes. Large construction companies and contractors engaged in infrastructure development in the hilly regions will undertake campaigns to sensitise their members to the risk and vulnerability resulting from landslides in various parts of the country so that necessary attention is paid to this hazard and mitigation measures are included in design and construction in vulnerable areas.

The state governments/SDMAs, in collaboration with GSI, NGOs, and other identified agencies, will organise awareness programmes on the various aspects of landslide management for specific target groups of stakeholders, elected representatives, civil servants, members of local authorities, school administrators, members of management boards of educational institutions and hospitals, school children, representatives of the corporate sector, the media, etc.

The campaign will also highlight the risks and vulnerability of the states and the roles/responsibilities of all the communities and stakeholders in addressing the risk. GSI will maintain a list of resource personnel and organisations capable of conducting awareness generation campaigns, which will be updated from time to time.

Public awareness campaigns will be conducted at the national, state, and district centres and in high risk areas for disseminating information on landslide risk management among all stakeholders. Case studies documenting major landslides will be prepared and used for creating greater public awareness among professional and critical stakeholders. Landslide risk management will be done by applying available knowledge and customising the same through R&D for specific situations, and by generating new adaptive techniques.

The state governments/SDMAs and professional bodies will organise knowledge and experience sharing workshops for societal benefits. They will also support private agencies to develop their capacities to assess, predict, and monitor landslides as well as implement appropriate remedial measures.

The National Disaster Response Force (NDRF) will continue with its familiarisation and community awareness programme on response and relief in the landslide affected regions. These efforts will be strengthened.

Landslide Preparedness Strategy

Management plans for landslide prone areas should be systematically developed to prepare the stakeholders to address landslide risk. These plans should be region specific and should consider the risk profile and the special characteristics of a particular geographic area. Mock drills should be conducted in offices, schools and industrial units etc. and in the neighbourhood of the sites vulnerable to landslides. The people operating in the mountainous regions will be sensitized about the landslide hazard. They would be advised to remain vigilant and respond effectively in emergency situations.

An exercise in real sense is a focused practice that puts the participants in a simulated situation to function in the capacity that would be expected of them in a real event. Its purpose is to promote preparedness by testing policies and plans and training personnel.

Exercises should be conducted to evaluate an organization’s capability to execute one or more portions of its response or contingency plans. Many successful responses to emergencies over the years have demonstrated that exercising pays huge dividends.

As per the specific situation these exercises will be conducted to assess the preparedness for all the hazards present in the district rather than for individual hazards.

Community Preparedness

Local authorities like gram panchayats, with the help of NGOs and volunteer groups from within the community will prepare and implement community based DM plans. A database of these groups, their contact details, and fields of specialisation will be created and maintained at the district and state levels. The state governments/SDMAs will set up appropriate disaster management mechanisms to act as links between the state government/SDMA and different organisations.

Exercise programmes for each disaster prone district will be developed and made an essential part of the preparedness programme. The entire cycle of an exercise programme from orientation seminar to full scale exercise takes about 18–24 months. Complete exercises in disaster prone districts will be conducted at least once in 4 years after careful planning so that grey areas in the preparedness programme are identified and efforts are made to make the necessary modifications. As per the specific situation, these exercises will be conducted to assess preparedness for all the hazards present in the district rather than for individual hazards.

Conclusion

It may be concluded from the discussions above that disaster risk reduction is not an emergency service waiting the time of need. Rather, the subject can be placed in the midst of daily concerns of people where they live and work and among the people and property they value. Hazards need not become disasters with the widespread suffering and loss if people are sufficiently conversant with the nature of risks involved and the activities they can undertake reduce their own vulnerability. This involves full participation of the community and people who are exposed to these hazards. Public awareness strategies can motivate people to collaborate in different enterprises supported by their initiatives and multiple resources

Similarly preparedness against impending landslides risks and disasters would help affected communities act effectively and efficiently so that damages/losses can be minimized. Thus, an aware, informed and prepared community will be better able to avert and cope with the disaster risks than otherwise.

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Current Status of Landslide Guidelines Around the World

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Abstract

The Geological Survey of Canada (GSC) initiated a project in 2009 to develop national landslide guidelines and best practices as part of its natural hazard loss reduction effort. This project is part of the International Program on Landslides sponsored by the International Consortium on Landslides. A literature review was carried out as part of this project. More than 30 landslide guidelines from around the world were collected. This paper presents a brief review of these guidelines. The review will assist in the development of the GSC's landslide guidelines, as well as aid professionals and other stakeholders who wish to learn more about or develop their own landslide guidelines.

Keywords

Landslide • Guidelines • Review

Introduction

Thousands of landslides occur annually in Canada and on average about four lives have been claimed by landslides each year over the past 150 years (Clague and Bobrowsky 2010; Evans 1999). In May 2010, a landslide in the province of Quebec claimed the lives of a family of four. In Canada, landslide damage to infrastructure and secondary losses are estimated to exceed $200 million annually (Clague and Bobrowsky 2010).

A project was initiated at the Geological Survey of Canada (GSC) in 2009 to develop national landslide guidelines and best practices. It is part of GSC's natural hazard loss reduction effort. Development of landslide guidelines has been identified as one of the most valuable methods of landslide loss reduction. Similar to other sciences and technologies, knowledge of landslides has advanced exponentially in the past few decades. In other scientific and engineering disciplines, technical guidelines have helped raise standards of practice and have undoubtedly contributed to increased quality and consistency of professional practice.

There are currently no national landslide guidelines in Canada to assist and guide professionals. Although landslide guidelines exist in some provinces, they are limited to specific issues or for specific regions or industries. Landslide guidelines available from other countries are not necessarily directly applicable in Canada given physiographic, geological, climatic, and cultural differences. Nonetheless, such domestic and international documents are useful to help develop Canadian guidelines. Thus a literature review was carried out on more than 30 guidelines that were collected from 10 countries around the world and two international/multi-national bodies. Most guidelines reviewed were published in English; some were in French. There are other landslide guidelines written in other languages that are not included in this review.

This paper presents a brief review of the collected guidelines. The purpose is to aid in the development of the

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Table 1 List of guidelines collected

Country/region	Primary topics	References
Australia	Landslide zoning	AGS (2007a, b)
Australia	Landslide risk management	AGS (2000; 2007c, d)
Australia	General guide to understanding landslides	AGS (2007e)
Canada	Risk management	CSA (1997)
Canada	Risk management principles	CSA (2010a)
Canada/BC	Landslide assessments for residential development	APEGBC (2010)
Canada/BC	Landslide assessments in the forest sector	ABCFP/APEGBC (2009)
Canada/BC	Management of landslides in the forest sector	APEGBC/ABCFP (2008)
Canada/BC	Management of landslide-prone terrain	Chatwin et al. (1994)
Canada/BC	Landslide risk case studies in the forest sector	Wise et al. (2004)
Canada/Quebec	Use of landslide hazard maps for loss reduction	Québec (2005)
China/Hong Kong	Natural terrain landslides	Ng et al. (2003)
China/Hong Kong	Risk criteria for landslides	ERM HK (1998)
China/Hong Kong	Geotechnical manual for slopes	GEO (2000)
China/Hong Kong	Landslide debris-resisting barrier design	Lo (2000)
China/Hong Kong	Guide to engineered slope maintenance	GEO (2003)
European Union	Managing landslides in urban areas	McInnes (2000)
Germany	Disaster risk management	Kohler et al. (2004)
India	Management of landslides and snow avalanches	India (2009)
International	Risk management principles	ISO (2009)
International	Landslide zoning	JTC-1 (2008)
International	Open pit slope design	Read and Stacey (2009)
Malaysia	Slope maintenance in Malaysia	Malaysia (2006)
New Zealand	Planning policy and approval requirements	Saunders and Glassey (2007)
Switzerland	Landslide hazard mapping and land-use planning	OFAT et al. (1997)
UK/Scotland	Landslides in peat: hazard and risk assessments	Scottish Executive (2006)
USA	Landslide investigation and mitigation	TRB (1996)
USA	Landslides and planning	Schwab et al. (2005)
USA	General guide to understanding landslides	Highland and Bobrowsky (2008)
USA/California	Static and seismic slope stability assessments	ASCE L.A. Section (2002)
USA/California	Landslide management and storm damage response	Caltrans (2003)
USA/Colorado	Landslide guide for state/local government planning	Wold and Jochim (1989)
USA/Utah	Evaluation of landslides	Hylland (1996)

GSC's landslide guidelines and to assist other stakeholders who wish to learn more about or to develop and/or tailor their own landslide guidelines.

Collection of the Guideline Documents

A literature search was carried out to collect as many documents related to landslide guidelines as possible. Table 1 is a summary list of the collected guidelines. Although every effort was made for the collection to be as complete as possible, some guidelines may have been missed, especially those not in English or French. It should be noted that some of the guidelines that were reviewed are not specific to landslides, but provide useful reference/guidance for landslide loss reduction, e.g., ISO (2009) and Read and Stacey (2009).

Review of the Guidelines

Landslide loss reduction requires efforts from professionals, regulatory bodies and other stakeholders. Landslide guidelines therefore are aimed at those user groups for increasing awareness and the quality and consistency of professional practice. The landslide guidelines reviewed provide assistance to different landslide issues using different approaches; some focus on certain topics, regions or issues, others are more comprehensive or general. The following review categorizes the guidelines by common primary topics, however, most guidelines cover more than one topic.

Landslide Risk Management

Landslide risk management is one of the topics that are most commonly seen in the guidelines reviewed. The most comprehensive one is the 2007 Australian Geomechanics Society's "Landslide Practice Note" (AGS 2007c). This document provides guidelines for both regulators and practitioners. The guidelines for regulators outline the policy and evaluation process requirements, tolerable risk criteria, and roles and responsibilities of the practitioners. Relatively detailed procedures are provided for practitioners to follow on landslide hazard analysis, consequence analysis, risk estimation, assessment and management. The commentary document (AGS 2007d) provides an example risk evaluation case history and is a useful step-by-step illustration of how to apply the procedures.

The Geotechnical Engineering Office (GEO) of Hong Kong released an interim risk guideline for landslides and boulder falls from natural terrain (ERM Hong Kong Ltd. 1998). The document reviews the associated risk criteria available worldwide at the time. It recommends landslide and boulder fall risk assessment criteria on an interim basis for Hong Kong.

Germany published guidelines for risk analysis for disaster risk management (Kohler et al. 2004). The guidelines are directed to emergency aid, reconstruction and food security programs in regions threatened by natural hazards. The document describes general procedures for risk analysis with three examples illustrating applications of the procedures to floods, droughts and erosion. Although the guidelines are not specific to landslides, the general procedures can be applied to landslide risk assessments.

The International Organization for Standardization (ISO) released ISO 31000 "Risk management – principles and guidelines" (ISO 2009). The document provides generic guidance on risk management for general application. It is not specific to a particular country, industry or sector. Although it does not specifically address landslides, the document provides fundamental guidance for landslide risk management and provides definitions and terminology for effective risk management communication.

The Canadian Standard Association (CSA) published a Canadian standard for general risk management (CSA 1997). After the release of ISO 31000 (ISO 2009), CSA announced its adoption of ISO 31000 as the Canadian national standard on risk management (CSA 2010a). CSA is also in the process of updating its 1997 standard to supplement the international standard. The updated version will provide guidance for implementing the international standard taking into account the needs of Canadian stakeholders. A draft version was released for review in early 2010 (CSA 2010b).

Landslide Zoning

The Australian landslide zoning guidelines (AGS 2007a) are perhaps the most comprehensive guidelines on landslide zoning. The document, along with its companion commentary document (AGS 2007b), provides guidance on landslide susceptibility zoning, hazard zoning and risk zoning for land-use planning. A list of definitions, terminology, descriptions of the types and levels of landslide zoning are provided and various landslide zoning methods are described. Geotechnical evaluations, GIS-based techniques and landslide inventory are briefly discussed. The document specifies levels of zoning required, with the corresponding scales of zoning maps, for different applications. The Australian landslide zoning guidelines were endorsed by an international body. The Joint ISSMGE,[1] IAEG[2] and ISRM[3] Technical Committee on Landslides and Engineered Slopes (JTC-1) adopted the Australian landslide zoning guidelines with minor modification for international implementation (JTC-1 2008).

Switzerland published guidelines for landslide hazard mapping and land use planning (OFAT et al. 1997). The document targets three groups with specific objectives: (1) to guide geotechnical specialists in their practice for the evaluation of landslide hazards; (2) to assist politicians in their decision process on land-use planning; and (3) to inform land owners of the potential hazards that can affect their properties. The proposed methodology is based on basic risk management principles. The recommended process starts with landslide identification followed with an evaluation of frequency and consequences. Mitigation measures, including emergency planning, are recommended. The document is easy to read yet offers a relatively comprehensive overview of landslides and associated potential preparatory causes. It provides basic tools and a standard methodology and terminology, with examples for developing hazard maps and land-use planning throughout Switzerland.

Geotechnical Investigation and Hazard Assessment

Geotechnical investigation is necessary to understand the mechanics of slope failures and to develop appropriate mitigation. Mostly driven by engineering applications, guidelines for geotechnical investigation of slopes are widely available and typically contain relatively detailed technical procedures.

The international guidelines for open pit mine slope design (Read and Stacey 2009) provide detailed procedures

[1] ISSMGE: International Society for Soil Mechanics and Geotechnical Engineering;

[2] IAEG: International Association for Engineering Geology and the environment;

[3] ISRM: International Society for Rock Mechanics.

and methodologies to investigate and design open pit slopes. The guidelines include many state-of-the-art techniques and approaches for rock slopes. Although the document is focused on open pit slopes, the guidelines are very useful as they provide general geomechanical principles applicable to other rock slopes.

The guidelines from California (USA) for investigating and mitigating landslide hazards (ASCE L.A. Section 2002) provide guidance on geotechnical procedures for landslide mitigation. The document is focused on slope stability and displacement associated with seismic events. Although the document acknowledges that there is no consensus on appropriate seismic slope deformation analysis, it does provide useful information on mitigation of landslides induced by earthquakes.

The Hong Kong “Geotechnical Manual for Slopes” (GEO 2000) is one of the most comprehensive documents providing very detailed guidance on standard practices for design, construction and maintenance of engineered slopes. The manual covers topics ranging from local geology, site investigation, laboratory testing, groundwater, slope design, instrumentation to maintenance. Although the document is focused on slopes local to Hong Kong, geotechnical professionals can benefit from the document given its detailed geotechnical procedures for general slope stability and landslide investigations. It should be noted that the first edition of this manual was published in 1979. It was updated to its second edition in 1984. The second edition has been reprinted in 1991, 1994, 1997 and 2000. It was acknowledged with the fourth reprint of 2000 that more up-to-date guidance was progressively given in later GEO publications to supersede or supplement that given in the Manual. A list of such publications was provided in an Addendum at the end of the 2000 reprint.

The Utah Geological Survey (USA) published “Guidelines for evaluating landslide hazards in Utah” (Hylland 1996). The guidelines assist geologists and geotechnical engineers in carrying out landslide hazard studies and to help with technical reviews of hazard evaluation reports. They set out requirements for three levels of landslide hazard evaluations: (1) geological evaluations, (2) preliminary geotechnical evaluations, and (3) detailed geotechnical evaluations. They also outline requirements for landslide hazard evaluation reports. The guidelines address rotational and translational slides and, to a certain extent, liquefaction-induced slope failures of regional interest in Utah.

Land-Use Planning

New Zealand Geological and Nuclear Sciences (GNS) published “Guidelines for assessing planning policy and consent requirements for landslide prone land” (Saunders and Glassey 2007). The guidelines are primarily for land-use planners and provide non-prescriptive guidance on how landslide hazards can be incorporated into risk-based planning policy and approval requirements. They propose a risk-based approach to land-use planning and approval. The approach considers landslide recurrence interval and a “building-importance category” of the proposed building site. The approach does not guarantee that a building will not suffer damage from a landslide, but it determines if the risk of damage is sufficiently low to be acceptable.

The “Landslides Hazards and Planning, a Planning Advisory Service Report” released by the American Planning Association (Schwab et al. 2005) is a useful guideline for land-use planners. It describes how landslide risk can be minimized by appropriate development planning. It provides a comprehensive guide to identifying landslides and the legal and administrative tools to mitigate the hazards. Many examples in the document demonstrate how communities have successfully incorporated landslide information into their planning process.

Mitigation and Remediation

Most landslide guidelines reviewed in this study provide some guidance on mitigation or remediation. They typically address these topics at different levels of detail and use approaches that are consistent with the focus of the guidelines. Such documents often address mitigation and remediation of region specific issues. Landslide mitigation and remediation is also a topic of those guidelines associated with geotechnical investigation discussed previously.

Scotland published a best practice guide for landslides in peat (Scottish Executive 2006). The document provides guidance on the methods for identifying, mitigating and managing landslides in peat and their associated risks for electricity generation developments. The guidelines describe field and laboratory investigation methods, hazard analysis, risk assessment and mitigation measures, all specific to peat. This document provides an overview of the unique peat failure mechanisms and triggering factors followed by guidance on desk studies, field investigations, slope stability analysis, and reporting. The guidelines are concise and provide a valuable reference for professionals, especially for those who work with peat.

The Department of Transportation of California (USA) released draft guidelines for landslide management and storm damage response (Caltrans 2003). The guidelines are specific to the Highway 1 corridor along California’s Big Sur Coast. They address a range of strategies and actions for effective partnership and collaborative decision-making among stakeholders to improve the process of managing landslides along the highway. The document provides an overview of geology and landslides along the corridor, landslide management programs, processes and strategies, and many techniques available for landslide mitigation and remediation. Although the guidelines are of local/regional focus, they provide a useful reference for application to other similar settings.

The Hong Kong Geotechnical Engineering Office issued a set of guidelines for natural terrain hazard studies (Ng et al. 2003). The document describes the requirements and approaches for natural terrain hazard studies and summarizes the design requirements for appropriate mitigation. It recognizes the importance of studying and dealing with natural terrain hazards before project development, rather than addressing the problem as a response. As such, the document emphasizes terrain hazard screening procedures and criteria, approaches for studying different types of hazards (e.g., rock falls, deep-seated slides and debris flows) and strategies for risk mitigation.

The Hong Kong Geotechnical Engineering Office also issued a "Guide to Slope Maintenance" (GEO 2003). This document recommends a standard of good practice for the maintenance of engineered slopes and retaining structures, disturbed terrain features and natural terrain hazard mitigation structures. It supersedes an earlier version published in 2000. The guidelines are aimed at geotechnical engineers, although not intended to be mandatory. The document details the procedures and requirements for slope monitoring, inspection and maintenance. It also provides forms for slope maintenance records. The Public Works Department of Malaysia issued a modified version of GEO (2003) for implementation in Malaysia (Malaysia 2006).

The Hong Kong Geotechnical Engineering Office released a report on natural terrain landslide debris-resisting barrier design (Lo 2000). This report reviews design methodologies for landslide debris-resisting barriers, including rock/boulder fences, gabions, reinforced concrete retaining walls, earth fill berms and check dams. The report reviews methods that can estimate debris mobility and debris impact loads for use in engineering design. The identified approaches form interim guidelines for application to landslide debris barrier design in the region.

"Landslides: Investigation and Mitigation" published by the (USA) Transportation Research Board (1996) describes procedures and techniques for investigation and mitigating a wide variety of landslides, both in soil and rock, natural and engineered slopes. It supersedes previous versions published in 1958 and 1978. The document provides comprehensive guidance on a broad range of landslide topics that are grouped into five parts: principles, investigations, analysis, mitigation and special cases. Although this document is discussed in this category, it should be noted that it also provides considerable detail on topics that are well suited in the other categories, such as landslide zonation, risk assessment and geotechnical investigation.

The Colorado Geological Survey (USA) published a guide on landslide loss reduction for state and local government planning (Wold and Jochim 1989). The document was also published by the (USA) Federal Emergency Management Agency in 1989. It provides "a practical and politically feasible guide" for officials involved in landslide mitigation. The document introduces basic concepts about landslides. It presents landslide identification, assessment, mapping and loss-reduction techniques and steps to prepare landslide mitigation plans. It also provides information on available resources and offers suggestions on the formation of an interdisciplinary mitigation planning team and a permanent state natural hazards mitigation organization.

Codes of Responsibilities

Several regulatory agency guidelines exist that specify responsibilities for professionals and other parties involved with landslides investigations and assessments. Typical examples are those from the province of British Columbia (BC) in Canada (APEGBC 2010; APEGBC/ABCFP 2008; ABCFP/APEGBC 2009).

