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Consultative Workshop on Landslide Inventory, Risk Assessment, and Mitigation in Nepal

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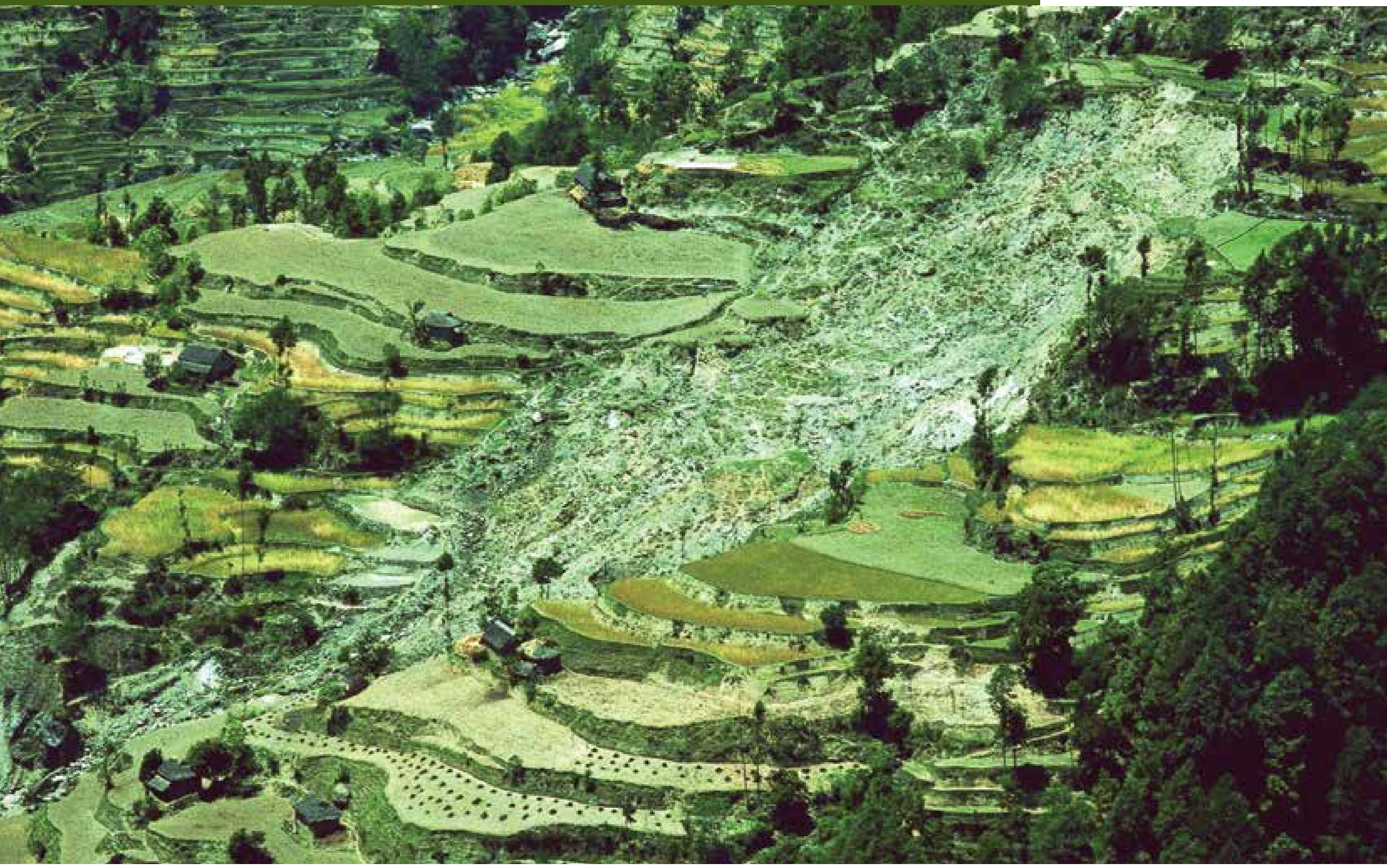

