CHALLENGES IN MITIGATION OF LANDSLIDES IN SELECTED HOT SPOT AREAS AROUND THE WORLD

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ABSTRACT: Landslides are among the most frequent and devastating natural hazards**.** Human and material damages are significant. Social impact of landslides is frequently under evaluated. The situation calls for intensified actors in the form of preventive measures. The paper addresses three pillars necessary for a proactive landslide risk mitigation: Pillar 1 advocates increased efforts in appropriate hazard and risk assessment, Pillar 2 focuses on optimum mitigation measures, and Pillar 3 highlights the importance of international collaboration efforts. Examples are given from a number of countries.

INTRODUCTION

Landslides represent a widespread hazard in most mountainous and hilly regions of the world. They cause significant loss of lives and material damage. Reliable numbers for the socio-economic impact from landslides are difficult to obtain on a global scale, mainly because landslide hazard is usually not dealt with separately from other hazards occurring simultaneously, such as earthquakes or floods. This often contributes to reducing the awareness and concern of both authorities and individuals about landslide risk.

It seems, however, that the frequency of landslide disasters is rising. The reason for this increase is not necessarily an increase in the intensity and/or re-occurrence of the natural processes, but increased vulnerability. Because of this vulnerability, the thresholds for damage, property loss and fatalities can be reached with ever lower intensity of landslides than before. There is increased susceptibility of surface soil to instability as a result of more extensive human interaction of different kinds, increased vulnerability of exposed population and infrastructure as a result of growing urbanization, uncontrolled land-use and increased forest clearance and cropping practice. In addition, more extreme weather believably will cause a significantly increase in the occurrence of landslides.

A study carried out for the World Bank (Dilley *et al.* 2005) predicted the following landslide challenges in a global prospective:

- Land area of the globe exposed to landslides: 3.7 million km^2
- Population exposed: 300 million, or 5% of the world population
- Land area identified as high risk zones: 820 000 km^2
- Population living in high risk areas: 66 million people

With a more proactive approach to risk management, loss of lives and material damage associated with the landslides hazard and other natural hazards can be significantly reduced. The major disasters that have taken place over the last 5-10 years have clearly changed people's mind in terms of acknowledging risk management as an alternative to emergency management. One can observe a positive trend internationally where preventive measures are increasingly recognised, both on the government level and among the international donors. There is, however, a great need for intensified efforts, because the risk associated with natural disasters clearly increases far more rapidly than the efforts made to reduce this risk.

Pillar 1: Hazard and Risk Assessment

Hazard and risk assessment are a central pillar in the management of landslide risk. Without knowledge and characteristics of hazard and risk, it can not be meaningful to plan and implement mitigation measures. The value of proper landslide risk assessment is convincingly highlighted in a publication issued by the US National Research Council on Partnership for Reducing Landslide Risk (National Research Council 2004). The report states that among the different activities in a national landslide mitigation strategy, proper risk assessment is the one with optimum cost-effectiveness. The same message is echoed in a report authorized by the European Commission on socio-economic impacts of natural disasters in Europe. The work was a part of the thematic network GeoTechNet (Koehorst *et al.* 2006).

There are several approaches to hazard and risk assessment, and several were discussed in the proceedings of the Landslide Risk Management Conference in Vancouver, May 2005 (Hungr *et al.* 2005). The important recent trend is that the estimates of hazard and risk assessment are increasingly quantitative, which will gradually make the approach more acceptable. The following presents one approach for landslide risk assessment in a global perspective.

Landslide Inventory

Landslide inventory is an essential part of the landslide hazard and risk assessment. Unfortunately, inventories for historic landslide events and their consequences are incomplete and even missing in many countries. The two open international sources for historical landslides are:

- EMDAT-CRED International Data Base (CRED 2005)
- The DesInventar/LaRed Data base (DesInventar 2005)

In addition, government agencies, geological surveys, research organisation and universities do hold national databases. The database EMDAT-CRED provides country-wide information on disasters between 1900 and 2006 and information from slides where 10 persons or more were reported killed, 100 persons or more were reported affected, and where appeal for international assistance was issued and/or a state of emergency was declared. DesInventar/LaRed focuses mainly on Latin American countries. The time span covered is much less, but the database contains much more information from the smaller events than is the case in EMDAT-CRED. Both databases suffer from lack of comprehensive information about economical losses associated with the events. In the databases, the smaller events are often not captured, and the events are recorded according to the trigger starting the event rather than the hazard itself that caused the damage.