The "Guidelines for Legislated Landslide Assessments for Proposed Residential Development in British Columbia" was first issued by the Association of Professional Engineers and Geoscientists of British Columbia (APEGBC) in 2006 and revised in 2008 and in 2010 (APEGBC 2010). The guidelines are for APEGBC members, land owners and approving authorities. However, they also outline relatively detailed geotechnical procedures related to seismic slope stability and deformation analysis.

Two other BC guidelines address terrain stability management (APEGBC/ABCFP 2008) and terrain stability assessment (ABCFP/APEGBC 2009) in the BC forest sector. The management guidelines set out general guidelines of professional practice for establishing, implementing and updating stability management models. The assessment guidelines specify professional obligations and guidance for professional practice.

Other Guidelines

There are some guidelines or handbooks that do not easily fit the categories discussed above, but do provide guidance for landslide loss reduction.

India released the "National Disaster Management Guidelines – Management of Landslides and Snow Avalanches" (India 2009). The guidelines are to help direct India's management plans and policies on geohazards. The guidelines specify areas that require special attention and identify appropriate activities including hazard zonation mapping, geological and geotechnical investigations, landslide risk management, and monitoring. The document outlines regulatory and non-regulatory frameworks with defined time schedules for all activities identified.

Building on several of these "general" guidelines Highland and Bobrowsky (2008) published "The Landslide Handbook: a guide to understanding landslides". Written specifically for the nontechnical community, this document includes significant technical information from the identification and classification of landslides to monitoring and mapping methods to options for stabilizing slopes. The guideline aims to help educate, inform and guide those individuals affected by or concerned with slope instability but lacking sufficient technical expertise to know where to proceed next. The document was written for an international audience and has been translated and published in several other languages including Chinese, Japanese, Portuguese and Spanish.

In addition to the landslide zoning and risk management guidelines discussed earlier, the Australian Geomechanics Society also released a set of GeoGuides (AGS 2007e). The GeoGuides are aimed at home owners, developers and other personnel of little or no technical knowledge about landslides. A total of 11 GeoGuides are included, each of which is a stand-alone document uniquely formatted so that it can be printed on two sides of a single A4 sheet. Basic concepts about landslides and critical information that nontechnical audience should be aware of are concisely described in the documents.

A guideline for the interpretation and use of existing landslide hazard maps was published by the Quebec provincial government in Canada (Quebec 2005). The guideline helps local authorities in the Lac St-Jean area of Quebec interpret and use hazard maps produced by the provincial government to help improve the safety of residents vulnerable to landslides. It offers a very brief overview of existing landslide risk management tools, elaborates on common causes and triggering factors of most common landslide types in the region. A particular emphasis is given to Champlain Sea clay. It also provides a basic and practical list of "do's" and "don'ts" when dealing with slopes because it has been found that up to 40 % of slope failures in the area are triggered, often out of ignorance, by improper human activity. The document also provides a list of the minimum requirements of an appropriate geotechnical report when further investigation is required.

The BC Ministry of Forests issued another land management handbook on landslide risk case studies (Wise et al. 2004). This handbook provides a common framework for landslide risk management based on the general framework for risk management described in CSA (1997) and AGS (2000). It also provides a basis for a common understanding of terms and concepts for effective communication among forest resource managers, terrain stability professionals, and stakeholders. The document uses eight case studies to demonstrate risk analysis and assessment procedures for forestry cutblocks, roads, gullies, and alluvial fans. It provides useful reference and guidance for both qualitative and quantitative risk management methods.

Supported by the European Union, a guideline on "Managing Ground Instability in Urban Areas" was published by the Isle of Wight Centre for the Coastal Environment, UK (McInnes 2000). The document provides guidance for managing ground instability. It targets a range of groups from scientists to land-use planners and decision makers. The guideline highlights the need to increase awareness of the range of methods available to mitigate ground instability. It encourages landslide hazard assessment at the land-use planning stage, and illustrates examples of good practice from the European Union and elsewhere.

In 1991, the BC Ministry of Forests published a land management handbook for management of landslide-prone terrain in the Pacific Northwest and updated it in 1994 (Chatwin et al. 1994). The handbook provides information on landslide processes, techniques for recognition of landslide-prone terrain, measures to manage unstable terrain and road deactivation and revegetation of unstable terrain. It was designed to be carried in the field by agency and industry personnel for handy reference.

Concluding Remarks

This paper briefly reviews more than 30 landslide guidelines that were collected from a number of domestic and international jurisdictions. It provides an entry point for professionals and others interested in landslides to learn more about landslide guidelines. It will form the basis of a chapter in the GSC national landslide guidelines and best practices.

Landslide loss reduction requires a multi-disciplinary approach. It also requires involvement of stakeholders with and without landslide technical expertise. It is therefore a challenge for any single landslide guideline to provide comprehensive coverage of all issues related to landslide loss reduction. The GSC recognizes this fact in its efforts to develop the Canadian landslide guidelines. A balance between breadth and depth will need to be maintained with these guidelines.

If readers know of other appropriate landslide guidelines not discussed in this paper, he/she should contact the primary author.

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Strengthening Landslide Awareness and Management in the Mountain Road Sector

Gareth Hearn and Tim Hunt

Abstract

Landslides pose a continuing and increasing threat to the management of rural infrastructure in many countries. In many parts of Asia this threat is compounded by limited resources and budgets and limited knowledge of ground conditions to develop and manage sustainable solutions. A 3-year programme is described that aimed to strengthen capacity in the road sector of Laos in order to manage and mitigate against landslide hazards. Trial slope stabilisation and road reinstatement measures were designed and constructed and best practice manuals produced as an aid to future practice and as a means of focusing capacity building through training. Workshops, hands-on secondments and trainer-training approaches were used to maximise the take-up of these outputs and to ensure sustainability for future applications.

Keywords

Stabilisation trials • Capacity building • Sustainability

Introduction

Landslides impact the transport infrastructure of most hilly and mountainous regions and pose a significant hazard to the travelling public and the socio-economic prosperity and well-being of communities located in road corridors (see review in Hearn 2011). The management and mitigation of landslide hazards is difficult enough in the more advanced economies of Europe and North America, but is particularly problematic in those countries that are challenged by lack of technical and capital resources. In the past, many multilateral funded development projects have, with the best of intentions, bolted on training and capacity development almost as an afterthought as part of the knowledge transfer package. If this type of 'lip-service' is allowed to prevail over a dedicated programme of hands-on training and practitioner strengthening, the outcome becomes little more than a vehicle for increasing the programme scope, rather than a means of sustainable capacity building.

The problem stems from the need to cultivate an interest, leading to knowledge and eventually a working ability in the application of the training. In this paper, the training is concerned with the strengthening of awareness and know-how amongst public sector and private sector practitioners engaged in the management of slopes in the road sector of the Asian region. Historically, this training has tended to comprise powerpoint presentations, possibly combined with field visits. The period of training is usually short and often undertaken towards the end of a project timeframe. In addition, trainees are often selected on the basis of seniority or availability rather than a structured plan that maximises the use of existing skills and knowledge, uptake, and the subsequent rollout or mainstreaming of the training benefits.

This paper describes and reviews some of the features and achievements of a capacity building programme of slope management in Laos. Laos is typical of many countries where progress in slope management is often hampered by lack of information on landslide locations and on the

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geological and geotechnical parameters that govern the stability of slopes along the road network.

Strengthening Landslide Awareness in the Road Sector in Laos

Laos is a country landlocked between Thailand, Vietnam, China, Burma and Cambodia (Fig. 1) and occupies an area of 2,37,000 km^2. Seventy-five percent of the area is hilly or mountainous and forest accounts for over 50 % of the land cover. The climate is humid subtropical and the annual average rainfall can exceed 4,500 mm. Metamorphic rocks are commonplace, though sedimentary and igneous rocks also occur, and weathering has advanced significantly to yield tropical residual soils and weakened rock masses already highly disturbed as a result of folding and shearing. Approximately half of the 7,000 km of road network is located in steep terrain and between 50 % and 80 % of emergency maintenance expenditure is directed towards landslide clearance and road repairs (Hearn et al. 2008).

The Ministry of Public Works and Transport (MPWT) is responsible for the management of the road network in Laos and utilises in-house staff in a technical and project management role, but mainly engages local consultants and contractors to design and construct the works.

Between 2006 and 2008 a programme of slope stabilisation trials was put in place with the main aim of trialling sustainable techniques of roadside slope management. The project was implemented as part of the South East Asia Community Access Programme (SEACAP) funded by the Department for International Development, UK. An important element of the Laos programme involved the training of public sector and private sector engineers in a range of topics relevant to the management of roads in relation to slope hazards. Some of the more important training topics are listed below.

- Geology and geography of Laos
- Causes of slope instability
- Mechanisms of instability
- Mapping techniques and ground investigation
- Risk assessment and prioritisation
- Design of slope works and remedial measures
- Construction of works and remedial measures
- Standards and specifications
- Maintenance of slopes and drainage.

The capacity building comprised three main elements:

- Workshops and seminars
- Full time hands-on training
- Trainer-training courses and start-up trainer-trainee courses.

All three elements were facilitated through the programme of slope stabilisation trials carried out at 13 locations along 140 km of mountain roads north of Vientiane, the capital. These 13 sites were selected from a shortlist of 22 with an elevation range of 450–1,450 m and an annual rainfall in excess of 2,000 mm. The selection criteria included the need to include sites of highest risk and also to ensure that the final list included a range of landslide mechanisms representative of typical ground conditions along the road network. Essentially, four types of slope failure were included in the final list:

- Shallow failure and slope erosion above the road
- Shallow failure and erosion of fill slopes below the road
- Deep-seated failure of the slopes above the road
- Deep-seated failure of the slopes below the road, including examples where this had extended into the road formation itself, causing road displacement.

A combination of geotechnical and bio-engineering techniques of slope and road reinstatement were considered. The bio-engineering methods included planting and small-scale and shallow drainage structures to stabilise erosion and shallow slope failure. The civil engineering measures included retaining walls, revetments, scour protection and deeper drainage measures to stabilise deeper slope failures.

At the commencement and at various key stages throughout the project, workshops were held at which the purpose, approach and outcomes of the various project activities were described. The Vientiane workshops were attended by both

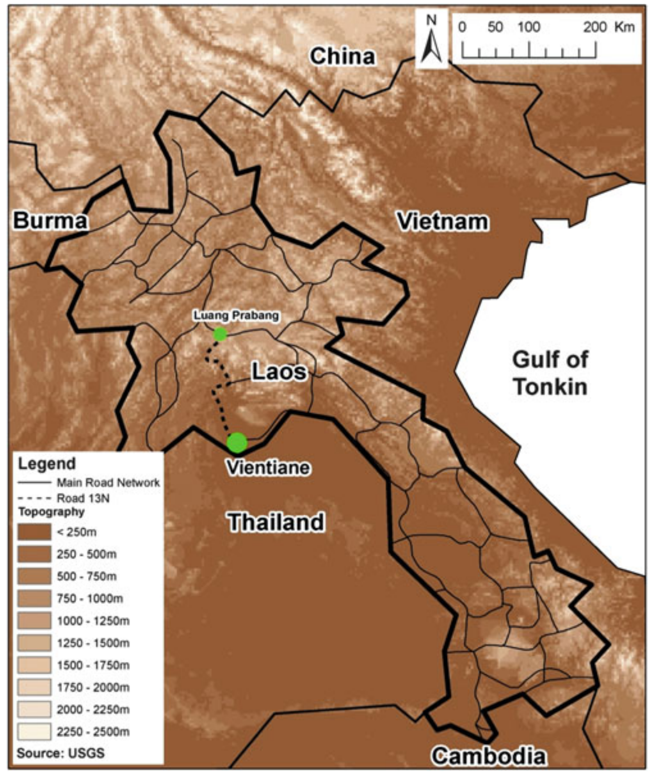

Fig. 1 Geography of Laos

Fig. 2 Trainees at typical site of shallow failure and slope erosion above the road

Fig. 3 Demonstration of bioengineering techniques

public and private sector road engineers and managers but, while they were well-received, they failed to generate the required feedback during the early stages of the project. Field workshops (Fig. 2) were more successful and generated useful discussion at each of the trial slope stabilisation sites.

A group of undergraduate students from the University of Laos attended one of the field workshops and this generated sufficient interest for some of them to carry out follow up fieldwork and review of project data for their dissertations.

Hands-on training was provided to selected engineers from the public and private sector and a forester was given full-time training in the use of bio-engineering techniques. The seconded engineers played an active role in all aspects of the work, including field mapping and ground investigation, design and supervision of remedial works. The forester was given training in the development of plant nurseries and the timing and method of planting and plant growth management. This proved to be a highly successful exercise, although it only ensured that a very small number of practitioners became trained (Fig. 3).

In order to broaden the training and capacity development, and to ensure sustainability, a programme of trainer training was established and slope management manuals were prepared. The manuals were produced in Lao and English. A Site Handbook was prepared aimed at providing technical support to field staff responsible for the maintenance of roadside slopes, and a Maintenance Manual was prepared to assist provincial engineers with responsibility for slope maintenance. Topics included inspection and investigation, determination of treatment measures, and the design and construction of remedial works. Standard details were also included for a variety of works, including retaining walls (cemented masonry, gabion and reinforced concrete), culverts, slope protection and drainage, earth reinforcement and bio-engineering.

The trainer training was undertaken in collaboration with the National University of Laos. The Faculties of Geology and Engineering at the university are the principal source of undergraduate and post-graduate teaching in geotechnical engineering and structural engineering. The curricula of the various courses provided by these faculties were reviewed and recommendations were made as to how they could be strengthened for the purpose of landslide and slope management in the road sector. It was decided that selected specialists from the university would be given training in the following themes most relevant to road side slope management:

- Landslide recognition and geomorphology
- Engineering geology
- Soil mechanics and slope stability analysis
- Retaining wall design
- Slope protection and slope stabilisation
- Bio-engineering methods of erosion control

Six university specialists were given part-time training (in English) as trainers over a 6 week period. The six specialists were selected to be champions for one of the training themes, supported by one or more of the others where required. Each champion was responsible for the development of training materials and training delivery relevant to his or her theme. The training comprised powerpoint presentations, classroom assignments and examinations. They were provided with the two manuals to refer to as well as additional notes and copies of the powerpoint presentations.

The MPWT, together with other public and private sector organisations involved in the road sector, were invited to send selected staff members to attend a week of slope management training at the university. The training course

Fig. 4 Slope management training

Fig. 5 Inspection of cemented masonry retaining wall

followed the structure of the trainer training but the training was delivered by the six trainers in Lao using training materials developed by themselves (Fig. 4).

The programme was divided into presentation sessions separated by discussion group sessions and classroom assignments. A visit to the slope stabilisation trial sites (Fig. 5) was included in the training where the trainees were given hands-on demonstrations, for example in some of the bio-engineering planting methods.

In total, 23 engineers attended the course. Pre-training and post training examinations indicated that level of take-up of the training was generally high, with only one engineer failing to obtain a pass mark.

Outcome of the Capacity Building

The capacity building was judged to have been highly successful. All trainees declared themselves to be extremely satisfied with the training course provided and those seconded for hands-on training during the 2 year period have gained positions of responsibility that enables them to put into practice what they have learnt. Further training courses have been given using the training materials. These outcomes were reached principally because the resources were made available to allow training and capacity building to take place over an extended period. The project period was approximately 30 months and involved 26 man months of work to carry out the feasibility studies, design, procurement, construction supervision and training. This represented a significant commitment to capacity building, as training was taking place more or less throughout this period. Its success was also significantly helped by the fact that slope stabilisation trials were able to provide ‘real life’ training for much of the capacity building, and the outcome and lessons learnt from the trials were incorporated into the manuals and training materials. Over 75 people were given on-site training in the development of the slope stabilisation trials.

Prior to the capacity building project there had been a tendency to derive an immediate solution without necessarily assessing the full extent, mechanism and causes of each slope problem. The training programme emphasised the need to look beyond the immediate boundaries of the failure area and to determine the true extent and causes of instability before deciding upon the optimum remedy. The value of a small-scale, simple and inexpensive ground investigation was demonstrated. Good site supervision was necessary, not only to ensure that the work was carried out in accordance with the specifications, but also so that the design could be adjusted to meet actual, rather than assumed, ground conditions.

Implications for Other Capacity Building Exercises

Most other capacity building courses that the authors have been responsible for have involved much shorter programme periods. They have tended to be seen as one-off exercises which, although well-intentioned, have only really been able to strengthen awareness and familiarity and not know-how and technique. Nevertheless, week-long training episodes in Azerbaijan and the Philippines, for the Azeri Ministry of Education and the Philippines Department of Public Works and Highways respectively, have yielded encouraging results. In the former case, a request has been made for more in-depth training in specific aspects of geohazards while in the latter case maximum usage was made of national specialist trainers to maximise the opportunities for sustainability.

The need to combine knowledge and skills training with real life applications is one of the key lessons to be learnt from the Laos work and was also applied to a 3 year capacity building programme in the rural access sector of Nepal and Bhutan, again funded by DFID (Hart et al. 2003; Petley et al. 2005). This project had the principal aim of developing desk study techniques of remote sensing and landslide susceptibility, hazard and risk mapping for rural road corridor development and was procured through agreements and commitments with the Ministry of Local Development in Nepal and the Department of Roads in Bhutan. Staff were seconded from both of these institutions from the commencement of project activities and a series of classroom and field workshops, supported by best practice guides, were undertaken to maximise exposure amongst practitioners to project outputs. Again, it was the full-time employment of key staff who then went on the put into practice the techniques they had helped to develop, that was the key to the success of the capacity building. This serves as a potentially useful model for future capacity building projects of this nature. Both the Nepal/Bhutan and the Laos programmes were awarded best international sustainability projects by the British Consultants and Construction Bureau and *Ground Engineering* respectively. A publication entitled *Slope Engineering for Mountain Roads* (Hearn 2011) has been another outcome of some of this work.

It goes without saying, but it is nevertheless important to highlight, that the selection of trainees and the delivery of varied and interesting training materials are paramount. There are often occasions when those that attend the training are not necessarily likely to find the training of greatest benefit. If training is seen as a perk; a means to get out of the office and paid a per diem for doing so, then it will be of only limited value. Furthermore, if the training itself amounts to little more than regurgitation of text books without case studies and varied and interesting content, then its impact will not be optimised. In the development of any training programme it is almost impossible to pitch the level of training to satisfy fully all the practitioners; there will be some that struggle with difficult concepts and others that find the course material too easy. To address this issue the course should be made as interesting as possible, quoting real examples wherever appropriate, conducting site visits and demonstrations of techniques. It is also recommended that consideration be given to discussing training content with trainees before the programme and training materials are finalised. This will help to ensure that the right topics are covered to the required level of detail.

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Landslide Awareness, Preparedness and Response Management in India

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Abstract

In India, the main cause of heavy losses during landslides is the lack of awareness among the common residents about the first aid, safety routes, warning signs and first response to landslide emergency situation. Other main cause of great losses is poor disaster and response management system of administration. The change agents of society like, dedicated NGO's, teachers, senior citizens and govt. officials need be trained as a trainers and be given time-slab responsibility to spread awareness regarding response to landslides in the work area assigned to them in their locality. The execution of this awareness programme be managed by District Disaster Management Authority under the chairman ship of Deputy Collector. Local print and electronic media can play a very important role in spreading awareness about landslides in common residents. A well equipped and coordinated quick response teams under Deputy Commissioner, comprising of trained rescue workers be kept ready for mitigation measures and quick response round the clock near vulnerable areas especially during monsoon season.

Keywords

Awareness • Preparedness • First aid • Safety routes • Warning signs • Mitigation

Introduction

> Building culture of prevention is not easy. While the cost of prevention had to be paid in the present, its benefit lies in the distant future. Moreover, the benefits are not tangible; they are disasters that did not happen. Kofi Annan, UN Secretary General, 1999

Whether it is a devastating landslide of Darjeeling in 1968 or on 18th August, 1993 at Malpa, disaster is unlike anything else in human experience. It strikes quickly and changes the lives of large number of people. Its effects are left long after the event.

In India, the main cause of heavy losses during any disaster is the lack of awareness among the common masses regarding the first aid, basic search and rescue techniques, safety routes and zones, reacting to warning signs and signals. To study the level of awareness among common masses in India and preparedness level by the communities and government is also a key subject of study. It is said that, in India, we are sitting on the dynamite of disasters which can explode any time without any pre-warning. Hence, the need for and importance of studying systematically the subject of landslide management.