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About ICIMOD

The International Centre for Integrated Mountain Development, ICIMOD, is a regional knowledge development and learning centre serving the eight regional member countries of the Hindu Kush Himalayas – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan – and based in Kathmandu, Nepal. Globalization and climate change have an increasing influence on the stability of fragile mountain ecosystems and the livelihoods of mountain people. ICIMOD aims to assist mountain people to understand these changes, adapt to them, and make the most of new opportunities, while addressing upstream-downstream issues. We support regional transboundary programmes through partnerships with regional partner institutions, facilitate the exchange of experience, and serve as a regional knowledge hub. We strengthen networking among regional and global centres of excellence. Overall, we are working to develop an economically and environmentally sound mountain ecosystem to improve the living standards of mountain populations and to sustain vital ecosystem services for the billions of people living downstream – now, and for the future.

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Foreword

Landslides and floods constitute over 40% of the disaster events in Nepal. Eighty per cent of Nepal's landscape is mountainous, which are prone to landslides triggered by monsoon rain, as well as tectonic activities. Every monsoon, catastrophic landslides triggered by episodic and intense rainfall events are common across hills slopes, resulting in the loss of lives and damage to infrastructure. The livelihoods of the rural poor are challenged by landslides and secondary hazards. One single event like the Jure landslide of 2014 killed 155 people, destroyed 157 houses, and inflicted economic losses in the order of millions of Nepali rupees due to disruption in trade.

The 2015 Gorkha Earthquake and its aftershocks triggered and reactivated many landslides. Although it was long overdue, the earthquake brought back the focus on instituting efficient landslide risk management in Nepal, a task that will require collaboration among diverse stakeholders. This consultative workshop was timely, as reconstruction work in districts affected by the Gorkha Earthquake were soon to begin. The workshop created a common platform for close to 100 participants from the region and beyond together to come together and share expertise and experiences, particularly from China and Pakistan. It was an excellent opportunity for national disaster managers and practitioners to learn from others, and rebuild Nepal better. Through two days of deliberation, many action points evolved, giving clear direction to future strategies in landslide risk management.

The Department of Soil Conservation and Watershed Management (DSCWM) immensely values the contributions from all the experts and participants. The Department remains committed to lead through the action points that came out of the workshop. On behalf of the Government of Nepal, I would like to sincerely thank ICIMOD, UNEP, UNDP, IUCN, WWF, and FAO for their support to organize this event. I also offer my sincere gratitude to regional and international experts, local participants, and presenters for their participation. Finally, sincere appreciation to the organizing team for their hard work in putting this event together.

Pem N Kandel
Director General
Department of Soil Conservation and Watershed Management, Government of Nepal

Foreword

Nepal is the 11th most earthquake-prone country in the world. The 7.6 magnitude Gorkha Earthquake, as recorded by Nepal's National Seismological Centre (NSC), and ensuing aftershocks were a stark reminder of this region's propensity for natural hazards. The earthquake not only killed thousands of people and destroyed valuable infrastructure, it also triggered or reactivated numerous landslides and rock falls, which were responsible for many of the lives lost in rural areas. Landslides also damaged road networks and high-value infrastructure like bridges, hydropower, and cultural sites.

Many settlements threatened by landslide had to be temporarily relocated after the earthquake, but that was only a temporary solution. Landslides are a recurring problem, threatening infrastructure, biodiversity, and the lives and livelihoods of people living in the hills and mountains of Nepal, and across the Hindu Kush Himalayas, each year.

In Nepal, there is an urgent need to develop uniform practices for generating landslide inventories and assessing landslide hazard, vulnerability, and risk. The consultation workshop led by the Department of Soil Conservation and Watershed Management (DSCWM) and supported by ICIMOD, UNEP, UNDP, IUCN, FAO and WWF, was held as an important first step to bring relevant stakeholders together to begin this discussion. It was a timely event, held as efforts to rebuild what was lost in the earthquake began to pick up, a time when reliable information on landslide risk plays a critical role. The outcomes of the workshop highlighted the need for uniform protocol for landslide inventory, hazard, and risk management; mitigation; and the need for capacity building, which I hope all the participants will take forward under the leadership of DSCWM. On behalf of ICIMOD, I offer our support to DSCWM in implementing the action points and recommendations emerging from the two-day deliberation.