Given that reasonable time series do exists, it might be useful to present the historical loss data in a statistical manner, in terms of a loss-frequency diagram. Examples of such plots are shown in Figure 1. The profiles for Columbia and Nepal were derived by NGI in landslide screening studies for the World Bank. Data used originate from respectively DesInventar (2005) and a national database for Nepal, Khanal (2004). The loss frequency diagram for the other countries shown in Figure 1, originate from work done by Guzzetti (2000).

For Nepal, the figure indicates that a) the return period for a single landslide causing more than 200 fatalities is about 10 years and b) a landslide disaster with fatalities of 500 or more may statistically occur every 40 years.

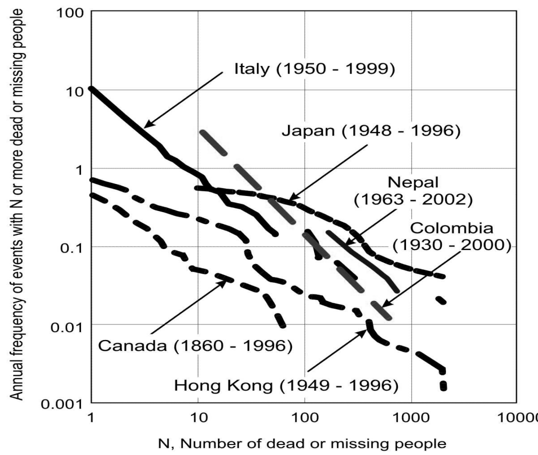

Figure 1 Landslide loss-frequency diagram for selected countries

When a reasonable quantity of economic loss data is available, it is useful to prepare a statistical evaluation of economic loss potential by plotting losses versus annual exceedence probability. Such an exercise was for instance carried out by the World Bank for a number of countries in Central Asia (Pusch 2004).

Unless loss data are available in one form or another, experience has shown that it is difficult to convince decision-makers to invest in mitigation measures, support the build-up of national competence or invest in R&D for improved understanding of the landslide process. It is an important challenge for the geotechnical profession to get involved not only on the technical aspect of landslides, but also in the gathering of loss data from landslide events.

Landslide Hazard Zonation

In many countries, organizations have successfully applied a Mora Varson GIS based approach (Mora and Varson 1994) to achieve an overview of the geographical distribution of landslide susceptibility, often in popular terms referred to as landslide hazard zonation maps. Examples are Thailand, the Philippines, China, Nepal and Sri Lanka. The number of input parameters and the weighting procedures of the parameters can vary significantly from country to country. A calibration of the predictions with landslide inventories is highly recommended.

Some countries have also prepared detailed national hazard maps based on comprehensive geological surveys. Sri Lanka chose to apply a rather advanced and demanding approach with a high number of input parameters in a modified Mora Varson model, where several of the input parameters are based on detailed information gathered from field work, for instance hydrological conditions, landform, vegetation and land use (Bandara 2002).

The scale of the landslide hazard zonation maps varies. Many countries find it useful to have a national map where it is easy to get an overview of the landslide hotspot areas of the country. For detailed planning on a municipality level, a larger scale is necessary.

Landslide risk assessment and mapping

Methods for risk assessment and risk mapping cover a wide range, from advanced modelling in probabilistic terms to simplified scoring methods. The term “risk” associated with natural hazards is frequently misused. Risk refers to the hazard and the potential impact of the hazard if it takes place. The potential impact (damage) may be in the form of loss of lives or loss of land and property, or both. The potential impacts of the hazard depend on the elements at risk and their vulnerability. Risk is strictly the expected degree of loss in a defined area due to a potential damaging phenomenon within a given time period. To comply with this definition, it is necessary also to establish site-specific return periods for the landslide hazard.

To carry out landslide risk mapping on a national level by following a quantitative or numerical approach is quite demanding. An example is part of the Global Disaster Hotspots study where NGI with support from UNEP, Grid Geneva, did a pilot study on the assessment of global landslide risk. In this work, predicted landslide hazard was combined with proxy of vulnerability estimates to obtain risk estimates expressed as risk of loss of life per year per km^2. An illustration of the results is shown in Figure 2.