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Objectives

1. To study the level of awareness and preparedness by local residents to the disaster caused by landslides in India.
2. To study the level of response management by government to cope up with the disaster caused by landslide in India.

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3. To give suggestions and recommendations to spread awareness among common masses, improve response management by govt. and Community capacity building to cope up with emergency situation generated by sudden onset of landslides in India.

Scope of Study

Main emphasis of the study is the prevention of landslides. Where prevention is not possible, emphasis is on reducing its consequences. The scope of the study covers the awareness in common residents, preparedness, plans and policies of government and the type of training which should be imparted to rescue workers and common masses for both prevention and mitigation of disasters caused by landslides in Indian scenario, hazard mapping and resource mapping.

The study is conducted at Pitthoragarh city. Pitthoragarh is a vulnerable city to landslides, earthquake and avalanche related disasters. It has got a history of earthquakes and landslides due to which it has suffered a big loss of life and property.

1. The study limits itself to the disaster management agencies operating in Pitthoragarh City because of its past disasters profile, convenience reasons and to make study manageable.
2. The study is more concerned with practice than policies
3. The study restricts itself only to well reputed and govt. registered agencies engaged in planning and disaster management

This will make the study more useful for administration and society as a whole and develops the scope for development of disaster management plans for various cities in India.

Respondents

A total of 300 respondents from various segments of society with different education and financial background and of both the sexes were selected by stratified sampling and administered a questionnaire to analyze the level of awareness to landslide disasters in common residents. To study the level of preparedness by govt. of India, 200 respondents from various govt. departments who play the stakeholders during any landslide were personally interviewed by the researcher.

Modern technology is capable of predicting landslides and many other natural disasters like hurricanes, tornadoes, tsunamis and now sometimes earthquakes. However, the warnings issued before such an event are often ignored to a notorious degree.

On the midnight of 18th August, 1998 the Malpa rock avalanche tragedy, hit headlines as it instantly killed 221 people and wiped out the entire village of Malpa on the right bank of river Kali in the Kumaun Himalaya. Famous dancer Protima Bedi was also killed during this disaster. The sudden rock fall from heights of 3,000–2,100 m, which occurred on 18 August 1998 at 3.00 a.m., brought down rock chunks varying from 1 to 5 m in size. The dust cloud generated spread 1–2 km on either side of the Kali valley. The rock fall started on 16 August morning, giving an early warning and killing three mules. The rock fall was followed immediately by flash flood in the Malpa stream due to bursting of the debris dam that was formed due to rockfall. The Malpa stream was blocked at a height of 2,280 m. The flood brought huge amount of boulder debris to the other side of village Malpa where the camping site of Kailas–Mansarovar tourists and pilgrims was located. The dam gave way on 17 August night. On 18th night there was yet another rock fall blocking the stream again and giving rise to a lake. On 19th evening the lake water burst out and flushed some of the dead bodies into the Kali river. The rock fall continued till 21 August. In all 221 people died including 60 members of Kailas–Mansarovar team, 120 porters, 9 GREF personnel, 8 ITBP people (Singh 1997).

Thus, we have seen that many disasters like landslide cast their shadows before the actual onset. Due to lack of professional environment, our officials fail to recognize the alarm raised by the nature itself, and ultimately lead our innocent citizens to the grip of death by inviting disasters. Common people due to lack of awareness are unable to heed the signals of nature and fell easy prey to disasters caused by landslides. Moreover, most of the time, administration also fails to generate warning signals and execute evacuation, well in time. George Santayana said. “Those who cannot remember the past are condemned to repeat it”.

To analyze the level of awareness and preparedness among common residents of a landslide prone area, Pitthoragarh city of Uttarkhand state, regarding quick response to emergency situation created by landslide, a study was carried out considering the following parameters:

1. Awareness to Landslide proneness and vulnerability in their city.
2. Awareness of natural warning signs and issued warning signals of landslide
3. First response by residents during landslide
4. Financial implications during landslides

Taking into considerations hazards present in landslide prone area which have already or can in future invite a great disaster, information about awareness and preparedness of common residents to different nature of disasters need to be considered.

As revealed in Table 1, teachers have the maximum awareness (36 %) while housewives have the least (4 %)

Table 1 Respondents having general awareness to landslides (Source: Primary Field Work)

Variable ⇨	Awareness about landslide prone zones of city they live in		Awareness about warning signs and signals of landslide	
	No	%	No	%
Student	6	12	5	10
House wife	2	4	2	4
Teacher	18	36	8	15
Employee	4	8	20	40
Shopkeeper	5	10	8	16
Senior citizens	4	8	4	8
Total	39	13	45	15

Table 2 Awareness of respondants to face disasters caused by landslides (Source: Primary Field Work)

Variable ⇨	Evacuate the area and provide first aid to victims as first response		Updation of disaster plan at home, work place, school etc. since last 1 year		Having done insurance of important and expensive household items	
	No	%	No	%	No	%
Student	20	40	3	5	5	10
House wife	13	26	1	2	1	2
Teacher	28	58	2	5	7	15
Employee	37	74	7	15	10	20
Shopkeeper	36	72	13	25	5	10
Senior citizens	25	50	5	10	3	5
Total	159	53	33	11	33	11

followed by senior citizens(8 %) awareness about the landslide prone zones of the city they live in. This makes housewives and senior citizens more vulnerable group to disasters caused by landslides.

For warning signs of landslide, employees (46 %) have the maximum while housewives (4 %) again have minimum awareness followed by senior citizens and students. It is due to the lack of disaster management training in schools and colleges that students and hence the major portion of society remains unaware about the warning signs and signals of landslide and people waste lot of time bringing their lives near danger.

Most of the time, during landslides, casualities occur due to delay in getting medical care. So people should have awareness of basic first aid and pre-hospital treatment so as to give basic life support to victim till higher medical care arrives.

In case the landslide occurs, employees have the maximum awareness about evacuating the area and provide first aid as a first response to the affected victims while housewives have minimum awareness. Table 2 reveals the only 11 % of the total population of the city have updation of disaster management plan and also have got insured their household items to any such calamity. It means majority of population is not aware of financial aspects for any crisis situation caused by landslide.

Preparedness and Response Management by Government/City Administration

A hazard becomes a disaster when it is not taken care and mitigated in the initial stage. Most of the time, the response system is activated by city administration only after the onset of landslide. This delay in response results in a great loss of life and property in India. With continues urbanization, the stakeholders of the development of society lay down their whole emphasis on economic development without taking into care the safety precautions and preparedness for unseen calamities and emergencies. Due to this, many a times, the economy build up in years is washed away in hours due to sudden onset of natural disasters like landslides.

While preparedness is aimed at preventing a landslide from occurring, personal preparedness focuses on preparing equipment and procedures for use *when* it occurs, i.e., planning. Preparedness measures can take many forms including the construction of shelters, installation of warning devices, creation of back-up life-line services (e.g., power, water, sewage), and rehearsing evacuation plans. Preparedness is a continuous cycle of planning, organizing, training, equipping, exercising, evaluation and improvement activities to ensure effective coordination and the enhancement of capabilities to prevent

Table 3 showing distribution of respondent's prevention aspects for flood disasters prevention of various departments (Source: Primary field survey)

Department	Total respondents	Establishment of landslide/flood control room		Adequate cement bags arranged at vulnerable sites	
		NO	%	No	%
Deputy Commissioner's Office	50	0	0	–	–
Drainage Department	30	0	0	15	50
Uttarkhand Police	50	0	0	–	–
Uttarkhand fire service	20	0	0	–	
Health and Medical	50	0	0	–	–
Total	200				

Table 4 showing distribution of respondent's prevention aspects for flood disasters prevention of various departments (Source: Primary field Survey)

Department	Total respondents	No coordinated mock exercise conducted in city since last 3 years		Adequate equipment not available	
		NO	%	No	%
Deputy Commissioner's Office	50	50	100	50	100
Drainage Department	30	30	100	30	100
Uttarkhand Police	50	50	100	50	100
Uttarkhand fire service	20	20	100	20	100
Health and Medical	50	50	100	50	100

and protect against disasters (FEMA-Department of Homeland Security 2007).

To study the level of preparation by the administration to deal with any crisis/disaster situation, researcher conducted a field survey in which he visited various government departments which are stakeholders of response management at the time of any emergency or disaster situation. The level of preparedness of government to face any disaster situation in Pitthoragarh city is analyzed by considering the following parameters:

1. Prevention and mitigation measures taken
2. Quick Response management
3. Resource Management
4. Rehabilitation management
5. Proper organization and coordination

For the purpose of evaluating the preparedness and execution of planning's in practice researcher interviewed 200 officials from various departments who are stakeholders of disaster management in Pitthoragarh city administration. Table 3 shows the response from various government department officials regarding their preparation to mitigate disaster caused by landslide if it occurs.

As indicated in Table 3, district administration has not established any Landslide control room as a precautionary measure to have an eye on the developments of landslide, if it develops. As a precautionary measure to mitigate the developing landslide situation drainage department has only arranged availability of cement bags. Fifty percent of the officials of drainage department revealed that cement bags available are not sufficient enough, practically to provide retrofitting at a vulnerable sites. Moreover, their stock is placed very much far away from vulnerable areas causing a very inefficient resource mapping.

Table 4 indicates that no mock exercise has been conducted since last 3 years to prepare and evaluate the response management of the administration. Mock exercise is the basic preparation aspect where the administration and rescue workers understand the need of proper pre-planning and coordination within various participating agencies.

Table 4 further reveals that the officials from various government departments feel that they lack needful equipment to mitigate or to conduct proper search, rescue and evacuation operations. As indicated by the table none of the government official was satisfied with the adequacy of equipment they possess.

Suggestions and Recommendations for Developing Awareness Among Common Residents

To give training to common residents, a team of trained personnel need to be organized at the district headquarter who select some change agents in communities residing in landslide vulnerable areas. These change agents like, dedicated NGO's, teachers, senior citizens and govt. officials be trained as a trainers and be given responsibility to spread awareness in the work area assigned to them in their locality.

Awareness workshops and seminars be organized at all public and private schools and colleges and educational institutions. They should be given honor and incentives **time to time** for their contribution and also given backup of resources fulfilling the community training needs. The administration of this awareness programme to be managed by District Disaster Management Authority under the chairman ship of Deputy Collector.

Local print and electronic media can play a very important role in spreading awareness about landslides in common residents. Special features and articles on disaster's nature, causes and response skills be printed periodically in daily newspapers and talk shows, special programs on warning signs, response management be broadcast from local cable TV network time to time.

Schools and colleges should include Disaster management as a subject of SUPW (Social Useful Productive Work) and at least one session of learning be provided every week for students in the form of lectures, workshops, group activities, quiz, mock exercise and visits to model places of safety. The program be strictly followed and report be sent to DEO every month about the activities held.

At state level, Education Boards should include Disaster Management a compulsory subject for all classes and streams. The subject has been introduced by CBSE in 8th class. For practical exposure schools, college and universities should invite resource personnel from DDMA and should also appoint trained instructor/advisor on Disaster Management.

Suggestions and Recommendations to Develop Preparedness to Mitigate and Respond to Emergency Created by Landslides in India

The district administrations should not only take into consideration the lessons learnt from the past disasters but also follow the new lead provided by the fresh direction of prevention and mitigation taken up by Ministry of Home Affairs.

Management Information System (MIS) need to be developed through state level institutions by providing training and organizing workshops for the government departments as well as NGO's and citizens from the public at large. Creation of a web enabled information system would also provide information and act as a link with other states and the central government in a calamity.

A participatory approach to the planning and implementation process is recommended in order to maintain sustainability of the programs launched by the administration for Disaster Management. People's involvement is cardinal to the success of any initiative and it creates a self-regenerating process that requires less administrative interventions in the long run and eases pressure on the administration.

This participation approach in cities, need to be modified to suit the urban context. The urban populace is not as attached to the community as they are ironically part of as their rural counterparts. Neither are they conscious of their environment and surroundings. The urban concrete jungle confuses the mind and makes people oblivious to smaller details. Even though urbanities have relatively less bonding within their community, they are more aware citizens and display greater knowledge of issues and their usefulness can be driven for exercises involved in participatory work.

The urban community usually has less time to spend for social issues due to professional and personal commitments. It is also observed that women took a backseat in the community work in the middle and upper class areas as they are either too tied up with their professions or home or both commitments. Hence it is wise to tap potential of senior citizens for community work. It was observed during the initial sensitization during earthquake preparedness week organized by Jalandhar administration on 26 January, 2004, a mixed crowd of children, women and senior citizens participated. But the more activity oriented exercises like mapping saw 90 % senior citizens as participants.(Ahmed Hussain). Along with children, women and senior citizens, young professionals who still have idealism of their profession instilled within react with more enthusiasm and can be involved with the process after some persuasion. Also professional students (doctors, engineers, architects, etc.) are usually enthusiastic participants in the community planning.

Planning and coordination within various departments of city is must to cope up and mitigate any disaster. This should not be limited to meetings by the officials and paper work only but the practice of joint operations along with community participation should be conducted periodically so that the shortcomings and need of improvements be practically assessed for further planning's and coordination.

The participatory management of planning and coordination can be made effective by involving the method having following steps:

Sensitization of the people through lectures, screening of movies and information brochures at schools, colleges, community halls, parks, religious places etc.

Mobilization of the community by identifying key persons (change agents) like RWA presidents, local NGO's, retired persons, professionals like engineers and doctors who can act as a contact between the community and the administration.

Risk and Opportunity Mapping (community level/area wise). The risk factors like landslide proneness due to over grazing, hill angle more than 60°, broken or narrow roads, high tension wires, bottlenecks, explosive factories and godowns can be mapped at the larger scale with factors like open spaces, parks, hospitals etc. that represent opportunity in case of a disaster.

Hazard Mapping: Landslide hazard prone areas be marked by the administration and complete 'hazard mapping' of that area be made and should not be encouraged for development of habitation and commercial projects. **Vulnerability Mapping** at the household level: The house hold vulnerability maps can be more detailed representation of the community with characteristics of each household graphically represented through symbols for a quick data check. This will enable the workers in a post landslide scenario to react in a specific and effective manner.

Once the hazard mapping is complete, an intensive **resource mapping** should be done. Resources like, JCB, light bulldozers, airlift facilities, rescue tools and equipments, and trained rescue teams be made available at the proximity of hazard but at safe place from where quick response action can be initiated for search and rescue operation, in case landslide occurs.

Vulnerability to landslides develops with development process, if not taken care well in time. Illegal settlements in landslide prone areas of hills need to be totally discouraged and the people already settled there should be moved and rehabitated at some safer place or newly developing well planned urban areas in the outskirts of the city.

The most important thing to mitigate landslide disaster is Public education. Awareness programs on do's and don'ts, warning signs and signals, survival drills, first aid and community participation during any crisis should be organized in schools, colleges, offices, religious places, specific especially vulnerable areas to landslide through workshops, seminars, lectures and Demonstrations, movie and laser shows, billboards, local electronic and print media Theodre (2001). **Mock drills** involving the administration, NGO's and community is the ultimate test of the disaster management planning and coordination success.

A well trained quick response teams along with their equipments under Deputy Commissioner Office, comprising of trained rescue workers from various departments including Police, Health, Fire, Drainage, CPWD etc be established and kept ready for response round the clock especially during monsoon season.

Conclusion

This is the time when we should wake up and make our cities resilient to disasters. The first step towards developing safety and mitigation of disasters is creating awareness among common residents. For the purpose the officials from administration should themselves be given awareness which can be spread in society and communities by selecting some change agents. The second step is to develop preparedness to various disasters by govt. and common people for mitigating or coping up, if it strikes. For this, proper human and inventory resources need to be managed well in time and proper coordination and planning be made for its efficient utilization. The third step is to develop proper organization structure for response management. Special trained teams need to be build and coordination between various departments for management of any emergency situation in city is to be made.

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Landslide Public Awareness and Education Programs in Malaysia

Eriko Motoyama and Che Hassandi Abdullah

Abstract

Malaysia receives high rainfall throughout the year that results in floods and landslides. A National Slope Master Plan that was completed recently shows that landslides have cost Malaysia close to USD 1 billion. One of the components under the Master Plan is Public Awareness and Education. The Slope Engineering Branch in the Public Works Department of Malaysia has been running a public awareness and education program to provide information to the public since 2008. The objective of the program is to create awareness on minimizing the effects of landslides through actions and measures that can be taken by community members as well as by government and private owners of slopes. The program focuses on three sets of actions: (1) identifying key target audiences and finding out their information needs, (2) building capacity and capability of the federal, state and local authority stakeholders, and (3) exploring effective ways to reach out to the message recipients. There are several key messages that are conveyed to the audiences in this campaign, which are: "Learn, Monitor, Maintain and Report". The program is targeted to the entire country with emphasis given to communities in at-risk areas. One of the outcomes from the program is the formation of a community-based organization on slope safety. In Bukit Antarabangsa where a major landslide occurred in 2008, a group of residents got together to form a watchdog group that became the eyes and ears of the local authority for detecting signs of landslides and slope failures. This group is represented by 4,000 residents in the hills of Bukit Antarabangsa and works very closely with the local authority. Another outcome is the formation of a slope unit within the engineering department of some local authorities in at-risk areas. Realizing that they are no longer able to manage slopes with the current staffing resources, budget and skills, they have begun to upgrade themselves by forming a unit that oversees slope issues. Public awareness programs on landslides have flourished since the last major landslide in Bukit Antarabangsa.

Keywords

Public awareness • Landslide risk reduction • Community resilience • Slope safety • Public participation

Introduction

Nestled comfortably between the Indonesian island of Sumatra to the west, Thailand at the north, and the chain of various islands to the southeast, Malaysia has been relatively free of major disasters. Or so it was widely thought until recently. Now with heavy rainfall events that show record levels that are off the charts and hillslope developments that

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started in the mid-1990s, landslides have become the number two major disaster in the country, after floods.

Major Landslide Events in Malaysia

Malaysia's penchant for development on hillsides and the construction of roads in hilly terrain have increased the occurrences of landslides in Malaysia. Landslides, which claim lives, damage properties and affect major transportation networks, have caused major economic losses to the country. Some of the major landslides that have crippled the nation are Highland Towers in 1993 that killed 48 people, Pos Dipang in 1996 that claimed 44 lives, and Keningau, Sabah in the same year that took 304 lives. The 2008 Bukit Antarabangsa landslide and the more recent Ulu Langat disaster that wiped out 16 lives at an orphanage shattered the nation's sense of security and complacency.

Formation of an Agency for Slope Management

The watershed landslide event that captured the attention of the Malaysian Government was the 2003 landslide in Bukit Lanjan, north of Kuala Lumpur, which incurred heavy losses to the Government in terms of extensive damage to the expressway, closure of a major artery to the cities, and loss of productivity and massive congestion due to the closure. In an effort to prevent such future events, a new unit within the Public Works Department called the Slope Engineering Branch was established to manage all slopes in the country.

A Roadmap for Malaysian Slopes

One of the tasks that the Slope Engineering Branch set out to do soon after formation was to commission the National Slope Master Plan, which is a 15-year roadmap on how to manage the slopes within the country.

The National Slope Master Plan is a comprehensive strategic plan that covers areas as diverse as institutional framework, hazard mapping, monitoring systems, information technology, loss assessment, training, public awareness, loss reduction measures, emergency preparedness, and research & development. Replete with strategic directions, action plans and key performance indicator measures, the Master Plan helps planners set priorities on what needs to be done to stem the increasing tide of landslides and landslips.

Fig. 1 The mascot for the campaign is a friendly engineer ready to dispense advice to residents

About the Public Awareness and Education Program

One of the first programs to be rolled out upon completion of the Master Plan was public awareness and education. The program was about creating awareness of slope safety by minimizing the effects of landslides through proactive actions and measures that can be taken by community members as well as by government and private owners of slopes (Yassim Ajam et al. 2004; Rashid bin Jaaper 2006).

Generally speaking, people tend to focus on safety only after a disaster happens, so the program aimed at getting them thinking about averting disasters before they occur.

Objectives and Key Messages

Although the main target groups of the program were the communities-at-risk and the general public, there were other target groups consisting of the state and local governments, private slope owners, media, universities and schools.

The objective of the awareness program was to convey two key messages to the public. The first was to let the public know that there is a body of useful information that is available to the public on the phenomenon of landslides and tips on monitoring and maintenance. The second is that there is a government agency dedicated to safeguarding the interest of public safety.