I would like to thank all the experts, participants, and presenters for their valuable contributions. I would also like to extend gratitude to consortium of partners who came together to support this event. Finally sincere gratitude to the Government of Australia for providing support to the event and for bringing out these proceedings.

David Molden, PhD
Director General
ICIMOD

Foreword

The earthquake in Nepal on 25 April 2015 caused significant loss of lives, livelihoods, and infrastructure. Registering 7.8 on the Richter scale, the earthquake was followed by several aftershocks, including another sizeable 7.3 magnitude earthquake on 12 May 2015. According to estimates from the Government of Nepal, the earthquake resulted in over 8,600 casualties and displaced millions of people. The earthquake and subsequent aftershocks destroyed over 269,000 buildings, 7,500 schools, and 1,000 healthcare facilities. Several historical monuments and cultural icons were also lost.

As the country surveyed the extent of damage, it quickly became apparent that the earthquake triggered several thousands of landslides and rockfall incidences, which caused hundreds of fatalities, blocked rivers and roads, and isolated villages. The monsoon season that followed then triggered more landslides, as cracks initially created by the earthquake made slopes more susceptible to rainfall-induced landslides.

In a country where over 80% of the terrain is mountainous, landslides are a prevalent feature and have always posed a serious threat. Thus, Nepal has long attracted international researchers to study and inventory landslides. After the Gorkha Earthquake, international organizations, including the International Centre for Integrated Mountain Development (ICIMOD), quickly deployed state-of-the-art technologies to rapidly gather data and generate landslide inventories that were critical for prioritizing areas most in need of humanitarian assistance. However, in reality, landslide research in Nepal is often undertaken in an ad hoc manner, with little coordination or sharing of data. Almost one year after the earthquake, the Government of Nepal is still faced with the challenge of accessing available datasets and making the best use of landslide inventories. Consolidating landslide information is not only useful for guiding humanitarian response, it is also crucial for identifying and prioritizing landslide mitigation and prevention efforts.

The Consultative Workshop on 'Landslide Inventories, Risk Assessments, and Mitigation', was organised 28–29 September 2015 by the Department of Soil Conservation and Watershed Management (DSCWM) under the Ministry of Forests and Soil Conservation in collaboration with the United Nations Environment Programme (UNEP), ICIMOD, Food and Agriculture Organization (FAO), International Union for Conservation of Nature (IUCN) and the United Nations Development Programme (UNDP). The workshop brought together over 50 participants from 30 international and Nepal-based organizations with the aim of convening major actors currently involved in landslide research, landslide risk assessments, and sustainable landslide rehabilitation in Nepal. The event aimed to take stock of available landslide information and create a platform for data sharing and collaboration amongst international and national landslide experts, government agencies, and international organizations.

As the main national entity mandated to conduct soil conservation, landslide mitigation, and watershed management in Nepal, DSCWM is clearly cognisant of the challenges, as well as the opportunities, ahead in taking a proactive and preventative approach to landslides in Nepal. DSCWM is taking the lead in convening four national working groups, representing a broad consortium of organizations, to focus on harmonizing landslide risk assessments and inventories, consolidating available data and identifying effective landslide treatment and mitigation approaches. On 19–22 January 2016, DSCWM together with UNEP organized a training workshop for district soil conservation officers from the 14 most earthquake-affected districts to discuss methods for landslide prioritization and sustainable landslide mitigation. With the national reconstruction process underway, there is clear scope for promoting landslide risk reduction in Nepal, based on improved sharing of data and expertise, coordination, and mutual collaboration.