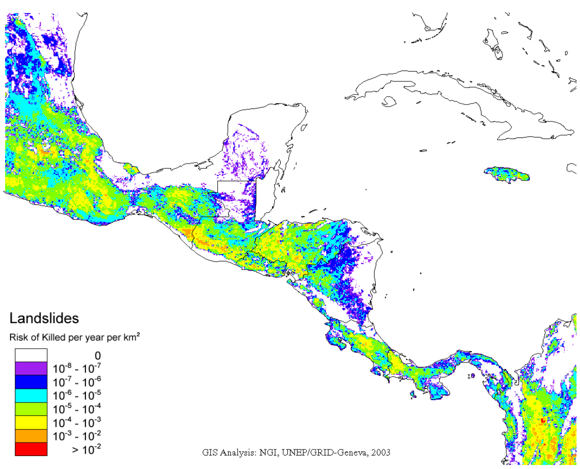

Figure 2 Hotspot landslide risk zonation for Central America

National organizations in most countries that have the responsibility for natural disasters and their prevention and mitigation, seem to favour one or both of the following two approaches in their national landslide risk mapping:

- Overlay GIS-based landslide hazard maps with elements at risk (population and infrastructure) and obtain potential hotspot “risk areas”, where the product of the hazard and the exposure is high. Number of people and extent of elements at risk can then be easily identified and quantified.
- Make use of risk index, for instance in the range 1-5, assessed in a risk matrix where the two major governing factors within a defined unit area are the level of predicted hazard and the anticipated consequence.

Figure 3 shows an example from Madagascar using the first mentioned approach (NGI 2004a). The exploratory pilot study showed that only 5% of the population lives in the very high landslide-prone areas, while more than 10% of the major roads in the country are located in the same areas.

Use of risk index or risk classes for zonation of the landslide risk, the latter approach, is a method that is very much favoured in many countries in Europe. A typical risk matrix is shown in Table 1, where 5 risk classes are used.

Assessment of the hazard level can be done systematically with the use of scores for hazards and weights for the different parameters that are considered to be of most importance. The same applies to consequences. An example of the scoring arrangement for potential quick clay landslide-prone areas in Norway is shown in Table 2 (Lacasse *et al.* 2004) and (ICG 2004).

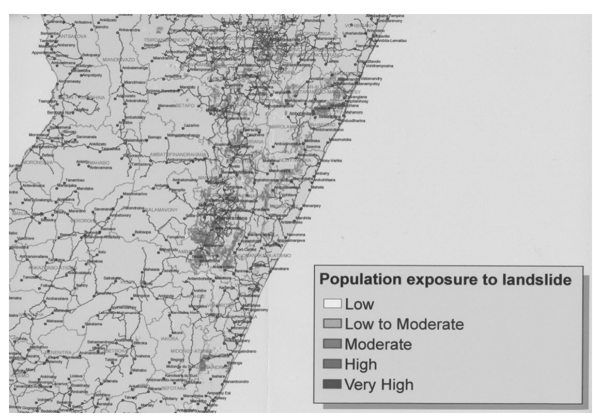

Figure 3 Population-weighted hazard areas on Madagascar (Source: NGI 2004a)

Table 1 Matrix for landslide risk classes

Consequence class	Hazard Low	Hazard Medium	Hazard High
Low	1	2	3
Important	2	3	4
Very important	3	4	5

Table 2 Example of scoring system for the assessment of landslide consequences (after Lacasse *et al.* 2004)

Factor	**Weighting**	**Consequence (score)**			
		3	**2**	**1**	**0**
Dwellings, number	4	Dense	Spread >5	Spread >5	No
Commercial buildings	3	>50	10-15	<10	No
Other buildings	1	High	Considerable	Limited	No
Road, average no. cars/day	2	>5000	1001-5000	100-1000	<100
Railway, track priority	2	1-2	3-4	5	No
Power line	1	Central	Regional	Distribution	Local
Floods/inundation	2	Serious	Medium	Little	No
Sum		45	30	15	0
% of total score		100	67	33	0

After the risk classes are established, it is important to construct an activity matrix that states what type of action needs to be considered for each of the classes. Such an approach will be most practical to apply on the municipality level. Local participation in the establishment of both hazard and risk maps proves to have the best effect and ensures ownership.

Pillar 2: Landslide mitigation measures

Mitigation means implementing activities that prevent or reduce the adverse effects of extreme natural events. In a broad prospective, mitigation includes structural and geotechnical measures, and political, legal and administrative measures. Mitigation also includes efforts to influence the lifestyle and behaviour of endangered population in order to reduce the risk. This paper will concentrate on challenges related to roads and the protection of human settlements.

Roads in landslide-prone areas

Roads in mountainous areas can be extremely damaged by landslides. Direct costs for repair of road damage might be as high as for buildings or other infrastructure. The socio-economic consequences of disrupted transportation routes may typically include stranded communities, sometimes with food shortage, loss of income, loss of ability to deliver agricultural products, scarcity of fuel, and sometimes complete isolation of large groups of people.

Mountain slopes are only conditional stable. They are continuously subjected to the effect of gravity and natural process from hydrological and climate variations. The construction of roads, if done without slope design, might make the slopes even more susceptible to landslides. The triggering factors are usually intensive precipitation or earthquakes. The Hindu Kush -Himalaya region (HKH), typically the area from Afghanistan to Myanmar, represents one of the most exposed areas of the world in this respect. This region is characterized by weak rocks structure, intensive seasonal precipitation and highly rugged topography.