These messages were encapsulated in the campaign theme of "Learn, Maintain, Monitor and Report" and all activities of the awareness program were centered around this theme. The motif that tied all these activities together was the slogan "Safe Slopes Save Lives", courtesy of the Geotechnical Engineering Office in Hong Kong (Fig. 1).

Programs for Target Groups

The program consisted of campaign activities for various target groups. To ensure that each group received the right kind of information in the right amount, a needs analysis was undertaken. At the same time, a baseline survey was conducted for residents in communities-at-risk to get a measurement of the knowledge, attitude, perception and behavior of the target audience before the program was implemented.

Communities-At-Risk

One of the most important groups is the communities in at-risk areas because of the obvious risk to life and property (Emergency Management Australia 2000; Infrastructure Development Institute 2004; Emergency Management Accreditation Program 2006). The assumption at the outset of the program was that public awareness to this group would yield the best results among all the target groups because of the immediate safety concern to themselves.

During implementation, it was found that this assumption did indeed hold, and the program has elicited a wide range of responses from this target group. With some communities, the response was positive, with residents energized to embark on a community program of their own, while with others it opened a forum for spirited discussion. While sometimes the response was not always necessarily positive, the talks and interaction between the Project Team, presenters and residents served as a platform for discussing issues of slope safety.

Activities for this group comprised community talks on the residents' home turf for a grassroots level of interaction. Residents were pleased that a federal agency came to their communities on topics that concerned them. At these events, posters and brochures were given out (Fig. 2).

To sustain the awareness given to the residents, mini signboards were placed in strategic locations in key communities to reinforce the message of monitoring and reporting signs and maintaining the slopes in their surroundings (Fig. 3).

Fig. 2 A resident expressing his views on slope safety at a community talk

Fig. 3 A mini-billboard installed at key locations in at-risk communities to remind them to watch out for signs of slope failures

General Public

Although the general public may include members of the population who do not live in hillside areas, it is important that this group is also aware of slope safety. This is because many federal roads and favorite tourist destinations in Malaysia are located in hilly areas.

For the general public, activities such as roadshows featuring exhibit displays that explain the landslide phenomenon and safety tips are carried out throughout the country. Colorful brochures and posters with cartoons helped visitors retain their knowledge long after they visited the booth (Fig. 4).

Children as well as adults visited the booths, and to make the event fun for them, coloring contests and quizzes were organized. The coloring contests elicited a lot of interest among children of all ages, and each session was packed with eager participants and hopeful parents.

At the request of the visitors, a virtual 3D exhibit was created so that participants can actually see how landslides form and take place (Fig. 5).

Local Authorities

Next to communities-at-risk, the most important target group is the local authorities. The authorities are the only government body with the charter to enforce safety

Fig. 4 Coloring contest for children at a mall

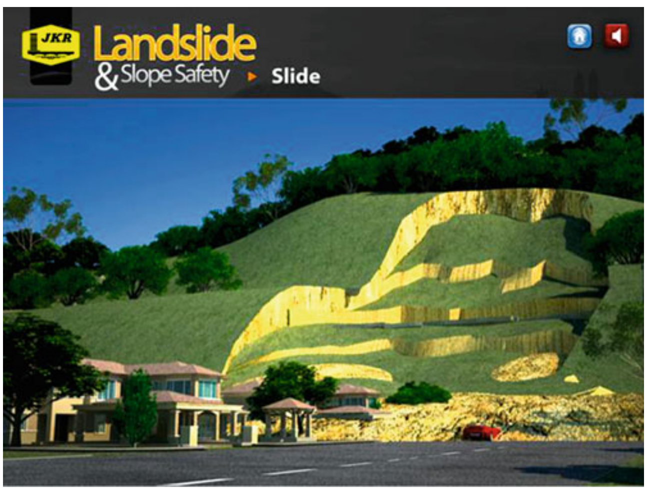

Fig. 5 3D animation of a landslide

guidelines and by-laws and engage in maintenance measures. Because they are the first line of contact with the residents, it is crucial that the engineering departments of the authorities are well-trained and well-equipped.

Slope safety is a still a nascent field in the works scope of local authorities, and the framework for addressing the problems and issues is not fully developed. However, the public's awareness of landslides and need for safety assurances is growing. As such, it is important that public awareness and education and training is provided to the local authorities to help support their growing expectations.

Information on design, construction and maintenance of slopes is given to local authority officials in seminars that last a half day (Fig. 6).

State Government

Because land is a state matter in Malaysia, an understanding of the impact of state government decisions on land use was

Fig. 6 Local authority officers attending an awareness seminar

Fig. 7 State government officials at a seminar

critical. Thus it was necessary to ensure that all levels of state government body were aware of issues in hillside development.

As with the local authorities, topics such as design, construction and maintenance of slopes were presented in seminars around the country.

Seminar attendees included planning and engineering departments of the state government as well as other technical agencies such as Drainage and Irrigation Department, Department of Environment, Mineral and Geoscience Department and the police and fire rescue departments (Fig. 7).

Schools

Schoolchildren are our hope for the next generation of planners, builders and engineers, and education on good practices starts in the schools. In four simple presentations,

Fig. 8 An elated student for winning a prize in the match-and-win contest

Fig. 9 Students from the Faculty of Engineering at a university

children are taught to learn about landslides, monitor for signs, maintain slopes and prepare for landslide emergencies.

Children by nature are observant, making them prime volunteers for watching out for the signs of landslides and slope failures. A special poster was created for schoolchildren, telling them to report to school authorities should they see any signs of developing around the school area. They could also take this knowledge back to their homes, where they can practice it in their home surroundings.

Talks in the school auditorium are given to audiences comprising mostly Grade 8 and 10 high school students. A match-and-win contest with prizes usually elicits a lot of enthusiasm from the students (Fig. 8).

Universities

At universities and institutions of higher learning, students normally learn the fundamentals of civil engineering and theories associated with the field.

Fig. 10 Local TV station interviewing residents on their views on slope safety

The public awareness program aims to get students to realize that in the real world there is more than technical knowledge when it comes to slope engineering. Students are made aware of the impact that their designs and works may have on society as future engineers. Through the program, they also come to realize that there are social responsibilities in ensuring that design of slopes are safe for the communities and adhere to the principles of sustainability.

Activities for this group consisted of booths set up at convocations so that families of students were also able to view the information, as well as talks in auditoriums for first- and second-year university students (Fig. 9).

Media

The media plays a critical role in informing the public on slope safety. In the Master Plan, the media was identified as an 'information disseminator' rather than an 'information receiver.' This is because the media plays a powerful role in shaping people's opinion and thoughts on various subjects.

Up until recently, the media has played the role of reporting on landslide events as they occurred. This tended to cast a negative view of hillside developments in general. However, given the fact that hillside developments are going to continue in the future, a different perspective must be presented such that slope safety is perceived as being managed rather than left to the forces of nature and the whim of human developers.

To do this, mass media is used to provide useful tips and information to the public at large. This is done through educational advertorials in the newspapers and 60-s info-mercial spots on television. A website dedicated to slope safety is also set up (Fig. 10).

To get journalists informed on slope safety, a media briefing is provided from time to time during shopping mall exhibitions.

Impact of the Program

The program ran for a period of 2 years and 8 months. A baseline measurement survey on communities at risk was carried out prior to commencement of the programs for residents, and a follow-up survey was taken at the end of the program period. The measurement instrument used was a Knowledge, Attitude, Perception and Behavior (KAPB) study. Comparative analysis was conducted, and results showed that the public awareness program met the target set in the National Slope Master Plan for phase one.

Qualitatively, there were many impacts resulting from the public awareness. The program impacted various target groups differently. Due to the program's phase one emphasis on capacity building, the groups that were most influenced were the state and local governments and the communities-at-risk. This reflected the time and commitment the Project Team spent on these two groups in particular.

The outcomes resulting from this program are significant in that they reflect institutional and long-term changes that affect the way hillside developments will be carried out in the future. They are as follows:

1. Awareness among local authorities in hilly areas for a proper slope management mechanism within their scope of work and the subsequent establishment of Slope Departments within eight local authorities in three of the high-risk states in the country
2. Establishment of state-level independent slope oversight committees for checking and approving all new development orders involving hills
3. Reporters of newspapers providing regular coverage of slope issues in the local beat, and coverage now includes educational material in addition to problem cases
4. Formation of SlopeWatch, a community-based organization that has grown into an non-governmental organization due to demand by residents for more information and advice on averting slope problems and pushing the authorities for stricter supervision of developers
5. Residents associations in urban areas establishing sub-committees on slope monitoring so that residents can do their own monitoring and report to the authorities on any signs

These are some of the changes that the program has effected, although there is much more work to be done. However, what the Public Works Department has achieved through the Public Awareness and Education Program on Landslides and Slope Safety was to create opportunities for the federal government, the public, local and state governments and other stakeholders to engage in a fruitful dialogue and collaboration that is hoped will continue for years to come.

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Learning by Doing: Community Based Landslide Risk Reduction

Elizabeth Holcombe, Malcolm Anderson, and Niels Holm-Nielsen

Abstract

'Knowledge into action' and 'community engagement' are terms widely used in disaster risk management. We challenge the efficacy of such advocacy by reviewing knowledge gaps that restrict delivery of landslide mitigation on-the-ground in the most vulnerable communities in developing countries. We outline a holistic strategy which embraces *both* 'action into knowledge' and 'knowledge into action', and which engages all stakeholders throughout implementation cycle. This strategy formed the basis for the development of a community-based landslide risk reduction programme (MoSSaiC – Management of Slope Stability in Communities) in several Eastern Caribbean communities during the period 2005–2011. Outcomes included changes in policy (support for ex-ante DRR), new institutional practices (creation of a cross-ministry Government team), enhanced the local skill base (communities learned construction skills) and raised awareness (of landslide 'science' and hazard reduction). Such outcomes support the view that 'learning by doing' offers considerable benefits in the delivery of landslide mitigation measures.

Keywords

Urban • Community • Developing countries • Learning • Landslide hazard reduction

Introduction

Landslide risk is increasing, especially in developing countries (UN-ISDR 2009). Rapid urbanisation, the consequential growth of slum population (Buckley and Kalarickal 2005), and development of communities on landslide-prone slopes are powerful drivers in a cycle of risk accumulation. Property on landslide prone slopes is cheaper to rent, so it is unsurprising that the most vulnerable live in these areas. Planning control policies would typically aim to restrict development in potentially hazardous zones; for example, suggesting that no houses should be built on slopes that exceed 14° (Schuster and Highland 2007). In reality, informal settlements are often found on considerably steeper slopes. Such development usually involves deforestation, earthworks, slope loading, and drainage changes which can, in turn, further decrease slope stability. This is a particular issue in the humid tropics where deep weather soil profiles are prone to rainfall-triggered landslides. Any climate change induced increase in the intensity or duration of these triggering events will inevitable exacerbate the situation.

Practical implementation of landslide hazard reduction measures is rare, and so too is the evidence that disaster risk mitigation works or is cost-effective in this context (Wamsler 2007). Reversing landslide risk accumulation is hampered by

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the fact that risk reduction is a complex issue, and is viewed as "ranking low on the tractability dimension" (Prater and Lindell 2000), being difficult to implement. It requires an understanding of the interactions between the physical and human risk drivers (hazard, exposure and vulnerability), and importantly, how to assess the risk and deliver solutions at a scale that relates to these risk drivers. This necessitates a multi-disciplinary approach and the engagement of the complete spectrum of stakeholders – from residents to policy-makers.

Despite the broad policy recognition of Disaster Risk Reduction (DRR), there is a lag in funding and the effectiveness of those policies 'on the ground'. The knowledge and practices identified at international and national scales aren't trickling down fast enough to achieve the Hyogo Framework of Action goals (Wisner 2009). This could be accounted for by the fact that three inter-related components are missing: the evidence-base for investment (benefits lie in the future and are 'unseen'); the scientific basis for reducing the hazard (top down drivers do not focus on the scale of the hazard trigger); and the community basis for delivery on the ground (generally a failure to involve those most at risk in the process). Current policies for landslide risk reduction often emphasise the translation of 'knowledge into action' without always turning 'action into knowledge', and focus on vulnerability reduction without always investigating ways to address the landslide hazard. Finally, the relative lack of on-the-ground delivery is to some extent also encouraged by key literature on disaster risk management that commonly makes use of such terms as 'coping strategy', 'resilience' and 'capacity build', without defining them (Wamsler 2007).

We report an alternative strategy which identifies and addresses landslide hazard drivers at the appropriate local scale, acknowledges that communities can be part of both "the cause of the problem *and the solution*" (World Bank 2010), and demonstrates that 'action leads to knowledge'. Such a strategy makes the following clear distinctions regarding knowledge and action:

1. Knowledge-to-Action (K-A): Events are designed, run, and debriefed primarily to enable or encourage participants to apply previous knowledge to some practical situation.
2. Action-to-Knowledge (A-K): Events are designed, run, and debriefed primarily to enable or encourage participants to generate understanding, learn new skills, and gain new knowledge from a concrete experience.

(Crookall and Thorngate 2009, p 19)

Accordingly, our strategy adopts a holistic, 'complexity paradigm' (Malamud and Petley 2009) which integrates natural science and social science, and recognises the need for *both* 'action-into-knowledge' and 'knowledge into action'. We implemented this strategy in deploying a community-based landslide risk reduction programme (MoSSaiC – Management of Slope Stability in Communities) in several Eastern Caribbean communities during the period 2005–2011.

The MoSSaiC 'Learning by Doing' Strategy

The concept began with a critical review of current landslide hazard and community vulnerability reduction activities (Table 1). We regarded the relative lack of evidence of landside hazard reduction at the community level as a rate limiting step in delivering measurable risk reduction on-the-ground. Hazard reduction was therefore at the heart of the conceptualisation of MoSSaiC.

The MoSSaiC strategy for landslide hazard reduction sought to be holistic by ensuring that physical hazard drivers were identified and understood (science) and by engaging teams of stakeholders throughout the project cycle (communities, Community Based Organisations, Government managers, engineers and development practitioners, policy-makers, and landslide experts). Each stakeholder is then able to both share knowledge and learn from the other stakeholders. Communities become the classrooms in which all of the elements of the project are grounded.

The 'knowledge society' (a fashionable term in the developed world) implies that knowledge is the only reliable basis for effective action (Crookall and Thorngate 2009). Here, training and education could be seen as the start of the process – *inputs* – as they are in so many disaster risk reduction 'capacity-build' programmes. Contrary to this viewpoint, our programme saw these elements as *outputs*. The programme deliberately started with community-based mapping and the *implementation* of landslide hazard reduction measures by the residents. Engaging residents in detailed slope mapping revealed localised slope features related to the landslide hazard and provided the context for discussing the 'science' with both the community and with the Government team. In particular, the concentration of rainfall runoff and infiltration of household waste-water was identified as a key driver for this hazard in the majority of the communities involved. In each case, the local knowledge and mapped information allowed a user-friendly dynamic slope stability model to be used for assessing the potential effectiveness of surface water drainage measures for improving slope stability. Government engineers,

Table 1 Conceptualising current landslide risk drivers, actors and risk reduction strategies with respect to vulnerable urban communities in developing countries

	Community vulnerability	Landslide hazard at the community scale
Risk drivers (risk as the product of hazard, exposure and vulnerability)	Root causes (limited access to power and resources, political and economic systems)	Physical preparatory factors (slope angle, material properties, hydrology, vegetation)
	Dynamic pressures (lack of local capacity, population change, urbanisation, national debt, unfair markets)	Physical triggers (e.g. rainfall)
	Unsafe conditions (exposure: living in hazardous locations, lack of building control, low income, lack of preparedness)	Human aggravating factors (cutting/filling slopes, altering drainage, loading the slope, removing vegetation)
Research disciplines	Social scientists	Scientists
	Economists	Engineers
Risk reduction policy makers and practitioners	International development agencies	Engineers
	Government social development agencies	Very few dedicated landslide *hazard reduction* policies and practices at community scale
	NGOs and CBOs	
Risk assessment methods	Wide-area vulnerability assessment	Wide-area (GIS-based) susceptibility analysis or hazard zonation mapping
	Quantitative and qualitative studies of community vulnerability	Participatory Disaster Risk Assessment to generate landslide susceptibility maps
	Participatory Disaster Risk Assessment (e.g. Vulnerability and Capacity Assessment)	Site-specific hazard assessment and modelling for hazard reduction
Risk reduction options	Exposure reduction (relocate at-risk households or communities)	Exposure reduction (avoid landslide hazards through planning controls)
	Preparedness and mitigation of impacts (public awareness, emergency warning, disaster planning and training, sustainable livelihoods, poverty reduction, micro-insurance)	Landslide hazard reduction using engineering measures (retaining structures, geotextiles, drainage, bio-engineering)
		Improve slope management practices to reduce hazard
Risk reduction reality	Vulnerability 'assessment mapping' for vulnerability reduction is the most common activity with respect to landslide risk	*Very few reports of landslide hazard reduction projects in communities*

planners and community development personnel then worked alongside the communities to design appropriate drainage networks to manage surface water. Community members tendered for projects, procured materials, constructed drains and led sessions in subsequent technical training events and wider conferences.

Starting with all the stakeholders 'on-site', and making the community the focus of activities, yields a powerful platform for learning by doing. MoSSaiC provides a case study for this approach to landslide education, training and capacity development which needs both exposition and, in due course, further impact analysis (Holcombe et al. 2011).

The MoSSaiC 'Learning by Doing' Case Study

In disaster risk reduction the critical word is "delivery", the key to which is local knowledge (Wisner 2009). In light of this, MoSSaiC sought to deliver landslide hazard reduction measures in at-risk communities with the active engagement of a broad local stakeholder base. At the onset a target was set to spend 80 % of funds in the community (in the form of local contracts, labour and materials). To ensure effective delivery and financial efficiency, a management committee comprising *existing* Government staff (the MoSSaiC Core Unit – 'MCU') was established. The hazard reduction approach centred on the identification of landslide prone slopes in vulnerable urban communities, and ascertaining whether surface water management (construction of intercept drains and holistic management of household grey water and roof water) would deliver significant improvements in slope stability.

Over a 6 year period, using this community-based approach, mitigation measures were undertaken in 12 communities (~3,000 households) in the Eastern Caribbean. This strategy deliberately recognised that "we must avoid romanticising indigenous knowledge, and combine it with scientific knowledge" . . . and that ". . . bridging the learning-action gap requires innovative programming, external recognition and financial investment" (Pelling 2007).