Henrik Slotte
United Nations Environment Programme
Chief, Post-Conflict and Disaster Management Branch
Geneva, Switzerland

Acknowledgements

The organizing team would like to thank all of the participants and participating organizations for their active involvement in the event. Special thanks to international participants who travelled to Kathmandu for the workshop, and those who made presentations through Skype. The support and guidance from the management of the organizing agencies – Department of Soil Conservation and Watershed Management (DSCWM), International Centre for Integrated Mountain Development (ICIMOD), UNEP, UNDP, FAO, WWF and IUCN – to organize this important event was invaluable to its success. This event would not have been possible without generous support from the organizing agencies. The organizing committee offers its sincere gratitude to the funding organizations. In addiiton to being the source of funding for ICIMOD's contribution to organizing the event, the Australian Government throuhg the Department of Foreign Affairs and Trade supported the publication of the workshop proceedings and development of distribution materials.

Acronyms and Abbreviations

AUC	Area under curve
BGS	British Geological Society
CB-EWS	Community based early warning system
CDES	Central Department of Environmental Science
DDRC	District Disaster Relief Committee
DEM	Digital Elevation Model
DHM	Department of Hydrology and Meteorology
DMG	Department of Mines and Geology
DPNET	Disaster Preparedness Network Nepal
DOE	Department of Education
DoLIDAR	Department of Local Infrastructure Development and Agricultural Roads
DOR	Department of Roads
DRM	Disaster risk management
DRR	Disaster Risk Reduction
DSCO	District Soil Conservation Office
DSCWM	Department of Soil Conservation and Watershed Management
DWIDP	Department of Water Induced Disaster Prevention
EB-DRR	Ecosystem-based disaster risk reduction
EPIC	Ecosystems Preserving Infrastructure and Communities
EWS	Early warning system
FAO	Food and Agriculture Organization
GIS	Geographical Information System
GLC	Global landslide catalogue
GLM	Generalized linear model
GoN	Government of Nepal
HKH	Hindu Kush Himalaya
ICIMOD	International Centre for Integrated Mountain Development
IIT	Indian Institute of Technology
IMHE	Institute of Mountain Hazards and Environment
IMSRN	Ingeniería de Movimientos de Suelo y de Riesgos Naturales
INGO	International non-government organization

IOE	Institute of Engineering
ISRO	Indian Space Research Organization
IT	Information Technology
IUCN	International Union for Conservation of Nature
JAXA	Japan Aerospace Exploration Agency
KBP	Koshi Basin Programme
KU	Kathmandu University
LiDAR	Light Detection and Ranging
LDOF	Landslide dammed outburst flood
MoHA	Ministry of Home Affairs
MoSTE	Ministry of Science, Technology and Environment
M&E	Monitoring and Evaluation
NASA	National Aeronautics and Space Administration
NGO	Non-government organization
NSET	National Society for Earthquake Technology
NPC	National Planning Commission
PDNA	Post Disaster Need Assessment
PGA	Peak ground acceleration
PRA	Participatory rural appraisal
REA	Rapid environmental assessment
ROC	Receiver operating characteristics
RS	Remote Sensing
SLIP	Southern Landslide Identification Product
TOR	Terms of Reference
TU	Tribhuvan University
UAV	Unmanned aerial vehicle
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNIL	University of Lausanne
UNIMIB	University of Milano–Bicocca
USGS	United States Geological Survey
VDC	Village development committee
WCDRR	World Conference on Disaster Risk Reduction
WWF	World Wildlife Fund

Executive Summary

Nepal is vulnerable to landslides due to the landscape's geological fragility and steep terrain, unsustainable development practices, and extreme rainfall events. Each year, economic losses and the loss of lives from landslides constitute a significant portion of Nepal's disaster loss database. The recent Gorkha Earthquake on 25 April 2015 and subsequent aftershocks have further weakened valley slopes across the country, further increasing the risk of landslide.