Roads in Nepal, India and Bhutan are each year badly damaged by landslides in the monsoon season, typically between May and September. In the period 1959-1993, Nepal reported 19 exceptionally high precipitation events where the 24-hour rainfall exceeded 400 mm (Chalise 2001). The cost for rehabilitation of damaged roads due to landslides in Nepal has been reported to be 2 500 million rupees for the period 1980 till 2004 (Koirala 2004). Typical damage on roads caused by rainfall-induced slides is shown in Figures 4 to 6.

In the Pakistan 2005 earthquake, 2 300 km of roads were damaged, mainly by landslides. The damage happened in a rather concentrated area around the city of Mustafarabad north of the capital city Islamabad. An example of the consequences of devastating forces is shown in Figure 7. The damage assessment report carried out by the international development banks, led by Asian Development Bank (2005), predicted that the cost for rehabilitation of damaged roads, including bridges, was of the order of 416 million USD, which corresponds to 12% of the total cost for reconstruction of all damaged areas in the country after the earthquake.

Figure 4: Bhutan: the highway between Thimpu and Phuentsholing experiences severe landslides in most monsoon periods and was closed for 3 months in 2001 due to complete blockage (Photo NGI, Bhasin et al 2009)

Figure 5 India: Typical consequence of landslides caused by heavy rain in Sikkim (Photo NGI)

Figure 6 Brazil, Road in the vicinity of Rio de Janeiro that collapsed due to a rainfall triggered landslide in 2005, isolating a small neighbouring town (Photo F. Bogossian)

Figure 7: Pakistan The main road from Mustafarabad along the Jellum Valley towards the Indian border after the December 2005 Earthquake of Magnitude 7.4 (Photo Earthquake Reconstruction and Rehabilitation Authority (ERRA)

Earthquake triggered landslides that block roads occur far less frequently, but may often have huge consequences. During the El Salvador Magnitude 7.6 earthquake in 2001, a massive landslide blocked the Pan American Highway at La Leona some 55 km east of the capital city San Salvador (Fig. 8). The volume of the slide was of about 600 000 m^3. Rehabilitation of the road across the damaged area was quite complicated and took more than a year.

Figure 8 El Salvador: Blocking of the Pan American Highway at La Leona from a landslide caused by the 2001 Earthquake of Magnitude 7.6 (Photo Servicio Nacional de Estudios Territorales (SNET)

Landslide stabilization of roads in mountainous areas may typically include:

Water management and drainage measures

- Surface water drainage
- Near surface water drainage and
- Deep surface drainage

Structural support measures

- Retaining walls, where gabions probably are the most successful one
- Anchored structures
- Shotcrete and bolting

Surface treatment measures

- Bio-engineering
- Immediate surface treatment to avoid erosion

A few examples of classical solutions for slope stabilization are shown in Figures 9 and 11.

The use of inexpensive material and unskilled local labour forces plays a key role in the choice and implementation of mitigation measures. In El Salvador, coca mats are used for road slope protection (Fig. 12). Figure 13 shows another innovative solution from El Salvador: the slope is stabilized by anchored concrete ribs in a grid where the opening between the ribs is secured by fully permeable material protected by a net.

Another low cost landslide mitigation approach to mention, which was applied in Bhutan is the use of plastic sheets for reading tension cracks near by a potential sliding area. Figure 14 shows the site which is located on the highway close to Phuentsholing. In addition to the use of check dams in the slope, the following procedure was successfully applied:

- Removal of the soil and peat (organic material) at the surface above and around the cracks (see Fig. 15)
- Filling of the soil material in the open cracks
- Placement of elastic plastic sheets on the ground surface
- At least 30 cm overlap was provided in the 2 plastic sheets to take into account some possible movement in the ground
- Covering the plastic sheet with soil and organic material (see Fig. 16)
- Plantation of grass in the surface for natural and aesthetic appearance and for preventing erosion of soil during rainfall

The above procedure has helped to stabilize the affected area behind the road where the tension cracks were observed.