Table 2 summarises how the synthesis of the knowledge and actions each of groups of MoSSaiC participants contributed to delivery of landslide hazard reduction measures. The need to identify and solve problems as the presented themselves on-site created a dynamic learning environment and helped to bridge the learning-action gap. This outcome could not have been achieved if any one of these groups (and hence, their knowledge) had been excluded, if the landslide

Table 2 Conceptualising current landslide risk drivers, actors and risk reduction strategies with respect to vulnerable urban communities in Small Island Developing States (SIDS)

Participants	Typical landslide hazard assessment and hazard reduction knowledge in SIDS	Typical landslide hazard knowledge-action gaps in SIDS	MoSSaiC case study: Action-to-Knowledge (A-K) and Knowledge-to-Action (K-A)
Households and local contractors	Slope and community history	Good slope management practices to avoid increasing landslide hazard	Contractors used from within the community (K-A)
	Detailed familiarity with slope features (drainage, cuts/fills, soil depth, signs of instability)	Good construction practices for improving slope stability	Residents involved in the process see the direct results of good slope management practices and simple measures in their own household (A-K)
			Good construction practice shared between contractors (A-K)
Government engineers	General slope history and soil properties	How to work with communities to identify detailed slope-stability features	Delivery of high quality construction supervision (K-A)
	Topographic survey methods	How to identify slope stability controls for a whole hillside	Government team members develop new local knowledge and practices whilst working with local contractors in the communities (A-K)
	Soil shear strength testing	How to design integrated slope stabilising measures to protect a whole community	
	Static slope stability assessment methods for single-sites	How to work with community-based contractors and labourers	
	Design and construction of generic slope stabilising structures at single sites (retaining walls, gabion baskets, benching)		
Community development practitioners (NGOs, Social Funds and Social Government Ministries)	Awareness of landslides in communities – their physical and human impacts	Awareness that there are ways to reduce landslide hazard at a community scale	Delivery of high quality community liaison (K-A)
			Learning the science from other team members and integrating community mobilisation skills with hazard reduction agenda (A-K)
Government project managers and politicians Development agencies	Awareness of landslides in communities	How to reduce landslide hazard at a community scale using cost-effective methods and local knowledge	Multi-ministry MoSSaiC management committee briefed on science of landslide hazard reduction (K-A)
	Identification of broad landslide hazard zones from national or municipal scale maps	How to interface with the scientific basis for assessing and addressing landslide hazard at community scales	Existing project management skills employed in new way (K-A)
	Awareness of pilot studies to reduce landslide hazard		Report of MoSSaiC projects provides new evidence-base for policy (A-K)
Researchers and engineering consultants	Slope hydrology and stability processes	How to work with communities to identify detailed slope features affecting stability	Application of landslide theory 'in the field' (K-A)
	Sophisticated slope stability assessment models (typically data- and computationally-intensive)	How to interface local knowledge and science	Refinement of approach to landslide research – experience of working with end-users results in new priorities, scientific methods and ways of communicating (A-K)
	Sophisticated engineering design for landslide hazard reduction (typically high cost)	How to work with local practitioners, project managers and policy-makers to implement appropriate landslide hazard reduction measures	

hazard drivers had not been identified, or if the process had started in a classroom. Thus, the community-based mapping process enabled residents' knowledge of the local slope features and history to be combined with engineering and scientific knowledge of slope processes. Landslide hazard drivers could then be identified at the correct scale and

Fig. 1 Knowledge-to-Action (K-A): community contractors discussing local construction practices and contributing drainage design ideas

Fig. 2 Action-to-Knowledge (A-K): community residents commencing drainage construction in a vulnerable community in which houses had previously been destroyed by landslides

everyone learned where and why there was a slope stability problem, and how it might be solved. Scientists and local engineers worked together to further analyse the physical hazard drivers and determine the most effective mitigation approach. Again in the community, local contractors contributed their experience and detailed knowledge of local construction practices to drainage design (Fig. 1). For many residents knowledge of good construction practices was achieved through their involvement in drain construction and the associated on-site guidance from engineers and experienced local contractors (Fig. 2).

Community members were also involved in managing the procurement of materials and speaking at community meetings and post-project conferences. This level of participation was seen to be a direct result of their initial engagement in the mapping process. Within the Government the experience resulted in new knowledge of managing community contracts, maintaining standards of construction and developing innovative policies to enable more interventions.

Conclusions

'Learning by doing' for landslide risk reduction has a core advantage for *all* participants – the speed of education and training is rapid and highly focussed. Community residents and researchers alike broaden their knowledge and skill-base with enthusiasm because they can see the results. Familiarity with the science of the hazard reduction measures is an integral part of the process; so much so that community members are subsequently able to participate in technical training days and to provide instruction to Government staff. Sohail and Baldwin (2004), in a review of community partnered projects, confirm them to be as successful as conventionally contracted small projects, but additionally have wider socio-economic benefits. Our experience confirms this and asserts that creating an 'action-learning' environment of itself creates a learning experience for everyone.

By starting with community-based activities as the classroom, the MoSSaiC approach has shown that:

- The core skills and local knowledge conjointly exist within communities and governments for this starting point in the educative and training cycle (Anderson et al. 2007);
- Immediate, and enduring, community engagement occurs because of the immediacy of construction activity (Holcombe and Anderson 2010)
- Landslide hazard can often be reduced through improved drainage (Anderson et al. 2011)
- Benefit-cost ratios of such projects can be ~3:1 (Holcombe et al. 2011)
- Donors and Governments have learned from the experience, due to the short delivery times for the community contracts and the rapid availability of quantitative performance measures. By contrast, capacity build in many projects is ill-defined, and of unspecified duration (Holcombe and Anderson 2009).
- Donors are supportive of a 'learning by doing' approach (Anderson and Holcombe 2011).

This process is strategic and incremental since each example of effectiveness on the ground enables greater learning and adoption. Donors, governments, social funds, community members and academics (and thus 'society' in the broadest sense) have all participated in this process, supported construction from the start, and recognised behavioural change to be an *outcome*. The approach has witnessed changes of policy (budget support for ex-ante mitigation), new practices (cross-Government MoSSaiC management team), enhanced local skill base (community residents learn and develop construction skills) and awareness (communities fully involved in the 'science' of mitigation) (Anderson et al. 2011). We believe such outcomes supports the view that 'learning by doing' offers considerable major benefits in the delivery of landslide mitigation measures.

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PASTI (Preparedness Assessment Tools for Indonesia): Diagnostic Tools for Disaster Preparedness

Hening Purwati Parlan

Abstract

PASTI is an instrument used to measure community based preparedness that cover 3 basic aspects: basic human service, community development and disaster risk analysis for 9 typical threats. There are earthquake, tsunami, volcanic eruption, landslide, flood, forest fire, drought, epidemic and mud. When analyzing the community preparedness, those aspects are working in synergy among each other since there is an interconnection between them. Basic Human Services instrument to understand the accompanied population means identifying basic needs and the extent to meet them. If the fulfillment of such needs is low, community resilience capacity against the threats is less consequently. Community Development is to reconstruct the community as the learning centre of experience, human needs, and reconstruction of state structures, welfare, global economic, bureaucracy, etc. Disaster Risk Analysis analysis is a perspective that becomes of harazd, vulnerability and capability. The instrument can used by all kinds of stakeholders

Keywords

Landslide • Disaster preparedness • Basic human service • Community development and disaster risk analysis

Introduction

Preparedness Assessment Tools for Indonesia

Disaster is not only a study on vulnerability, weakness and degradation.

Disaster also comprises happiness, strength and welfare.

Preparedness is an activity that largely demonstrates the level of effective disaster response of a community. Community preparedness is part of disaster risk reduction initiatives. The end goal of such preparedness is indeed to build up community resilience towards disaster threats. Activities involving preparedness instrument have been carried out by a number of institutions either of local or national scale with different approaches. UNESCO in cooperation with Humanitarian Forum Indonesia (HFI) and Muhammadiyah Disaster Management Centre (MDMC) are currently preparing an instrument model and a module to measure community preparedness in an intelligible format that can be easily used by both the community and the local government. PASTI (Preparedness Assessment Tools for Indonesia), is an instrument to diagnose community situation as regards to their preparedness initiative towards disaster (Purwati et al. 2009). PASTI is believed to be a user-friendly diagnostic tool for the community to evaluate threat, risk and resource they have in disaster management context.

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Preparedness Tools

In preparing the disaster preparedness tools, we basically relied on our initial concept of Preparedness, which is a series of activity undertaken to anticipate disaster hit through organizing it; a suitable and applicable measures,[1] as well as the recent ISDR concept[2]: *Activities and measures taken in advance to ensure effective response to the impact of hazard, including the issuance of timely and effective early warning and the temporary evacuation of people and property from threatened locations*.

There are a number of critical parts to be observed: (a) Explanation on Hazard is a critical part and becomes a preface of all tools. It is the resume from the nine experts after finishing ‘the basic knowledge’ which contains hazard-related information, (b) To enrich the tool, the available articles can be used as the basis of all hazards to get to the tools of Disaster Risk Analysis, Community Development and Basic Human Security (BHS). The above two points will be translated into tools which were previously discussed by experts of relevant aspect to be incorporated.

Community as People Centre

Community as people centre basically resembles a part of triangle of life where community is depicted as a triangle and its legs are families, state politic and market. **P**eople centre context the risk analysis and disaster preparedness tools have to see that occurrence in community is not solely caused by the hazard, but the community themselves must be able to see and provide judgment on the hazard or vulnerability.

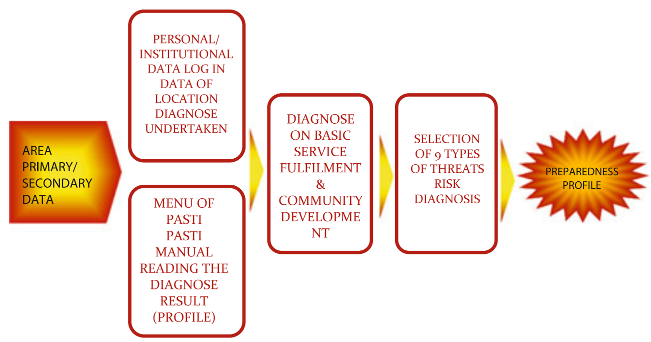
Principles in Measuring Preparedness

Conventionally, the community basic need is a domain of program ‘development’ and it is deliberately distinguished from other disaster management program (relief) that makes disaster preparedness is the combination between the ‘relief’ and the ‘development’ which was used be separated. The pre-disaster phase is the most important phase in disaster preparedness as in the normal situation, non-emergency, the basic need fulfillment programs run normally and the foundation of comprehensive community resilience is easily constructed.

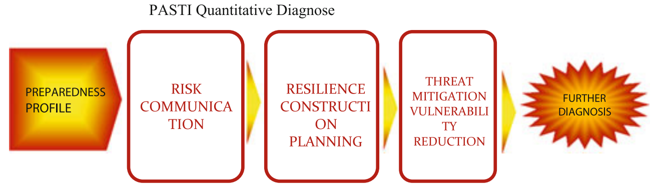
Picture: Basic Scheme of PASTI

The Objective of Developing PASTI

To prepare the instrument to be more applicable and easily deployed by the end-user that is community leaders or the social workers at community level. The objective of applying such instrument is to have a clear idea on community preparedness extent and function as a reference to follow up action(s) which contribute to increase community disaster resilience



PASTI Quantitative Diagnose



PASTI Qualitative Diagnose

Methodology and Valuation Format of PASTI

The quantitative method with descriptive format becomes the background of PASTI instrument. The valuation format utilizes category system against observed fact/phenomenon. Category is the question that describes a class of phenomenon into observed attitude so that it can be symbolized. The system endeavors to synthesized references (frame of reference) for observer and allows relevant aspects may

[1] PASTI Team that consists of Karisma Nugroho, Barry Adhitya, Jenik Andreas, Surya Rahman Muhammad, Herni Ramdhaningrum, Denden F. Arief.

[2] Terminology, ISDR, 2009.

convincingly be observed.[3] PASTI uses five categories in grouping answers from the instrument users so that a picture on comprehensive disaster preparedness may be obtained.

Score 0	Nothing or no idea whether the instrument is applied
Score 1	Start to be applied, however limited on or only implemented by a number of persons
Score 2	Already available/has been developed at village level and or has achieved significant improvement
Score 3	Already available, as has been integrated successfully at community level or has been the community need
Score 4	Yes, and the practice has been internalized/culture

Media Format

PASTI will be available in interactive CD format and web-based survey which allows review and revision if necessary.

Basic Components of PASTI

Basic Service: Disaster Preparedness and Basic Needs

The world population has been suffering from increasingly natural and social disaster occurrences than the last few decades. Such situation has caused instability and disturbance within community groups which affecting material loss and significant environmental destructions. To build community resilience is to recognize basic human right and to ensure that the community understands the most basic right, starting from the right to live up to the right to utilize resources. Awareness and understanding of the relationship between disaster and community basic right is a critically important. Fulfillment of basic right is the foundation of disaster risk reduction which will increase community readiness to face disaster. The focus of community preparedness measurement towards disaster is the elements of community resistance themselves

The preparedness plan should be arranged at targeting population, health service, service provider organizations and the government since the effort to mitigate disaster impact – by preparing appropriate response plan and providing timely and effective reaction towards disaster – is quite specific at every level of population/types of institutions. Lessons from disaster hit areas in Indonesia demonstrate that a written document on disaster preparedness only is insufficient to make a disaster prone population becomes well-prepared. The disaster preparedness plan must be practical and adaptable with the respective community groups or institutional situations. Map is one of the best ways to present the vulnerability and risk analysis results. The map is not always representing a 'picture of an area', although the visualization is largely more explaining.

The instrument will help you to appraise the level of common basic needs fulfillment, making profile on targeted population as well as the level of disaster exposure. The profile is crucial since it is not a homogenous population. Disaster and social stability corresponds closely to each other. Disaster does not only destroy physical facilities but also deprives the social system that greatly contributes to disaster risk reduction. On the other hand, the fragile social system may increase the vulnerability to disaster.

Community Development

There are numbers of model applied to community development practices.[4] One among the others is a model of the local based development (locality development) which is aiming at ensuring significant shifting in community and can be done comprehensively by wide range of community participation from different community spectrum. In several UN[5] publications, it is mentioned the community development as:

> Community development can be tentatively defined as a process designed to create conditions of economic and social progress for the whole community with its active participation and the fullest possible reliance on the community initiative.

Meanwhile, Arthur Dunham[6] defined it as:

> Some themes emphasized in locality development include democratic procedures, voluntary operations, self-help, development of indigenous leadership and educational objectives.

The objective of community development is to reconstruct the community as a centre of human outstanding experiences, fulfilling the human needs and to rebuild the state structures of welfare, global economic, bureaucracy professional elite and so on which is insensitive to humanitarian issues and hard to access. Six dimensions of community development are used including participatory aspect, there Social development, Economic development, Political development, Cultural development, Environmental development, Personal/spiritual development

[3] Prof. Dr. H. M. Burhan Bungin, S. Sos., M. Si; Metodologi Penelitian Kuantitatif; Edisi Pertama, Jakarta: Kencana, 2008.

[4] Manual of Pengembangan Masyarakat dalam PASTI adopted from Jim Ife; Community Development (2002).

[5] United Nations, Social Progress through Community Development (New York: United Nations, 1955) in "Strategies of Community Organization", Fred M. Cox and colleagues (Peacock Publisher, 1972).

[6] Arthur Dunham: "Some Principles of Community Development", International Review of Community Development, No. 11 (1963) in "Strategies of Community Organization", Fred M. Cox and colleagues (Peacock Publisher, 1972).

Threat Analysis

Disaster Risk Analysis (DRA)

The Disaster Risk Analysis is a perspective as well as a part of *Disaster Risk Reduction* that serve as the ground to review and complete the PASTI. Risks face by a community group are differ from the other, depending on geographic and geology situation, social conditions, economic and culture, as well as lifestyle and political economic influence in every region.

Disasters in Indonesia tend to continually increase. It is noted that in 2006 there are statistically 162 disaster hits of which doubled in 2007 with 379 occurrences which consist of flood, landslide, flood and landslide, wave surge, earthquake, technological failure and volcanic eruption.[7]

The issue is now more focused on the disaster risk. The Bill number 24 of 2007 on Disaster Management, the disaster risk is defined as potential loss caused by disaster on a region in certain period of time, causing death, injuries, wounded, life at risk, lost of safety, evacuate, property damaged or lost and disturbance to community activities.[8]

Meanwhile, according to ISDR, it is mentioned that[9]:

> The probability of harmful consequences, or expected losses (death, injuries, property, livelihoods, economic activity disrupted or environmental damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions.
>
> Conventionally risk is expressed by the notation
>
> Risk = hazard × Vulnerability. Some disciplines also include the concept of exposure to refer particularly to the physical aspect of vulnerability.
>
> Beyond expressing a possibility of physical harm, it is crucial to recognize that risks are inherent or can be created or exist within social system. It is important to consider the social context in which risks occur and that people therefore do not necessarily share the same perception of risk and their underlying causes.

Landslide Preparedness Assessment Tools for Indonesia

What Is the Landslide. The landslide is the shifting or the movement of rocks, mass, soils downwards into the lower part of a slope. The landslide may occur on soil or rock materials of the combination of the two. Soil and rocks consists of different kind of components that when there is disturbance, the composition imbalance will occur and the components will detach from each other.

[7] Data Bakornas PB, 2007.

[8] The Bill Number 24 of 2007 on Disaster Management.

[9] Terminology, ISDR, 2009.

The Cause of the Landslide

The landslide occur as the result of changes, either sudden or gradual on the structure and the type of rock or soil, the nature of water contained in the rock or soil and trees or vegetations around the rocks or soil. Even if the landslide can happen due to earthquake, flood and volcanic activity, however, the hazard of the landslide is far spreading than other hazards in certain period of time, which can cause loss of property such as house, plantation, etc. The landslide occurs when the strength of rocks or soil to form a slope is surpassed by pressure of the lower slope. The resistance of a slope can decrease due to: Increasing water containment by the torrential rain or the raising of the underground water level AND Increasing angle of the slope due to new constructions or river erosion.

Meanwhile, pressure on the lower part of the slope can be due to:

(a) Tremors from earthquake, explosion, machines, traffic and thunderstorm.
(b) The missing of side abutment by previous slope collapse, building constructions and excavations.
(c) Lost of trees or vegetations due to fire, uncontrollable tree-cutting.
(d) Heavy weight held by the rocks or soil from building, irrigation leakage, etc.

Typical Character of the Landslide

Landslide occurrence is usually because of heavy storms, earthquake and volcanic eruption as well as continuous rainfall. Materials of the landslide are distinguished into two groups: basic rocks or soil (earth) and organic debris.

Movement Types of the Landslide

Collapse: Collapse is a big number of rocks or other materials that move downwards by falling or bouncing in the air. This is the most common occurrences along a steeply roads or railway dikes, steeply bunds or steeply cliffs especially in coastal area. Those big rocks may provoke significant damages.

Current: The current is moving like a sticky substance, sometime can be so fast and may reach few kilometers away. The water is not so important to keep the current flows; however, it mostly formed after the torrential in certain period of time. The mud flow that comes from the mount slope can be triggered by rain which is common in Indonesia. In Europe, the snow melts in sudden, or water that flows down from the crater. The flow of debris is the mixture of water and soil, rocks and organic materials combined by air and water. The debris flow is usually happened in steep ditches. Very slow, almost unrecognizable, the flow of soil and basic rock is called 'creep'. After quite a long time, the creep can make telephone and electric pools or other up right objects leaning down to the ground.

What Provokes the Landslide and Where They Likely to Happen

In principle, the landslide happens if the thrust (burden) can not be held by the lift power of the soil or rocks that the imbalance condition created. The lift power is usually affected by the strength of rocks and soil density, while the thrust is affected by the degree of the slope, water, burden (gravity) and the specific gravity of the soil/rocks. The landslide can be in slow movement or sudden, with the size of few meters only up to thousands of kilometers. Besides, the occurrence can be of natural or triggered by human. The landslide incidents provoked by human activity is the forest cutting around the sloping area, improper water management, land clearing from dry land into wet land, especially on the steeply slope area. Even if the main cause of the landslide is the gravity that affects a steeply slope, there are other influential factors contribute to it.

1. **Erosion by the river and sea waves**
   Erosion is an event of soil scraping by wind, water or ice on the river banks to the cliff. Erosion can happen either naturally or of human activities. The natural cause of erosion is rain characteristic, degree of the slope, covering vegetations and the soil capacity to absorb and release the water into the shallow soil layers. Erosion by human activities is generally due to deforestations, mining activities, plantation and land clearing. Abrasion is a process of coastal scraping by the destructive sea wave and sea current. Abrasion can be called as coastal erosion. The destruction of the coastal lines affected by abrasion is triggered by the disturbed natural balance in the coastal area. Even the abrasion can be stimulated by natural causes; man has often be the main cause of it. One way to prevent the abrasion is by planting mangroves along the coastal lines. Erosion caused by rivers or sea waves created extreme steep of the cliffs.
2. **Weak rock or soil slope due to rain water infiltration**
   Type of soil that loose and fragile is clay that potentially can cause the landslide especially after the rain comes. In addition, the soil is extremely vulnerable to earth movement since it turns soft when expose to water and broken when the air is hot. Meanwhile, a fragile rock is volcanic deposit and sediment of sand size and mixture between gravels, sand and clay. Such rock easily turns to soil if expose to weathering process and commonly vulnerable to landslide if located at the steep slope. Water is almost always contained in the soil/rocks on earth surface with porous and cracks or in between granules. The influence of water in the landslide is to add burden (increase the gravity), to diminish cohesion due to water pressure, and to dissolve granules adhesiveness.
3. **Earthquake**
   Earthquake is the tremor occurred on earth surface. It can be due to the earth plate movement and may provoke big pressure that collapsing the weak slopes. Earthquake can be measured by a device called seismograph and divided in scale from 1 to 9 based on the Richter scaling. In addition to that, it can also be measured using the Mercalli scale.
4. **Volcano**
   The volcano can take many forms. The active volcano may change into half active, or even inactive before died. Therefore, it is difficult to determine the actual situation of a volcano, whether sleeping or died. The volcanic eruption can create dust, dust rain and dust flow.
5. **Tremors**
   Usually the tremor occurred due to the earthquake, explosion or volcanic eruption, the use of explosive materials, vibrating machines, road traffic and even lightning. All these causes may result in cracks in soil, road paving, and floor and brick walls.
6. **Additional burden**
   An excessive additional burden such as building construction on the cliff and vehicles will enhance the thrust of the landslide, particularly around the street corner in valleys. As the result there is land subduction and cracks directing to the valley.
7. **Types of land use**
   The landslide are frequently happening at the land use area such as rice field, dry field and puddles on the steeply slopes. On the rice field, the vegetation roots are not strong enough to tie up soil granules and make the soil soft and unable to absorb water which easily becomes a landslide. As to the dry lands the cause is the tree roots can not penetrate deep inside the loose granules and largely happens in an old landslide area.
8. **Deforestation**
   The landslide generally occurs in relatively bald area as there are no adhesive elements in the soil water.