In view of the need for collective and coordinated engagement for landslide risk management, particularly as post-earthquake rehabilitation and reconstruction began, a two-day national consultation was organized in September 2015 covering all aspects of landslide risk management. The event attracted close to 100 participants (Figure 1, Annex 1) including ten international experts and representatives from 30 national and international organizations. The consultation workshop was led by the Department of Soil Conservation and Watershed Management (DSCWM) with support from the International Centre for Integrated Mountain Development (ICIMOD), United Nations Environment Programme (UNEP), Food and Agriculture Organization (FAO), United Nations Development Programme (UNDP), and International Union for Conservation of Nature (IUCN). Funding support from ICIMOD came from the Koshi Basin Programme, which is funded by the Government of Australia.

The event had five technical sessions, excluding the opening and closing session. Bishwa Nath Oli, Joint Secretary of the Ministry of Forest and Soil Conservation, was the chief guest during the opening session, and Bhartendu Mishra, Member of the Nepal National Planning Commission, presided over the closing session. Four technical sessions (Annex II) were designed to share information on different aspects of landslide risk management, and a fifth session included group work to collect feedback.

Technical Session I:	Post-Earthquake Landslide Inventories and Interventions
Technical Session II:	Landslide Hazard, Vulnerability, and Risk Assessments and Mapping Methodologies
Technical Session III:	Development of a Common Platform
Technical Session IV:	Landslide Treatment, Rehabilitation, and Mitigation
Technical Session V:	Group work and Plenary

During the opening session representatives from coordinating organizations highlighted the importance and timeliness of the workshop, noting its relevance in the post-earthquake situation when long-term reconstruction and rehabilitation would soon be underway. The call for strong leadership was unanimous, and all development partners remained committed to support the Nepal Government in every way possible. The event was designed to help build partnerships and to facilitate the exchange of best practices and the sharing of lessons learned from past earthquake events.

Nineteen presentations were made during the four technical sessions. The lack of harmonized methodology and protocol came out very strongly in all aspects of landslide risk management: inventory; hazard and risk mapping, data sharing, and treatment. It is this vacuum that resulted in inconsistent outputs (data, maps, etc.) from past activities incomparable with each other. The need for capacity building was featured prominently in all of the technical sessions. Multi-level engagement was favoured, and having policy, legislation, and institutional mechanisms in place were deemed imperative to facilitating ground-level interventions. Experiences from Pakistan and China highlighted the importance of community engagement in all aspects of landslide risk management for the success of interventions. Lessons from Pakistan on implementing a landslide rehabilitation strategy after the 2005 earthquake demonstrated the importance of rebuilding the livelihoods of local communities and enhancing food security by adopting indigenous species to build resilience for sustaining recovery. Similarly, experiences from these countries showed that the use of civil engineering structures together with bioengineering measures has a high rate of success, rather than depending on one type of intervention.

The provision of actionable information resonated strongly with participants, as the case studies presented on landslide hazard mapping in technical sessions were coarse and, thus, were found to be irrelevant for local level planning and interventions. The need to develop hazard and risk maps at the VDC and watershed levels (at scales of 1:10,000 or 1:25,000) was proposed. There was strong preference for combining top-down (traditional) and bottom-up (community) approaches to integrate technological input and community engagement for more effective interventions.

The following actions points were recommended during deliberation and discussion:

- Develop harmonized methodologies and protocols for landslide inventory, hazard and risk assessments, and data sharing
- Develop a framework for prioritizing landslides for treatment
- Establish working groups to work on the above points
- Develop and implement activities to build the capacity of national agencies
- Evolve outputs from aforementioned action points into a long-term landslide risk management project

In the closing session, the director general of DSCWM expressed strong ownership of the process and outcomes coming out of the two-day consultation workshop. Development partners also committed support to take this process to a logical end.