Perhaps not as innovative as the above solutions, but a reliable long-term solution is the use of a by-pass tunnel when stabilization of the road slope presents major difficulties. In the very rugged terrain in Bhutan, the use of a tunnel seems to be an attractive solution for crossing several of the mountain passes. NGI, together with the Bhutan Department of Geology of Mines and the Road Department, has carried out a feasibility study for such a solution in Bhutan (NGI 2006). The outcome seems favourable both from a technical and economic point of view. For the Jumbja slide area shown on Figure 17, where the conditions in the slope are extremely difficult, the bypass tunnel will be 1 km long. The tunnel will reduce the driving distance by 3-4 km, contribute to increased safety and regularity and certainly eliminate maintenance costs which are substantial today. Prediction of the construction costs indicates that the costs can be repaid in 10 years, accounting only for savings done with the shorter driving distance. Including the other factors, the repayment period could be as short as 5 years. There are reasons to believe that this tunnel will be built in a reasonable time frame.

Figure 9 Bhutan: surface water system for stabilizing the road in an unstable slope that has experienced movements over many years (Photo NGI)

Figure 10 Madagascar: stabilization of slope with gabions. Though not fully successful in this case, the measure is usually effective and one of the most inexpensive and most widely used methods for road slope stabilization in developing countries (Photo NGI)

Figure 11 This planting of Vetiver grass is about 3 month old. Vetiver grass has shown to be an effective means of stabilization at a low cost in many countries (L. Highland,USGS)

Figure 12. El Salvador: Rehabilitation of the La Leona Landslide where erosion protection of the new slope made use of coca mats (Photo Servicio Nacional de Estudios Territorales (SNET)

Figure 14: Potential sliding area near Phuentsholing, Bhutan (Photo NGI, Bhasin et al 2009)

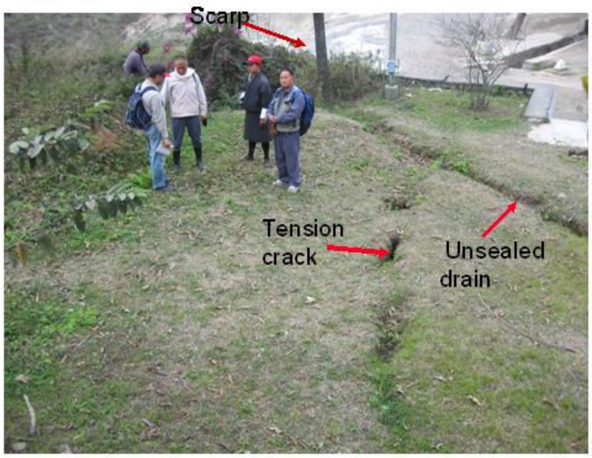

Figure 15: Deep tension cracks adjacent to the check post

Figure 16: Placement of plastic sheet on the tension cracks and covering with soil

Figure 13: El Salvador: road cut stabilization with anchored concrete ribs and large open net- protected weep holes (Photos University of El Salvador)

Figure 17 Bhutan: planned entrance portal for the by-pass tunnel to avoid the Jumbja slide area shown to the right. The highway is the major road connection between the capital Thimpu and India (Photos NGI)

Protecting human settlements

Unplanned human settlement, lack of legislation, poverty and inadequate land use and environmental practice are key causes to the high vulnerability of the population to landslides in many developing countries. Population growth in many parts of the world increases competition for limited resources and space, and forces the poor, who do not have access to ordinary land, to settle into marginal land, often along riverbanks and unstable hills, in both urban and rural areas. Inflow of rural population to the larger cities results in rapid urbanization and often creating poorly developed shanty-towns into marginal land (Fig. 18).

In rural areas, the expansion of agricultural frontiers and hunting for firewood leads to land degradation and soil erosion. There is no doubt about the linkage between landslide disasters and deforestation. An example is the mudflow disaster in Haiti in May 2004, where more than 2500 persons living in watershed areas in the foothills of unstable slopes lost their lives during heavy rain under Hurricane Ivan (Fig. 19). Haiti has only 3.2% of its area with forest cover left. In the neighbouring Dominican Republic, hit by the same storm, there were far less victims. Part of reason for this is that the hills in the Dominican Republic are still protected by forest. For the Central America Region, deforestation has also been high. Some researchers claim that only 10% of the original forests remain intact. In Asia, countries where deforestation has been extremely high include Nepal and Sri Lanka. The island of Madagascar is also very high on the list of the most deforestated countries in the world.