9. **Old landslide sites**
   The landslide is commonly take place during and after the volcanic material sedimentation accumulates on a relatively steep slope or after the Caesar movement on the earth crust. The old landslide site has the typical character as following:
   - There is a long bending steeply slope in a horseshoe shape.
   - The water spring is commonly found, relatively thick trees as the
   - Soil is loose and fertile.
   - The upper part of the sliding area is largely slope slightly.
   - Small landslide found especially at the valley slopes.
   - Relatively steeply slope found which is used to be a small landslide on the old landslide site.
   - On the cliffs of the valley channels found cracks and small landslides.
   - Many trees are leaning toward a certain direction.
   - The old landslide is vast.
10. **Waste dumping site**
    The use of soil layer with low capacity for garbage dumping in large amount can trigger the landslide, especially when there is a torrential

Example of Answering Table

PREPAREDNESS PROFILE OF LANDSLIDE DISASTER

Name of Dukuh/Village :
Sub District :
District/Municipality :
Province:
Name of Community Represntative :
Name of Community Coach :
Name of Accompanying Institution :
Community/Government Element :
Time :

Preparedness Value Table	
Score 0	Very Low/None
Score 0 - 5	Low/Start to perform
Score 6 - 10	Fair/Exist but not performing
Score 11 - 15	High/Start to perform by some stakeholder
Score 16 - 20	Very High/has been done by all community elements

COMMUNITY DISCUSSION NOTES

Measurement Instrument for Landside Preparedness

Dwikorita Karnawati, M.Sc.

No	Aspect
A	**Knowledge**
1	The cause of the landslide
2	Preliminary phenomenon of the landslide including the landslide early warning surveillance system
3	The map of land movement vulnerability level
4	The map of land use in landslide prone area
5	The map of landslide risks
B	**Practice/Prevention Mechanism/Mitigation**
1	Initiatives in preventing and controlling the landslide
2	The existence of the local wisdom supporting the disaster risk reduction initiative
3	The availability and effectiveness of the use/deployment of preventive/control and Early Warning System technology
4	There is willingness to encourage preparedness and prevention on landslide disaster
5	Comprehension on information of prevention/control of landslide hazard
C	**Practice/Emergency Response Mechanism and Recovery**
1	Emergency action when the phenomenon appear (DRR SOP)
2	The map of evacuation lanes
3	Contingency plan prepared by the government (together with community) – DRRSOP
4	Agility in coping with constraint/limitations to landslide disaster prevention and preparedness
5	The self-help mechanism and tasks division for emergency response and rehabilitation
D	**Regulations**
1	Interaction/togetherness/solidarity between individual in village community
2	Social interaction between village community, sub districts, districts, provinces
3	Existence of management instrument of prevention and control on landslide at village, sub district and district levels
4	The existence of local wisdom to support the community solidarity
5	The government regulation on development of supporting infrastructure on landslide prevention and control initiatives

Acknowledgments The Humanitarian Forum Indonesia sees that the standard and instrument used for measuring disaster preparedness in Indonesia has substantially comprehensive, however due to lack of use to develop knowledge, gaps prevail in humanitarian activity development especially in the most vulnerable community. PASTI Project or Preparedness Measurement Tool is the tool prepared by the HFI and the MDMC. Such measurement tool was prepared after three documents i.e. early warning system (EWS) for Tsunami by USAID and GTZ, and a LIPI-UNESCO document on community preparedness in anticipating the earthquake and tsunami being analyzed. The activity was done by MPBI-UNESCO. On the following step, HFI and MDMC by the support from UNESCO-ISDR-EU completing the preparedness materials by adding relevant elements of basic human services, disaster risk analysis and community development. The HFI and MDMC have also developed a manual as well as media to be easily digested by the community. We would sincerely like to forward our appreciation to PASTI Team that consists of Karisma Nugroho, Barry Adhitya, Jenik Andreas, Surya Rahman M, Herni Ramdaningrum, Denden F. Arief, Bambang Sasongko, colleagues in five community groups (East Java, East Kalimantan, Central Java, Yogyakarta and Jakarta), expert of the nine hazards. They are H. Danny Hilman Natawidjaja, Ph.D., Prof. Dr. Bambang Hero Saharjo M. Agr., Ir. Akhmad Zainuddin M.Sc., Dr. Astu Unadi M. Eng, Dr. Amien Widodo, Prof. Dr. Dwikorita Karnawati, Dr. Slamet Sudi Sntos MpdKED, Dra. Fegi Nurhabni, Ardito Kodijat, Yuli Sari Yeni and Yulia from UNESCO. They are fully dedicated their effort to make the project possible. It is our wish that the tool may be beneficial to all of us that make the life more decent due to capacity to do the disaster risk initiative.

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Active Landslides: Perception and Education in Slovakia

Alžbeta Medved'ová, Roberta Prokešová, and Zora Snopková

Abstract

Active landslides belong to major environmental hazards in Slovakia. More than 21,000 slope deformations have been registered in the Slovak part of the Western Carpathians covering 5.25 % of the area of Slovakia since the beginning of systematic investigation of landslides in the middle of the last century "Liščák et al. (Mineralia Slovaca 42:393–406, 2010)". Results of regional research of slope deformations during past 50 years can also be found in Atlas of slope stability maps in the Slovak Republic at scale 1:50,000 "Šimeková et al. (2006 Atlas máp stability svahov Slovenskej republiky 1:50,000. MŽP SR/INGEO-IGHP, Bratislava/Zilina)". There were 551 newly occurred slope deformations in the East Slovakia during the last year. It was generally anticipated that they were induced by natural factors (extremely heavy rain, favourable geological structure, suitable geomorphological, hydrogeological and climatic conditions) and human activities (constructions, deforestation, incorrect agriculture melioration works, etc.). Post-failure dynamics at 16 selected localities was monitored since 1993 by a set of traditional methods by State Geological Institute of Dionýz Štúr. In our contribution we analyze relations between changing landslides' nature (underground water level, surface displacements, inclinometric measurements, etc.) and natural (climate) as well as anthropogenic factors before and after the activation of sliding processes at these localities. We have also considered different political systems and ownership relations and their effects on land use changes and/or state of remedial works. Finally, we discuss possibilities to increase the public awareness of landslides by introducing topical case studies into the teaching process at elementary and secondary schools.

Keywords

Landslide monitoring • Landslide perception • Legislation • Teaching geography

Introduction

People in Slovakia used to perceive the landslides as scarce natural events. During last years there is a wide evidence of extreme natural events all over the world; in Europe as well as in Slovakia. In 2010 numerous rainfall-generated landslide occurred throughout Slovakia. According to Liščák (Liščák et al. 2010) "slope deformations, which evolved or reactivated in 2010 first half-year, damaged 102 buildings and 4,232 m of roads, and threatened 304 buildings and 18,064 m of communications (roads, railways) in

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regions of Košice. and Prešov, excluding the city of Košice and Nižná Myšľa." From the whole set of registered slope deformation 98 show a high and 29 a very high risk of landslide by the scale of European Commission for multirisk evaluation (Marzocchi et al. 2009). Tenths of families were evacuated. Although nobody died during these accidents the threat to dwellings persists henceforth. Unusual number of landslides activated in 2010 urge us to look for causalities and to concern on prevention. Article focuses on relations between the monitoring limitations of the slope deformations, people's attitudes and possibilities to increase the public awareness of landslides.

Landslide Monitoring

Methods Performed by the State Geological Institute

A large extent of landslides and landslide prone areas in Slovakia give no opportunity for monitoring all the slope deformations in Slovakia. The overview of landslide inventory and monitoring in the past are given in some studies (e.g. Nemčok 1982; Malgot and Baliak 2000, 2001; Liščák et al. 2010; Klukanová et al. 2008). There are only 16 sliding localities systematically monitored during the last decades by traditional methods (Fig. 1). State Geological Institute of Dionýz Štúr (ŠGÚDŠ) in Bratislava is responsible for these investigations in the frame of the Environmental monitoring system. Five methods are usually applied: measurements of ground water level, inclinometric and geodetic measurements, residual surface tension (RST) and pulse electromagnetic emissions (PEE).

The most damaged geological formations in Slovakia are Paleogene and Mesozoic of Klippen Belt and Palaeogene of Outer Flysch Belt. Slope deformations occurred in Neogene volcanics and also in the Central Carpathian Paleogene Basin (Kopecký et al. 2008).

Localities, Monitoring Results and Precipitation Regime

Although 16 localities (Veľká Čausa, Handlová, Fintice, Dolná Mičiná, Ľubietová, Slanec, Okoličné, Liptovská Mara, Bojnice, Kvašov, Hlohovec, Vištuk, Malá Čausa) are monitored at the present, they differ in the number and the quality of applied methods as well as in the regularity of the monitoring (see Table 1). Some of the localities are assessed only by one to two methods and moreover not every year. The absence of more monitoring methods applied to landslide causes the lack of information about stability of area

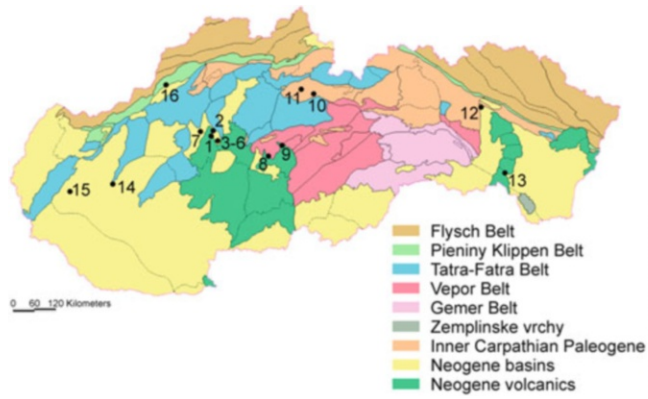

Fig. 1 Localities of landslides monitored by Slovak state geological institute (ŠGÚDŠ in Bratislava): *1* Veľká Čausa; *2* Malá Čausa; *3–6* Handlová, Handlová – Morovno, Handlová – SN, Handlová – Kunešovská cesta; *7* Bojnice; *8* Dolná Mičiná; *9* Ľubietová; *10* Okoličné; *11* Liptovská Mara; *12* Fintice; *13* Slanec; *14* Vištuk; *15* Hlohovec; *16* Kvašov

of high social importance (e.g. Slanec, Liptovská Mara, Vištuk).

After political changes in 1989 and years after there were changes in land ownership as well as land-use. Majority of monitored landslides and surrounding areas became unused mostly because of restricting in the land-use. Nobody took care of keeping the remedial works functional in many cases. Scientists of ŠGÚDŠ sent a repeating letters of advice to municipalities of localities with an evidence of worsening the drainage systems. In some places misleading stability of some landslide prone areas allowed landowners to start to use them for building the houses, roads, driveway, parking place, and/or for opencast mining.

Perception

One of our chief concerns was to see whether the large number of landslides in 2010 led to the increasing interest of touched people. Our second objective was to clarify how people perceive landslide risks and to discover if there are any differences in this perception between different parts of Slovakia.

Surveys of people opinions were conducted using the same questionnaire in 11 localities in Slovakia. The survey of landslide hazard perception covered inhabitants of towns as well as villages. Ten questions were formulated:

- Is any area in your surroundings affected by landslide/s?
- Have you any information about landslides in your town/village and surroundings (area, time of activation, etc.)
- What caused the sliding?
- Is there any human activity among the causes of slope deformation? (If yes, what kind of activity was it?)
- Were there any remediation measures taken after the event? (If yes, which ones?)

Table 1 Localities systematically monitored in 2010 respectively during the last decades by traditional methods by State Geological Institute of Dionýz Štúr (ŠGÚDŠ) in Bratislava. (Annual precipitation: high[a] exceed 110 % of mean annual rainfall, **very high**[b] exceed 120 % of mean annual rainfall) (to be continued)

Locality	Current land-use	Current stability of slope deformation	High activity of failure confirmed by a particular method	Annual precipitation (high[a] in . . ., **very high**[b] in . . .)
Veľká Čausa Damaged part of village	Mostly none, in surroundings the orchards, meadows, and grassland	Decreasing (no maintenance of drainages)	Inclinometers in 1995–2003, 2007–2009; geodetic measurements in 1985–1998; piezometers in 1997–1999, 2002, 2005–2009; PEE in 1999–2009 and RST in 1996–1998, 2000–2005	2002, 2005 **1994, 2010**
Handlová (three landslides) Damaged part of town (150 houses), wiring, road, housing estates and railway track	Forest, housing estates	Relatively stabilized; deterioration of the drainage system observed in 2000	Inclinometers in 1993–1997, 1999–2003, 2005; geodetic in 1986–1987, 1990, 2001, 2003–2007; and PEE in 1997, 1999–2009 (no measurement in 2010)	1992, 1994–1996, 1999–2001, 2004, 2005, 2007, 2009 **2002, 2010**
Fintice Damaged road, gas pipeline, pylons	Arable land, forest (pasture before)	Decreasing since 2005 (unrealized stabilization works)	Inclinometers in 1991–1994, 1997, 2000–2001, 2004–2005, 2007–2010; geodetic in 1996, 2004; PEE in 2003–2009 (no measurement in 2010)	2009 **2004–2005, 2010**
Dolná Mičiná Damaged road, local communications and houses	Grass and bushes	Relatively stabilized	Inclinometers in 1995–1997, 2004; PEE in 2000–2003, 2005–2008 and RST in 1997–2002	1995–1996, 2001–2002, 2008–2009 **2010**
Ľubietová Damaged houses, stream channel	Arable land and meadows, man disturbed succession of forest	Relatively stable (worsened due to no maintenance of drainages)	Geodetic measurements in 1994, 1996, 2001–2002, 2010	1994–1996, 2008–2009 **2002, 2010**
Okoličné Damages railway	Meadows, forest, railway trucks, nearby orchards and gardens with huts, pasture		Inclinometers in 1993–1996, 1998–2005, 2007, 2009–2010; geodetic measurements in 1974–1975, 1984, 1987, 1994–1998, 2000, 2006–2007, 2010 and RST in 1995–2006	1985, 1996, 1999, 2000, 2002, 2004 **2010**
Bojnice (two landslides) Damaged objects, road, gas pipe-line, sewerage	Grassland	Decreasing (due to defect on sewage conduit and infiltrations)	Inclinometers in 1997, 2000–2003, 2005–2006, 2009–2010; geodetic measurements in 1997–1998, 2001–2010	2002, 2005 **1994, 2010**
Kvašov Damaged houses, road, arable land and threat other objects	Grassland (at the past arable land)	Relatively stabilized	Inclinometers in 2004, 2006	2000–2002, 2004 **2005, 2007, 2010**
Hlohovec Landslides threaten arable land and the area of a planned water reservoir	Arable land and vineyards	Decreasing (tectonic activity of area, river abrasion, geology, no stabilization works)	Geodetic measurements in 1980–1982, 1991, 2004; and PEE in 1997–2002, 2005–2006, 2008–2009 (no measurement in 2010)	1994, 1996, 2002, 2005, 2010
Malá Čausa Two landslides; the larger one damaged water pipes, smaller one threatened the river valley	Grassland and scrub "lying fallow"	Unstable area	Inclinometers in 1997–2001; and RST in 1998, 2000–2004	2002, 2005 **1994, 2010**
Vištuk Damaged houses, road, and arable land	Arable land	Relatively stable with weak tendency of activation	PEE indicates gradual worsening of the landslide stability	
Slanec Damaged water and gas pipelines, optical cables, telecommunications, and wiring	Infrastructure	? (lack of information)	Absence of more monitoring methods	
Liptovská Mara Threats the dam embankment	Grassland	(?) vague	Rare measurements	

- Was there any prevention measures realised after the event on the affected area?
- Have you or your relatives or your neighbours suffered from the landslide?
- What was the land-use before and after the event?
- What did authorities do during the sliding processes? Did they help to affected people? What about prevention?
- What changed in your life after the event (moving, attitude, safety measures)?

Several people (students) were asked to formally pre-test the questionnaire, then it was revised based on the information obtained.

The opinion polls were realised concurrently in 5 towns (Banská Bystrica, Žilina, Martin, Krupina, Brezno) and 15 villages (Fig. 2). Hundreds of people were randomly selected from inhabitants. The sample was random; the respondents differed by education, economic situation, gender and age. The questionnaire was explained by students giving details of the survey reasons and instructions for giving the responses. The respondents´ answers were recorded by students of FPV UMB and surveys were anonymous. Finally, we analysed responses of 338 people. The surveys were evaluated in May 2011.

Evaluation showed that 72 % of respondents living in the damaged areas have no knowledge about landslides affected their surroundings. 28 % of people had no information. Respondents gave information about 64 particular localities affected by sliding processes, but 31 % of sample did not know more detail information (no idea about area, place, and time of event). Among the causes respondents more often told about were the precipitation, snow melting, construction works, source exploiting, geological structure, deforestation, floods, slope inclination, springs and human impact. 43 % of respondents had no idea about causes of events. 10 % of respondent did not know about any human activity causing the particular landslide in their surroundings. The rest 90 % of people mentioned constructions, deforestation, undercutting the slope, and mining. 44 % of respondents mentioned that no stabilizations were made after the event. 22 % of them did not know about any remediation works after the event. More often quoted answers were: constructions (wall, dike, embankment, way repaired), drainage, and afforestation. Among the prevention measures realised after the event on the affected area the respondents mentioned the afforestation, drainage and forbiddance of the construction. 19 % of them had no idea of preventions. Damage of property occurred scarcely, 3 % of respondents, their relatives and neighbours had damaged their plots, 1 % had problems with house's or garage's static and ways. 27 % of respondents did not registered changes of land-use after the event; the rest mentioned both the worsening (in case of construction! and mining! at damaged areas) and also improvement (in case of using the landslide prone areas for orchards, arable lands, and grasslands). 40 % of respondents though that authorities did nothing or had no information about steps realized by them. Majority registered the help of authorities in the case of housing threats and in the case of damages on communications (road, pipeline, railway, etc.). People had none or only a little information about prevention. Finally, answers of question about changing life after the event showed that 57 % of respondents did not change anything, 17 % felt they changed their attitude to nature, 13 % paid more attention for landslides, 3 % moved and 3 % forested their lands (estates).

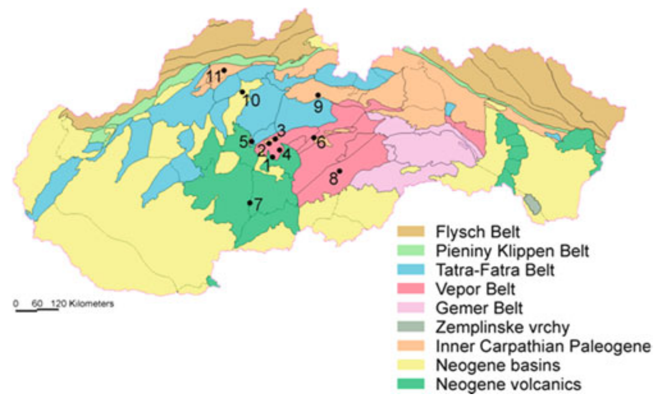

Fig. 2 Localities in which surveys of landslide perception were conducted (spring 2011): *1* Dolná Mičiná; *2* Banská Bystrica; *3* Selce, Nemce, Kynceľová; *4* Poniky; *5* Kordíky, Králiky; *6* Brezno; *7* Krupina; *8* Klenovec, Hačava; *9* Okoličné, Liptovská Mara; *10* Martin; *11* Žilina

Policy

Current Status and the Future

There are new possibilities in regional and/or urban planning thanks to the results of regional geological research of slope deformations in Slovakia presented in Atlas of slope stability maps at scale 1:50,000 (Šimeková et al. 2006). Municipalities can include them into territorial development plan. On the other hand, majors of municipalities with less than 2,000 inhabitants have no duty to follow the proposals of engineer geologists in the urban planning. Consequently it happens, that majors allow building constructions in threatened areas. The problem is the inconsonance of the state legislation and the planning.