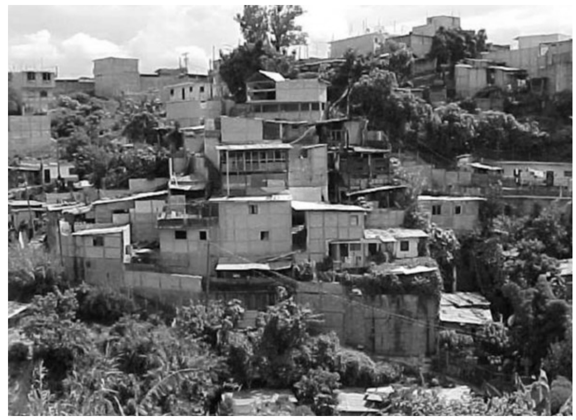

Figure 18 Guatemala: Example of shanty town in unstable hills in the outskirts of Guatemala City (Photo Mota 2006)

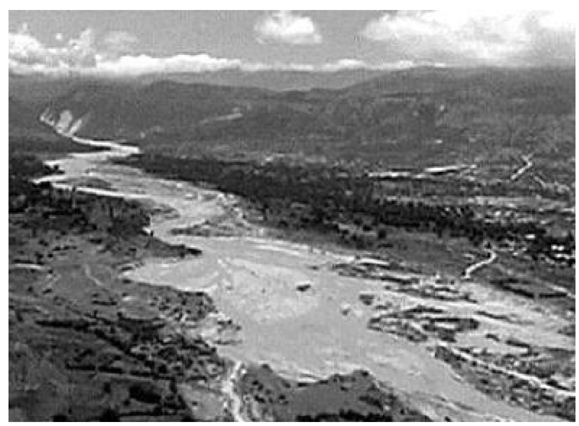

Figure 19 Haiti: mudflow disaster in 2004 caused by the Hurricane Ivan

Deforestation of hills leads to increased run-off, increased erosion, more frequent mudflows and more frequent landslides which in turn contribute to excess silting of rivers. These effects can over time greatly increase the flooding risk, as is the case for instance in many of the Caribbean Islands (Ahmad 2006).

Major elements in landslide risk mitigation to protect people include:

- Legal mechanisms , regulation and planning
- Institutional structure
- Risk zoning and mapping
- Technical operations
- Education and training
- Hazard monitoring and early warning

Legal mechanisms

It is a challenge for developing countries to have in place legal mechanisms in terms of suitable building regulations and technical codes. Many of the developing countries have institutionalised such legal mechanism that sets the platform for e.g. rational land use planning. But there is much to be still accomplished on the implementation side. Such mechanisms are of great importance when it comes to new developments, but of limited value for the poor people living in risk-prone shanty-towns.

There is a trend for government agencies to delegate to the local municipalities the follow-up of approved regulations. This practice poses a problem when a country has a great number of small municipalities with limited capacity and ability to follow up. An example is El Salvador which has in place rather modern regulations, but has delegated the work to its more than 400 municipalities.

Institutional structures

Institutional responsibility for natural disasters and preventive measures are in many countries fragmented and shared between several ministries, for instance ministries of agriculture, housing, construction and urban affairs. These are again supported by operational entities such as national emergency commissions and civil defence agencies.

Fragmentation is a hindrance for effective initiation of preventive measures. Often large disasters contribute to changes and improvements in the national set-up. That has been the case for instance in Central America (Kjekstad and Nadim 2005). In the period after the Hurricane Mitch Disaster in 1998, many governments in the Central America Region took initiatives to strengthen their institutional structure to deal with the management of risk caused by natural hazards, both for technical and operational matters.

Risk zoning and mapping

For government agencies, knowledge of the country's landslide risk hotspot areas is of critical importance for the follow-up of preventive measures. The same can be said for the municipalities located in hotspot areas. On the local level, risk mapping must be useful for direct actions. Experience has shown that risk zoning taken at the local level and supported by adequate oversight and coordination at the national level give the best results.
Local ownership is crucial.

Technical operations

Preventive or corrective work here referred to as technical operations can have the form of for instance stabilization and strengthening of slopes, channelling of water courses, measures to avoid erosion, reforestation programs, use of deflection dams to guide debris flow away from settlements (Domaas and Harbitz 2005) and relocation of people to safe areas. Such operation needs careful planning and assessment of possible alternatives, and their cost versus benefit.

An example of a comprehensive protective measure from El Salvador after the Las Colinas landslide in 2001 is shown in Figure 20. To protect the people in the foothills surrounding the slide area, the top of the hill was unloaded by excavation. Totally 1.6 million m^3 of soil was removed from the top of the ridge over a distance 1.8 km. The cost for the remediation was of the order of 18 million USD (Diaz 2006).

Figure 20 El Salvador: Remediation to protect people located in the foothills in the surroundings of the 2001 Las Colinas Landslide (Photo Servicio Nacional de Estudios Territorales (SNET)

Another example of a comprehensive preventive measure is the relocation of 200 families that the Government of Sri Lanka enforced after a landslide took place in May 2003 close to the city of Ratnapura, about 150 km east of Colombo, the capital city. As many as 250 people were killed in the disaster which also was caused by heavy flooding. The Ministry of Housing and Construction provided the families with new land, some financial incentives and technical support for the workmanship to construct their own new houses. Government support was given on the condition that the families that were forced to relocate could use their original land for agricultural purposes, but living in their old houses was prohibited.