In 2010 the members of Slovak association of engineering geologists (SAIG) prepared proposals for "Building law" according to which it would be compulsory to make a geology survey before any construction realization (Wagner and Liščák 2011). However the new "Building law" is still under the preparation.

Landslides and Education

It follows from the results of landslide perception (by people living in threatened areas) that the increase of the public awareness of landslides is inevitable (Tolmáči et al. 2008). Adults and labour force (economically active people) are knowledgeable by media such as local (municipality) web sites, local press, regional TV, radio and/or through the chat events with experts. Young people and pupils could be educated in schools.

Geography is likely the best subject for educating the geohazard. In accordance with content of the Slovak state educational programme the secondary education (primary schools for pupils aged 10–15 years and secondary schools for pupils aged 15/16–18/19 years) is appropriate for widening the knowledge of landslides. On September 2008 long expected reform of the school curriculum started. Schools were given the freedom to adapt up to 30 % of the school subjects by their own. The traditional focus on factual knowledge has been moved towards competences that pupils should receive during their geography education. Our experiences from the international project "Atlas of European Values" (http://www.atlasofeuropeanvalues.eu) showed the weaknesses in education of geography in Slovak grammar schools. There is an absence of a wider offer of textbooks from which teachers can choose compared to numerous resourceful materials e.g. in Germany (Fugel et al. 2009) or in Netherlands (Ten Brinke et al. 2007). Moreover Slovak pupils have difficulties with thinking critically about problems, and making connections (e.g. the effect that certain geographical issues have on their life).

In our article we describe the possibilities to integrate the theme of landslides into the teaching process at Slovak elementary and secondary schools: In lower secondary education (ages 12–15) geography is taught one lesson a week. The world regions are the main themes here (basic information about region, specialty of region, environmental context). Our proposals are for the grade 6, in which America is the main topic (e.g. Problems of life in big cities; Reasons of deforestation in South America), to widen the theme with consequences (e.g. broaden the poor quarters to areas unsuitable for building; worsening the geological stability, changing the circulation of ground water, overloading the slope, undercutting them by constructions . . .).

Africa and Asia are the main topics for the grade 7. The best themes to incorporation the 'slides' are: High population density; Threats of typhoons, earthquakes and floods. Here we suggest discussion of the scheme: earthquake – volcano – typhoon – monsoon – flood – landslide.

Europe is the main topic for the grade 8. We propose to use the materials (pictures, TV-shot, daily article) about disruption of line structures for discussion about causes of events during teaching the theme 'Environmental aspects of transport'. It is possible to mention Italy – as a country of natural disasters – tectonics, earthquakes, volcanoes, climate extreme and to look after their possible consequences.

'Geography in daily life' is the main topic for the grade 9. The authors of the textbook forgot to mention the landslides in chapter 'Calamites and natural hazards'. We suggest incorporating them, because of widespread sliding in Slovakia during the 2010. The chapter 'Differences between the regions of Slovakia' is also suitable for finding the most landslide prone areas based on heuristic methods – the best for pupils of this age.

Geography at grammar-school has to help pupils to understand changes and actual stage of nature and society and to know how they perform. Pupils ought to combine knowledge and to use that from other subjects and areas (history, biology and math). In higher secondary education (ages 15–19) geography is taught one lesson a week in grades 1 and 3 respectively two lessons a week in grade 2. The focus lies on physical and regional geography. Content of education in grade 1 is World nature (atmosphere; hydrosphere; lithosphere; biosphere, pedosphere, agriculture). There are some chapters, in which there is no problem to choose the methods and tasks related to landslides, e.g. 'Climate changes and global warming'; 'Orogenesis, earthquakes, tsunami, volcanic activity'; 'Human activities consequences onto soils, vegetation and animals'; 'Deforestation'. The main topic of grade 2 is 'Man and water caused processes and landforms society (world)'. Within the themes 'Man and the nature', 'Nature protection' (e.g. exploitation the sources, pollution, global consequences of human activities on ecosystems) we recommend inserting a chapter 'The failure and the prevention'. The leading topic of grade 3 'Man and society' is concentrated on regions of Slovakia. We suggest adding and/or discussing the failure prevention within the theme 'Factors of conveying means and road construction'.

There is the chapter Lithosphere in the new geography textbook for first grade pupils of grammar schools (Bizubová et al. 2008). Only a page about the landslides is incorporated in the theme 'Natural catastrophe'. There are some questions introducing the theme of 'Outer geological processes', e.g.: Can you make a short list of natural catastrophes in Slovakia? Let us know recurring catastrophic events in Slovakia. Do people activate natural catastrophes? Why? How do rocks influence the character of relief?

Questions (related to the chapter about landslides):

Review the examples of man-induced catastrophes which could be conserved for future palaeontologists. Give your idea (concept) how to stop catastrophes, modulate evolution of organisms, restore destroyed ecosystems and biotopes, enhance biodiversity, etc.

Activities/tasks (related to the chapter about landslides):

Where in Slovakia most of landslides have occurred? Give reasons for your answer. Use the geological map of

Slovakia from School atlas. Cogitate about the consequences for inhabitants/human society.

Facts to know: "Knowledge about lithosphere can be used for: (1) Catastrophe predictions (volcanic, earthquake, tsunami, landslide); (2) Study of negative impacts of mining; (3) Safe construction of foundations (buildings . . .)," . . .

Our suggestion is to widen the theme by more 'Questions and activities' e.g. Can scientists forecast the landslides? What kind of information do they need to solve the problem? Use the web-site of the Slovak state geological institute (www. sguds.sk). Look at the Map of landslides in Slovak republic.

The school system allows teachers to widen the theme which he/she wants. In our opinion the problem is in that the terms 'geohazard' and 'landslide' are not included in the Content nor in the Performance of the New educational standards (NES) of geography (subject) at grammar schools. On the other hand, integration of NES to the teaching process started on September 2008, but the textbooks for pupils of third grade are not yet printed.

Besides geography there are other subjects in which the aspects of slope deformations are applicable, e.g. math, civics, economy and environment.

Conclusions

From summarizing the knowledge about monitored landslides and the events of 2010 in Slovakia it is evident that stabilization works have saved old sliding areas from reactivation. Unstabilized areas affected by extreme rainfalls and widespread floods were not be possible to save. We could not probably avoid it but we could prevent extensive damage by rational decisions in the last years (decades). To avoid the similar situation in the future our legislation, awareness and decision making should be improved. There are essential changes in the current Slovak "Building law": (1) to incorporate a duty to make geological survey before building; (2) to complete the urban planning documents involving the maps of landslide risk at scale 1:50,000 (or more detailed maps); (3) to use the Atlas of landslides (Map of landslide risk) during the preparation of urban plans.

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Student Community Service Program for Landslide Disaster Risk Reduction in Indonesia

Dwikorita Karnawati, Wahyu Wilopo, Agung Setianto, Suharman Suharman, and Teuku Faisal Fathani

Abstract

This paper highlights the importance of student involvement to drive the community empowerment program for landslide disaster risk reduction at the village level in Indonesia, as a part of student community service action organized by Universitas Gadjah Mada. During the period of 2 months, 20–30 students with multi disciplinary backgrounds are deployed in the landslide prone area, to investigate the conditions of geology, environment, landuse and socio-culture which may control the occurrence of landslide disasters. Accordingly, strategic program for landslide prevention, mitigation and early warning can be developed and initiated by addressing the community participation and empowerment. Indeed, this community service program is an ideal media for the capacity development in terms of personality, community and institutional empowerment, with respect to sustainable development in landslide prone area.

Keywords

Personality • Community • Institution • Empowerment • Landslide risk reduction

Introduction

More than 50 % of Indonesian archipelagos are the mountainous area, situated in an active tectonic region with high precipitation. That is why landslide is considered as one of the most frequent disasters in Indonesia. Unfortunately, most of the landslide prone areas have been developed as the villages or cities with high population density, such as in Java and Sumatera. Thus, the risk of landslide disasters seriously increases in response to the increment of population and uncontrolled landuse changes. In fact, it has been recorded that 1,371 people died, more than hundreds missing and thousands of houses and lands buried/damaged due to landslide disasters. Accordingly, the improvement of community resilience in landslide prone area is the main challenge that should be tackled under this community service program, for assuring the human survivability and environmental sustainability.

In response to the problems and challenges above, a model of research-based education program, which is so called as **a student community service**, has been established at Universitas Gadjah Mada (UGM). This community service is conducted by deploying undergraduate students with multi-disciplinary background to stay at the village for a period of 2 months during the semester break. This student community service program is implemented as a compulsory subject (with 3 credits) in the curricula, especially obligated for the students who have collected 100 units of academic credits (normally for the student at semester 6). Various problems related to socio-cultural, socio-economical or environmental issue can be selected as the thematic program in the community service. Indeed, a special issue related to landslide mitigation and disaster risk reduction have

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been introduced in this community service program since the year 2007.

Concept and Mechanism

This student community service program was initially conducted 40 years ago, with the aim to support the Indonesian development program in the disadvantage regions. Recently, this program can be adjusted to support any development program at the village, including the program for disaster mitigation. Accordingly, the aim of this research-based education program is to provide a media for capacity development in terms of students' personality, community and institution empowerment for landslide disaster mitigation and risk reduction at the village.

This community service program is designed as the education model which integrates the research activities into learning process and community service, with respect to the university social responsibility. Accordingly, the implementation of this community service program at the village should be based on action-research, conducted by landslide experts (lecturer/professor/researcher), and assisted by the group of 20–30 students with various disciplines background.

Moreover, the model can also be designed to facilitate the final year students of undergraduate (with 5 credits) and/or for post graduate levels (with 8 credits), to conduct the research with various topics relevant to disaster mitigation, such as:

(a) Hazard, vulnerability and risk mapping as the one suggested by Saaty 1980, which is conducted as joint activities by students from Geological Engineering and from Faculty of Sociology and Psychology;
(b) Natural and social resources mapping as the joint activities conducted by the students from Faculty of Geography and Faculty of Social Science;
(c) Slope stability analysis and prediction for landslide prevention which is undertaken as joint activities by the students from Civil Engineering and Geological Engineering;
(d) Development of early warning system as the joint activities conducted by the students from Civil-Geology-Geodetical-Electrical Engineering;
(e) Psychological assessment for community empowerment which is carried out as the joint activities by students from Faculty of Psychology and Faculty of Social Sciences;
(f) Formulation of community-based disaster management as the joint activities by students from Faculty of Psychology and Faculty of Social Sciences.

Regarding the needs for multidisciplinary approach, this education program is directly coordinated and managed by the University Administration, It is crucial that prior to this program, one main Faculty or Department has to propose to the University one topic of problem (in which the main program in one particular village is deliberately developed to tackle this particular problem) for one session of student community service program. For instance, the Geological Engineering Department can propose to the University one particular topic to tackle the problem of geological disaster mitigation at one particular vulnerable village, and so the Geological Engineering Department should be assigned as the coordinator for the student community service for disaster mitigation program in such village.

Obviously, there should be a mechanism for cross-communication among students with different disciplines, and thus this program stimulate the development of a joint effort within the multi-disciplinary student team work, to synergize the mono discipline-based approach with several different but relevant disciplines, to perform one holistic mechanism for solving the landslide disaster mitigation problems. To facilitate this learning process, at least one lecturer or researcher should be assigned as the field supervisor. In addition, several supervisors from various disciplines may also involve as the student advisers in the final year student's project and/or master thesis work.

The duration of 2 months research-based community service is mainly provided for data collection and practical analysis, together with the community empowerment activities. Then it may be extended for the maximum of one semester in the studio and laboratory to complete the analysis of data, to develop synthesis and produce the research outputs for supporting disaster mitigation efforts at the village. The data collection may also be conducted prior to the community service program, such as 2 or 3 months earlier. Thus, some results from data analyses can be provided prior to the community service program. Those research results may include:

(a) Materials or facilities for disaster mitigation such as the hazard map, vulnerability map and risk map
(b) Modules or materials for public education with respect to disaster mitigation
(c) Tools or equipment or systems for disaster (such as landslide) prevention and early warning system.
(d) Formulation of concept and program activities for community empowerment.
(e) Establishment of community task force for disaster mitigation and the supporting action plan.

It is also crucial that this mechanism of education model is also useful to support the improvement of community awareness and empowerment for disaster mitigation.

Implementation

Problem Background

The student community service program has been Implemented in Ciwidey Area, at Bandung Regency, West Java (Fig. 1), in response to the rain-induced landslide disaster (Fig. 2) occurred in February 23, 2010 where 35 people killed, 9 people missing and hundreds hectare of tea plantation buried. Accordingly, the student community service program was conducted in nearby village, i.e. Sugihmukti Village at Pasir Jambu District, Bandung Regency, West Java, which may likely be struck by similar landslide disaster in near future.

This village was selected as the pilot area to implement this community service due to the similarity in conditions of geology, socio-economical and culture. Thus, it was considered that this nearby village has similar level of risk for landslide disasters.

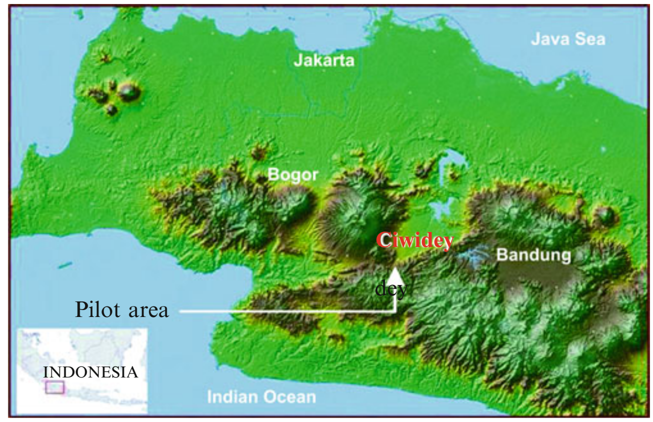

Fig. 1 The location of pilot area at Ciwidey, West Java, Indonesia

Fig. 2 Impact of landslide disaster in Ciwidey, West Java on February 23, 2010

Objectives and Method

Main objective of the mission in this student community service program was to reduce the risk of landslides by community empowerement program, which was based on the action research.

Within period of 2 months starting from July 5 to August 25, 2010, the student team worked at the site, especially to :

(a) Empower the local community to identify and investigate the controling factors that potentially cause the landslide (Cruden and Varnes 1996), such as the environmental conditions (morphology, geology, and the existing landuse). In addition, the socio-cultural conditions of the local community, such as the existing job profile and income conditions, level of education, local wisdom and tradition, existing knowledge about landslide phenomena and also the level of community's awareness to landslide disasters were also observed by the students as the potential causative fators for landslide, as suggested by (Andayani et al. 2008)

(b) Encourage and empower the local community to develop strategic program for landslide mitigation and disaster risk reduction as suggested by Karnawati et al. (2009a, b), by considering the above investigations conducted at the beginning of the program.

Geological mapping was also undertaken to develop landslide hazard map by adapting the method proposed in Saaty (1980) and also Lacasse and Nadim (2008). The level of landslide hazard was analyzed based on the morphology, geology and landuse conditions by applying weighting and scoring system. Meanwhile, the socio-cultural survey was carried out by circulating the questionairre to 150 respondents, and also by conducting in depth interview and focus group discussion. Descriptive statistical analysis was applied to identify the base line conditions of the socio-cultural aspect of the community, which then were used as the main consideration for community empowerment strategy and program.

Results of the Investigation

It was identified that the causative factors of landslides in the region was not only controlled by the natural conditions but also the existing landuse management. Despite the steep mountainous conditions of the area, with slopes mostly steeper than 40° and composed by weathered and jointed andesitic rocks, most of the land in such region (more than 50 %) was covered by tea plantation (Fig. 3).

Fig. 3 Tea plantation covered most of the village region

Fig. 4 Houses situated within the potential landslide travel distance

High rain precipitation which exceeding 70 mm/h or accumulative antecedent rainfall exceeding 100 mm in several hours or several days may also effectively induce the landslide in such region (Karnawati et al. 2005).

The community living in this pilot village area was mainly the employee of the tea plantation, most of them are the labour working in the tea farming sites. That is why their houses are commonly built and situated at the middle and lower parts of the slopes (Fig. 4).

Considering the shape of the slope, which is steeper at the upper part (steeper than 40°), then immediately change to the gentle slope (about 20°) at the middle part, and finally it gradually changes to the flat area, it was predicted that the landslide type which may occur can be initiated by earth slump at the upper steep slope, then when the slump reaches the middle slope which is more saturated and gentle, it may develop as the earth flow with the travel distance may reach

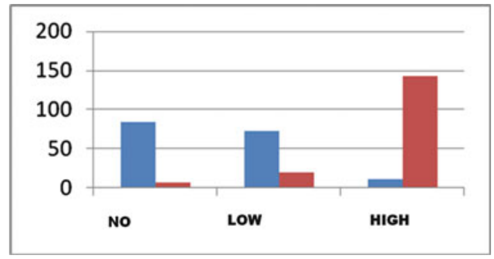

Fig. 5 The level of community understanding on landslide cause and prevention method with respect to the numbers of respondens, was indicated before (*blue*) the empowerment progam and after (*red*) (Karnawati et al. 2010)

500 m or beyond. Obviously, this can seriously result in devastating damage of the plantation area, and might also lead to the death toll due to the position of settlement (houses) area situated within those potential landslide travel distance (Fig. 4).

The village consists of several groups of houses, and each group is administratively managed by one selected leader. The education level of the local community varies from primary school to junior high school. Statistical data analysis in Fig. 5, indicates that level of community understanding and awareness about the cause and method for mitigation and prevention of landslide disaster were initially quite low (indicated in blue). This evidence was the one of major concern that should be tackled by the community service program. Accordingly, this level of understanding and awareness significantly increases (indicated in red) after the implementation of community service for the empowerment program.

Program for Landslide Mitigation and Disaster Risk Reduction

By considering the geology, landuse and socio-cultural conditions of the pilot area, the students worked together intensively within the period of 2 months, especially with the selected and appropriate key persons at the community, such as the school teachers and community leaders in the tea plantation, with the mission to develop a systematic program for landslide mitigation and disaster risk reduction. Those program include community-based landslide hazard mapping (Fig. 6), public education (Fig. 7), establishment of local community task force for disaster risk reduction (Fig. 8), development of landslide mitigation program and introduction to landslide early warning system and evacuation drill (Fig. 9).

The landslide hazard mapping was conducted by involving community participation and also facilitated and guided by the students. The map was crucial to support the evacuation plan and landuse management plan. By considering the

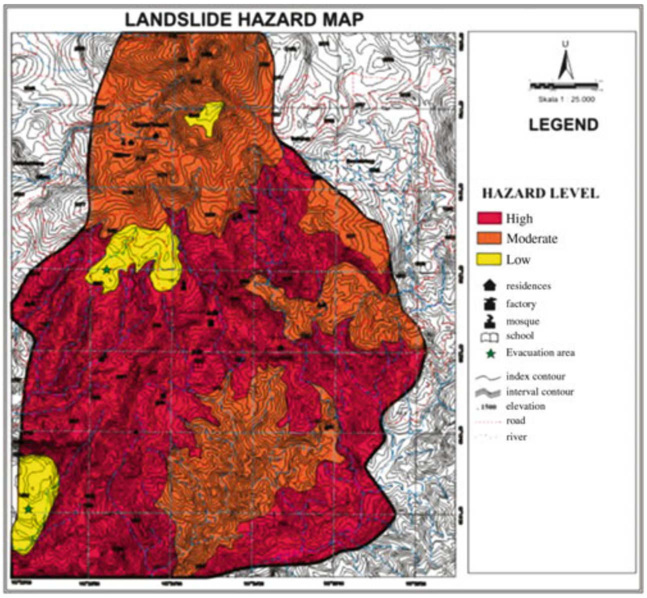

Fig. 6 Landslide hazard map indicating the zone with various levels of landslide hazard, i.e. high as the most likely (*red*), moderate (*orange*) and low as the most unlikely (*yellow*) zones for landslide occurrence

Fig. 7 Public education for various target groups

Fig. 8 Local task force for disaster mitigation and risk reduction

Fig. 9 Evacuation drill for landslide emergency response

landslide hazard map, the evacuation route and termporary shelter can be prepared to anticipate the emergency situation in response to the early warning of landslides.