Measures for protecting settlements in unstable slopes can sometimes be implemented rather inexpensively, for instance by taking proper care of the surface water. Figure 21 shows an example from Sikkim in Northern India where two villages located in the foothills of an unstable slope were protected by a comprehensive flexi drain system (Bhasin *et al.* 2002). In this area, annual precipitation is as high as 4000 mm, and extreme rainfall during a 24-hour period can be up to 220 mm.

There seems to be a growing interest for stabilizing slopes by reforestation. Reforestation can be an inexpensive measure and it makes effective use of local resources.

Figure 21 India: use of high capacity drainage channels for protecting villages in the Sikkim Area, after Bhasin *et al.* (2000)

Education and training

The effectiveness of preventive measures depends on making people aware of the necessity of the preventive measures, and gaining acceptance for them. Communication and educational actions, using media and schools, have proven to give good results. Similarly, technical training courses for land planners, engineers, architects and technicians are essential for gaining acceptance and respect for regulations and standards that govern planning, development and construction. International organizations play an important role, acting as facilitators in these processes.

Landslide monitoring and early warning

Methodologies for monitoring of site specific landslide problems are under development, and different series of equipment are available. Movement detectors can be used to issue alerts any time the movement rate increases. The threshold for alert to be issued is often computed based on acceleration patterns. Other techniques for early warning focus on the trigger rather than movement. Use of rainfall threshold values to alert an authority in a region classified as a risk area, is getting increased attention in many countries. The Government of Hong Kong has applied this method for more than 30 years and has wide experience.

In general the Government of Hong Kong might be characterized as a front runner in landslide risk management. Hong Kong is an excellent example of the evolution of public policy by confronting the challenges and successfully mitigating landslide risks (Fig.22). Their organization GEO is confronting their slope safety problems with the following measures:

- Imposing geotechnical control of new slopes
- Retrofitting substandard man-made slopes
- Setting standards
- Controlling land use in development planning
- Implementing a Landslide Warning and emergency service

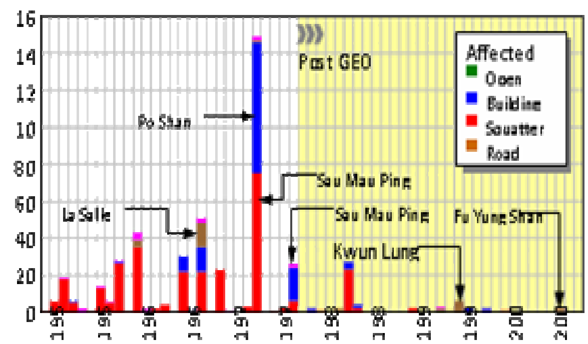

Figure 22 Shows the gradual reduction of the fatality rate from landslides, in Hong Kong, tracked beginning in the 1950's and falling drastically by 2005.

Nations around the world have a varying approach to mitigating landslides but as economics develop, the price of mitigating destructive hazards become cost effective, based on the rising value of infrastructure and economic investments.

Pillar 3: International collaboration General challenges

A milestone in international collaboration for natural disaster risk reduction is the approval of the "Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters" (ISDR 2005). This document, which was approved by 165 UN countries during the World Conference on Disaster Reduction in Kobe January 2005, clarifies international working modes, responsibilities and priority actions for the coming 10 years. The Hyogo Framework of Actions states three fundamental principles:

- Each nation has the prime responsibility for preventive measures to reduce disaster risk, and is expected to take concrete actions as outlined in the Action Plan

- Governments in risk exposed countries shall regularly report progress achieved to the UN coordinating unit which is the ISDR Secretariat (International Strategy for Disaster Reduction) with headquarters in Geneva.
- International cooperation is called upon to assist countries that need help.

The Hyogo Framework of Action has clearly increased the awareness and importance of preventive measures. It will also contribute to a much better practice for the implementation of risk reduction projects for two reasons: a) by the fact that governments will be in the driving seats, which means that coordination is likely to be improved and b) the fact that ISDR is given the responsibility for the follow-up of the plan will put a pressure for action.

Two new global initiatives where landslides mitigation measures play an important part are worth mentioning. The first one is the Global Risk Identification Program (GRIP) led by UNDP.

GRIP gives support to improved risk analysis in more than 10 countries and support capacity building on the national level. The other initiative is the Global Facility for Disaster Reduction and Recovery (GFDRR), institutionalised by the World Bank. By donor support, the World Bank has so far been able to mobilize more than 100 million USD for country level assistance to improve natural disaster risk management. Presently GFDRR has 22 countries on their priority list to receive technical assistance, many of which with a high landslide risk profile.

Another initiative to mention is the International Consortium for Landslide (ICL), registered in Japan. ICL, which has more than 50 member organisations from developed and developing countries around the world, is an excellent example of international cooperation and knowledge sharing within the geotechnical profession.

Experience from Norwegian Supported Institutional Cooperation Programs and Regional Training Programs

The Norwegian Government has supported a number of projects to reduce the consequences of future landslide disasters both in Central America and in South East Asia. One type of projects has the form of assistance for institutional strengthening of national organizations that have a key role in the management of the landslide hazard in the country. Examples are: Instituto Nicaraguense de Estudios Territorales (INETER) in Nicaragua, SNET in El Salvador and Department of Geology and Mines in Bhutan, Geological Survey of Bangladesh, Vietnam National University and Geological Survey of Pakistan.

Another type of projects is regional training programs where representatives from several countries and organizations are brought together in yearly practical training programs of several weeks duration. Participants carry out work tasks in the period between the training sessions and they have also responsibility to carry out national landslide mitigation demonstration projects. Examples are the Central America program RECLAIMM executed in the period 2004-2008 with 25-30 representatives from Guatemala, El Salvador, Nicaragua, Honduras, Costa Rica and Panama. NGI served here as the implementing organization on behalf of the regional organization Centro de Coordinacion para la Prevencion de los Desastres Naturales en America Central (CEPREDENAC).

A similar regional program is presently executed in Asia where NGI serves as partner to Asian Disaster Preparedness Centre (ADPC). This regional program under the name of RECLAIM which started in 2004 is presently implementing Phase III of the program. In this phase focus is on establishment of best practises for early warning of landslides in a changing climate scenario. Participating countries are: India, Sri Lanka, Thailand, Nepal, Bhutan, Indonesia, Philippines, China, Vietnam and Myanmar.

The experience gained in these types of projects is positive. It shows that international collaboration is useful because it:

- Increases the knowledge level for how to apply practical landslide mitigation measures.
- Enforces the responsible organizations for landslide mitigation measures to be more proactive rather than reactive.
- Serves as mediators to bring together the different national stakeholders, which not necessarily communicate frequently.
- Contributes to create regional networks and sharing of problems and solutions across country borders in a region.
- Provides a link to international professional entities.

Institutional cooperation schemes and capacity building programs are generally well received. Identification, appreciation and utilization of existing local knowledge are however fundamental factors for achieving favourable results and in such activities. Having these elements in place, international assistance can serve in a facilitator role rather a teaching role on how to best do things.

Summary and conclusions

Landslides are one of the most widespread hazards on Earth and cause thousands of deaths and injuries and billions of dollars in damage worldwide each year. Statistics from The Centre for Research on the Epidemiology of Disasters (CRED) in Brussels show that landslides contribute to about 17 % of the fatalities due to natural hazards. The social impact of landslides is frequently under-evaluated.

It is a nation's best interest to reduce these losses to better use its remaining budget and wealth for economic growth. This challenge applies to both developing and developed countries. There is a tendency that the frequency of the landslide disasters that hit developing countries is increasing.

The situation calls for intensified actions in forms of preventative measures. Logical steps and procedures for mitigating the hazard from landslide might include the following three key pillars:

- Take measures to identify and locate the landslide risk areas on national and sub-national level, in such a way that the risk is fairly well known. Equally important is to get national governments in risk-prone countries actively involved for improving institutional structure for dealing with natural disasters in their country and have in place the necessary legislations that regulate land use and construction practice.
- Implement mitigation measures, structural and non-structural measures, including the use of early-warning systems.
- Secure capacity development on different national levels, promote international collaboration and knowledge sharing, and also seek the financial support for implementing mitigation measures.

The approval of the ISDR Hyogo Framework for Action, 2005-2015, approved by 164 UN countries, was a milestone in international efforts for disaster reduction. It has paved the way for a number of new initiatives taken up in collaboration among key international players that are eager to help and that have in their mission to avoid that new disasters shall spoil the intended economical and social development in a number of risk-prone countries.

ACKNOWLEDGEMENT

The author would like to acknowledge the valuable support, from comments and suggestions from NGI colleagues in the preparation of this paper. The author also acknowledges NGI's major clients who have provided the opportunity for NGI to undertake a series of challenging projects related to natural disaster risk reduction in many countries. Special thanks in this context is addressed to the Norwegian Ministry of Foreign Affairs and NORAD, The World Bank, ISDR, Care International, CEPREDENAC and ADPC.

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