Public education and consultation was conducted to raise community's understanding and awareness about landslide cause and how to prevent, mitigate and provide the early warning as suggested by Karnawati et al. (2008 and 2009). Children of kinder garden to junior high school with their school teachers, as well as the community leaders, were the main target groups in this public education and consultation program. The supporting facilities for this education program, such as the training module, leaflets, and posters were provided by the students together with the school teachers. Evacuation drill (Fig. 9) was also conducted as a part of this public education, to improve the community's survivability in the emergency situation when the early warning of landslide occurred.

The community task force for landslide disaster risk reduction was established through series of community participation activities and public consultation. The task force members consist of the leaders and the security guard from each group of houses at the village (Fig. 8). The main responsibility of this task force is to be the driving force for disaster management program at the village, with the main mission to develop the plan for disaster management as well as to implement and maintain the sustainability of such management program. The students played an important role to encourage, initiate and facilitate the establishment of this local task force for disaster risk reduction.

Evaluation and the Social Impact

It was observed that the student faced some difficulties at the beginning of the program, especially during the first week. Such difficulties were due to several constrains such as the new living environment with mountainous geographical conditions, cooler weather and limited resources, and also the difference in culture and ethnical language. It was also difficult to initiate the communication and the program for disaster risk reduction during the working day, because most of the key leaders and the employee at the tea plantation were busy with their duties in the tea field or factory. However, those constrains had become very important challenges for the students to improve their capacity to adapt and survive in such new and challenging living environment.

Those constrains can be gradually solved by conducting more intensive communication with school teachers during the day, and also the leaders of tea plantation after the working time. More and more meeting and communication with various levels of community then also can be initiated at night after the working time, or during the weekend.

In fact, the evidence of landslide disaster which occurred 5 months before the community service program made the community more eager to actively participate in this program.

Finally, after having series of intensive communication, consultation, and interaction between the students and various levels of community members during 2 months of community service, a system for landslide disaster risk reduction and management can be introduced and established. Indeed, the establishment of the local community task force was important to sustain the established disaster management system.

This student community service program has been implemented in several other villages with various ethnical background in Indonesia, such as in Imogiri and Kulon Progo at Yogyakarta Special Province, Karanganyar and Banjarnegara at Central Java Province, Situbondo at East Java Province, Ciwidey at West Java Province, Tandikat at Pariaman Regency and Tanjugsani at Agam Regency in West Sumatera Province. It is apparent from those various pilot implementation programs, the student community service has such positive impact not only on the improvement of student capacity in terms of students' personality and social responsibility, but also on the community empowerment through the improvement of community's awareness and responsibility for landslide disaster risk reduction and management. Indeed, the local authorities highlighted the importance of this student community service program in terms of institutional empowerment to support the improvement of disaster management system at the village level. Considering the occurrence of landslides are localised and spread distributed in many villages at the mountain slopes in Indonesia, the community and institutional empowerment at the village levels will be very strategic and significant to reduce the risk of landslide disasters effectively. Yet, we can introduce and apply the student community service for disaster risk reduction by utilizing the network of universities in Indonesia, such as by coordinating hundreds of existing universities available in almost every province.

The involvement of private sectors may also be integrated into this student community service program, which will also be in line with the corporate social responsibility program of the industries/companies.

Conclusion

The student community service program is one ideal scheme of research-based education which dedicated for supporting the human survivability and environmental sustainability in landslide disaster prone area, in particular at the village level. This program is implemented as the university social responsibility, which can be an effective media for the improvement of student capacity and responsibility, together with the community and institutional empowerment program for landslide disaster risk reduction and management. This program can be implemented as the co-creation among university-community-local government and the private sectors. Therefore, it can be developed as a strategic and effective program for landslide disaster risk reduction and management in Indonesia, by utilizing the network of universities and local government in Indonesia.

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Soil Bioengineering Measures in Latin America: Authocthonal Cuttings Suitability

Alessandro Petrone and Federico Preti

Abstract

The variety of Soil bioengineering techniques usable for disaster mitigation, environmental restoration and poverty reduction is nowadays little known in developing countries. Research on authochtonal plants suitable for this kind of works is the essential first step for the divulgation of this discipline. The present paper is focused on this issue related to the realization of various typologies of Soil Bio-engineering works in the Humid tropic of Ecuador. Realizing live palisades alongside an unpaved road, an experimental plot was obtained by planting 100 cuttings of each of the following species: *Brugmansia versicolor Lagerh* (local common name: Guanto); *Euphorbia* cotinifolia L. (local common name: Lechoso); *Malvaviscus penduliflorus DC*. (local common name: Cucarda), *Trichanthera gigantea (Humb. & Bonpl.) Nees* (local common names: Nacedero, quiebrabarriga, inchabarriga).

Keywords

Landslides • Soil bioengineeering • Cuttings

Introduction

Protection measures against natural hazards focus on technical constructions that are, however, restricted to point-by-point or linear effects and often have a short lifespan. Environmentally compatible and long-term surface protection is one of the privileges of plants acting in concert with other organisms. The application of soil bioengineering measures is a key benefit of eco-engineering, particularly in view of sustainably combating erosion, shallow land-slides, bank instability, desertification, and drought. There is evidence to suggest that biological measures naturally contribute to the strength of soil all along the successional paths of plant associations with considerable influence on geotechnical, hydrological, and hydraulic characteristics. Additionally, biological activity is supposed to substantially increase in time below and above ground and to influence the physical and chemical properties of the soil and its drainage system. Yet, uncertainties are rather frequent, not least due to a missing reliable scientific base (Rauch et al. 2011).

Soil bioengineering is based on two fundamental issues independently from a world wide application. The basic for each application is the suitability of soil bioengineering plants and secondly special techniques are used depending on what is required for civil engineering structures.

Therefore it is possible to transfer soil bioengineering techniques to "underdeveloped countries" but for the potential local bio-technical plants basic research is essential: the main problem for the effective implementation of soil bioengineering techniques is the selection of site-specific appropriate plant species (Acharya and Lammeranner 2011).

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Fig. 1 The experimental site, Santo Domingo de los Tsáchilas (Ecuador)

The focus of the present paper is primarily on the role of vegetation for soil, slope, and river bank stability, particularly the technical and biological properties of the plants in Ecuador.

Materials and Methods

In the Province of Santo Domingo de los Tsáchilas, located in an area in the middle of the coastal and the andean regions of Ecuador, Soil bio-engineering installations were built in several sites. The particular structures built were: a vegetated live crib wall for riverbank protection coupled with brush layering, live palisades made of local bamboo (caña guadua), vegetative covering with grass transplantation and drainages with gravel-filled trenches and PVC piping.

In order to evaluate the suitability of the various plants used in the works, monitorings were performed on the live palisades alongside an unpaved road, collecting survival rate and morphological parameters data (Fig. 1).

For this purpose an experimental plot was established by planting 100 cuttings of each of the following species: *Brugmansia versicolor Lagerh* (local common name: Guanto); *Euphorbia* cotinifolia L. (local common name: Lechoso); *Malvaviscus penduliflorus DC*. (local common name: Cucarda), *Trichanthera gigantea (Humb. & Bonpl.) Nees* (local common names: Nacedero, quiebrabarriga, inchabarriga) Bernier et al. (1995); Duryea and Dougherty (1991); Euphorbiaceae (2011); Finegardening (2011); Floridata (2011); Florineth (2004); Ghimire and Karki (2004); Gray and Sotir (1996); Instituto Nacional de Estadística y Censos (INEC) (2011); Instituto Nacional de Estadística y Censos (INEC) (2001); Lammeraner et al. (2005); Miner and Villagran de Leon (2008); Montúfar and Pitman (2004); Petley et al. (2005); Petrone (2006); Petrone and Preti (2005); Petrone et al (2006); Preti (2006); Preti (2007); Preti et al. (2009); Preti and Milanese (2007); Sauli et al. (2006); Reubens et al. (2007); Rivera and Sinisterra (2006); Rosales (1997); Smgrowers (2011); Sutili et al. (2004); Tropicalforages (2011); Wikipedia: http://en.wikipedia.org/wiki/Brugmansia_versicolor (2011); Wikipedia: http://es.wikipedia.org/wiki/Euphorbia_cotinifolia (2011).

The method for education, capacity development, or training to introduce or apply this soil bioengineering measures is presented in Petrone and Preti 2013.

Results

In the present investigation the survival rate of the cuttings resulted 87 % after 1 month, 86 % after 2 months and 73 % after 5 months. As far as the individual species are concerned, the registered survival rates after 5 months from installation of the live palisades were:

- *B. versicolor: 88%;*
- *E. cotinifolia: 41 %;*
- *M. penduliflorus: 92 %;*
- *T. gigantea: 73 %.*

The Chi-square test (df 3, $p = 0.01$) revealed that the differences between the survival rates of the three species are statistically significant. If a deeper analysis of the Chi-square table is performed, we discover that two values, the percentage of living cuttings and the percentage of dead cuttings of *E. cotinifolia*, give 66 % of the total value for the Chi-square test. A comparison between the observed and expected values shows that the significativity is largely caused by the behaviour of the cuttings *of E. cotinifolia*.

As far as the development of the terminal shoots is concerned, the *M. penduliflorus* resulted as the species with the highest growing rate, followed by *E. cotinifolia*; *B. versicolor* and *T. gigantea* showed comparable results (even if *B. versicolor* was characterized by a greater variability among the measurements). The preliminary search for outliers revealed two suspicious data among the shoot length and three suspicious data among the diameter measurement. It is interesting to note that all these anomalous data are referred to *B. versicolor*. A crosscheck in the tables of field data showed that there was a correspondence between these data: the two shoots with anomalous length were the same that presented anomalous diameters. Thus these data were included in the statistical analysis.

A Bartlett test and a Levene test were performed to check for homogeneity of variance: both test showed that the differences between the four variances are statistically significant ($p = 0.005$). Due to inhomogeneity of variance a Kruskal-Wallis test instead of an Anova test was used and showed that the differences between the four species in the case of terminal shoots length medians are statistically significant ($p = 0.005$).

The Least Significant Difference test yielded the following results: as far as the development of the terminal shoots is concerned, there are no significant differences between *B. versicolor* and *T. gigantea* ($p = 0.05$) and also between *E. cotinifolia* and *M. penduliflorus* ($p = 0.05$), while the differences between the length of the shoots of *B. versicolor* and both *E. cotinifolia* and *M. penduliflorus* are significant ($p = 0.05$); also the differences between the length of shoots of *T. gigantea* and both *E. cotinifolia* and *M. penduliflorus* are significant ($p = 0.05$).

Also as far as the diameter of the shoots is concerned, *M. penduliflorus* and *T. gigantea* showed the highest growing rate. Also in this case the Bartlett test and the Levene test showed that the differences between the variances are statistically significant ($p = 0.005$). Post-hoc comparisons using the Least Significant Difference test (performed after a Kruskal-Wallis test that had showed a statistically significant difference between the four medians) yielded the following result: the only difference statistically relevant in the diametrical growth is the one between *E. cotinifolia* and *T. gigantea* ($p = 0.05$).

Further and systematic information will be available in Preti and Petrone 2013.

Discussion and Conclusions

It is well known that soil bioengineering entails the use of live materials, specifically plant parts (cuttings, roots and stems), which serve as the main structural and mechanical elements in a slope protection system (Schiechtl 1985). Live plants and other natural materials have been used for centuries to control erosion problems on slopes in different parts of the world.

In order to evaluate the transferability of soil bioengineering techniques, the situation in so-called developing countries is analyzed, evaluating the indications given by major international cooperation agencies. For example, FAO publications consider this technology to be the most appropriate for watershed management, landslide prevention measures, vegetative and soil treatment measures and, generally, in land reclamation (Costantinesco 1976; Sheng 1977a, b, 1979, 1990; Bostanoglou 1980; Marui 1988; Schiess 1994; Bruscoli et al. 2001).

The site is assessed visually to identify the basic site characteristics (slope angle, aspects, altitude, vegetation coverage, type of soil material, rainfall and climatic conditions etc.), the causes and mechanism of the slope failure or the existing erosion process. Then, suitable soil bioengineering techniques are identified based on the functional requirement of the site. Once the soil bioengineering techniques are defined and designed, the selection of appropriate plant species are made based on the (1) functional characteristics (catch, armour, reinforce, anchor, support or drain), (2) the topography (physical environment, climatic conditions) of the site, (3) the site conditions (soil, moisture conditions), (4) the economical aspects (fodder plants, fruits, medicinal plant) and also (5) the social aspects of particular plant species (Acharya and Lammeranner 2011).

Cost quantification for such interventions, compared to those referred to in conventional ones, for slope stabilization and riverbank protection, have almost the same importance as technical feasibility evaluation.

The stabilization of slopes through vegetation and soil treatment measures may be particularly appropriate in situations where an abundance of vegetative materials is present, and where manual labour, rather than machinery for installation, can be easily found (Petrone and Preti 2008; Evette et al. 2009). It is particularly important to understand if when faced with bank or slope instability situations it is possible to intervene with methods that can be adopted by user communities (e.g. Garrity et al. 2004).

In the present investigation we found that *Malvaviscus penduliflorus* showed the best performance in terms of survival and growth rate but also *Brugmansia versicolor* and *Trichanthera gigantea* reported a successful behaviour. *Euphorbia cotinifolia* was characterized by the worst survival rate. Further investigation should be carried on in order to evaluate the performance of the root system of the above mentioned species.

The first results of the above-mentioned studies show, without any doubt, the practical possibility of employing these techniques in places with differing environmental, economical and social conditions, as opposed to the European context, where soil bioengineering has been developed.

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EuroGeoSurveys, the Geological Surveys of Europe

Luca Demicheli, Claudia Delfini, and Woody Hunter

Abstract

EuroGeoSurveys (EGS) is the organisation of the Geological Surveys of Europe, the national institutions responsible for the geological inventory, monitoring, knowledge and research for the security, health and prosperity of society. With a membership that employs several thousand geoscientists from 33 European countries, EGS is a leading authority on Earth science issues in Europe.

Keywords

Geological surveys • Geology • EU

Introduction

EuroGeoSurveys is a non-profit making organisation of the Geological Surveys of Europe, the national institutions responsible for geological inventory, monitoring, knowledge and research. Our principal purpose is to provide geoscientific knowledge that underpins European policies and regulations for the security, health and prosperity of society. In our day-to-day activities, we contribute to the merging of economic, environmental and social agendas. We also facilitate networking among our members and promote their specific activities and projects.

EGS celebrated its 40th anniversary in March 2011, having begun as the Western European Geological Surveys (WEGS) back in 1971. The Directors of each member survey initially formed an amiable discussion group which created a network between individual surveys. As the organisation developed, a number of thematic working groups were set up which provided a platform for leading experts to exchange information, experience and opinions. After over 20 years of activity WEGS began to reach out beyond its borders and expanded its membership into Central and Eastern Europe, establishing the Forum of European Geological Surveys (FOREGS) in 1993 to replace WEGS. With increasing membership came more expertise and greater exposure, particularly to the European institutions. With a greater emphasis on providing the European institutions with expert advice and analysis, FOREGS was soon replaced by EuroGeoSurveys in 1995, which offered full membership to each European Member State's national geological survey and associate status to those of the European Free Trade Area.

As stated in the official statutory documents, the purpose of EGS shall be:

- To promote the contribution of geosciences to European Union affairs and action programmes;
- To provide a permanent network between the Geological Surveys of Europe and a common, but not unique, gateway to each of the Members and their national networks;
- To jointly address European issues of common interest in the field of geoscience;
- To publish, or see its Members publish, technical advice for the European Union Institutions.

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Although these aims are very much focussed on the requirements of the European Union, this does not rule out international activities that would be in the interest of European society, industry and economy.

At the Heart of EU Affairs

Thousands of Geoscientists at the Service of European Citizens

As a Europe-wide organisation, EuroGeoSurveys has a strong working relationship with the EU institutions.

The expert geoscientific knowledge provided by EGS can have a strong influence on European policy-making and regulations spanning a broad range of topics, for example the Directive on the Geological Storage of CO_2 or the European Technology Platform on Geological Disposal of Radioactive Wastes.

With the General Secretariat at the heart of the European Quarter in Brussels, EGS can easily interact with the European Commission, EU Council of Ministers, European Parliament and NATO.

Broadening Horizons

Having built its reputation as the leading source of European geological expertise to the European Institutions, EGS is now looking to develop its reputation in the private sector and build on its public profile both in Europe and further afield.

International Cooperation

EGS' international profile is gaining momentum through participation in international projects (such as OneGeology) and association with international geological organisations such as the International Union of Geological Sciences (IUGS). Most notably in 2010, agreements were signed for increased collaboration with the European Environment Agency (EEA) and the U.S. Geological Survey (USGS).

Supporting Research and Innovation

Due to the amount of research and innovation involved in our Members' work, EGS has developed close ties to universities and research institutions that sometimes form research partnerships to work on European or international projects such as OneGeology-Europe or PanGeo.

EGS and the Private Sector

Relations with industry is growing too, with EGS taking a leading administrative role in the European Technology Platform on Sustainable Mineral Resources – a public-private partnership which aims to modernise and improve sustainability in the European minerals industry. An international example can also be given through the participation of EGS as a partner in the Global Earth Observation System of Systems (GEOSS).

EGS and the Media

Through the EGS Communications Team a strong network of media contacts has been built up which helps in disseminating and promoting the work of EGS and its members Europe-wide.

In 2010, significant media exposure included interviews from Radio Vaticana and Ecoradio in Italy with the EGS Secretary General Luca Demicheli. There have also been many articles published in newspapers and journals on EGS and its activities.

EGS participates in conferences around the world to deliver key note speeches, promote discussion on topical issues and exhibit the work of EGS and its Members.

Geohazards

Nearly all members of EGS are involved in geohazard activities, whether it is in research, monitoring or mitigation for example. Such widespread interest is contrary to the general perception that there are just a few geohazards (namely earthquakes, volcanic eruptions, landslides and floods) – geologists have listed over 20 of them.

The question concerning whether these events, or at least some of them, could be forecasted and hence avoided always lurks somewhere in the human imagination. While for earthquakes only potential locations can be pre-defined, for floods and landslides the general location and the time frame of occurrence can be forecasted, up to several days in advance. In the case of volcanoes a good monitoring system helps to predict almost the exact time of eruption. It is still obvious that the most effective counter-measure to geohazards is prevention – either with engineering solutions or, even better, with the avoidance of inhabiting areas exposed to geohazards. While it is not that simple for existing populated areas, it is the most useful tool for planning future settlements.

EGS Members participate in numerous research projects that aim to increase knowledge on and help mitigate geohazards, such as the PanGeo project which is particularly relevant to landslides.

Members of EuroGeoSurveys

AGS GBA GSB MOEW HGI-CGS

GSD CGS GEUS EGK GTK

BRGM BGR IGME MAFI ISOR

GSI ISPRA LGT SGL TNO

NGU PGI LNEG GIR VSEGEI

SGUDS GeoZS IGME SGU Swisstopo

SGSU UkrSGRI BGS EGS

EGS Members in order of the logos above: Albanian Geological Survey, Geological Survey of Austria, Geological Survey of Belgium, Ministry of Environment and Water (Bulgaria), Hrvatski geološki institut (Croatian Geological Survey), Geological Survey Department (Cyprus), Czech Geological Survey, Geological Survey of Denmark and Greenland, Geological Survey of Estonia, Geological Survey of Finland, Bureau de Recherches Géologiques et Minières (France), Institute of Geology and Mineral Exploration (Greece), Geological Institute of Hungary, Iceland GeoSurvey, Geological Survey of Ireland, Istituto Superiore per la Protezione e la Ricerca Ambientale – Geological Survey of Italy, Geological Survey of Lithuania, Service Géologique du Luxembourg, Built Environment and Geosciences National Geological Survey (Netherlands), Geological Survey of Norway, Polish Geological Institute – National Research Institute, Laboratório Nacional de Energia e Geologia (Portugal), Geological Institute of Romania, A. P. Karpinsky All Russia Geological Research Institute, State Geological Institute of Dionyz Stur (Slovakia), Geological Survey of Slovenia, Instituto Geologico y Minero de España (Spain), Sveriges Geologiska Undersökning (Sweden), Ukrainian State Geological Research Institute, British Geological Survey, Malta Resources Authority, EuroGeoSurveys.