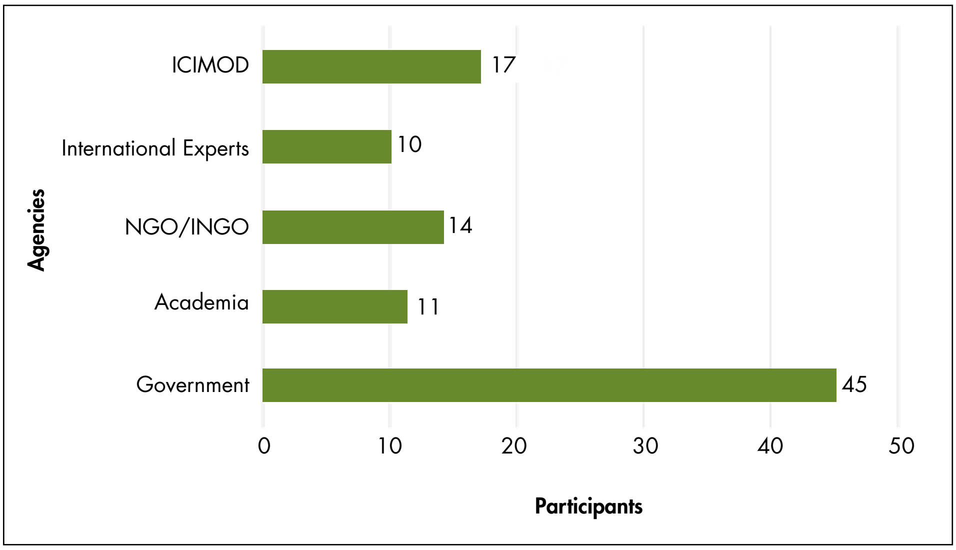


Figure 1: **Summary of participants**

Session Summaries

Inaugural Session

Speakers: David Molden, ICIMOD; Henrik Slotte, Post Conflict and Disaster Management Branch, UNEP; Yam Malla, IUCN Nepal; Eklabya Sharma, ICIMOD; CJ van Westen, University of Twente; Jagannath Joshi, DSCWM; Tara Nidhi Bhattarai, Tribhuvan University; Bishwa Nath Oli, MOFSC; Pem N Kandel, DSCWM

All the speakers expressed pleasure in being associated with this important and timely workshop bringing together experts and the actors working on landslides to collaborate and coordinate toward a common goal. David Molden noted that disaster risk management is a vehicle to attain sustainable mountain development and to improve the livelihoods of mountain people. All the speakers called for a harmonized framework for landslide mapping, assessment, and risk management, which all stakeholder should adopt to ensure that outputs from different agencies are consistent. The region is complex – geologically, topographically, and in many other regards – yet countries across the region deal with similar problems, thus exchanges like this will benefit the region as a whole.

An approach that combines ecosystem-based disaster risk reduction (EB-DRR) and structural measures was stressed by many speakers. A well-managed ecosystem is an asset for disaster risk reduction, minimizing both hazard (control) and vulnerability (livelihoods and food security). The need to work with communities in landslide-prone areas while implementing the outcomes of the workshop was stressed in order to gain their confidence and to sustain the activities. Eklabya Sharma urged experts and practitioners to engage in credible research on landslides and properly package information to feed into and influence policy making processes. This was also echoed by Tara Nidhi Bhattarai in his keynote address. Jagannath Joshi outlined the objectives and expected outcomes of the workshop:

Objectives

- Bring together a wide range of stakeholders currently involved in, or planning to get involved in, the field of landslide inventorying, hazard mapping, risk assessment, research, or restoration in Nepal
- Present the information currently available on landslide inventories, hazard mapping, risk assessment, and restoration measures
- Discuss scientific approaches to inventorying, hazard mapping, risk assessment, research, and restoration measures and recommend the most suitable options
- Create a platform for data sharing and continued collaboration

Expected outcomes

- Formulation of working groups on developing a harmonized methodology for landslide inventory, hazard mapping, and risk assessment
- Build networks with international agencies and create avenues and opportunities for support
- Create a common platform for data sharing and continued collaboration

In his keynote address Tara Nidhi Bhattarai identified the lack of harmonized methodology for different aspects of landslide risk reduction, lack of implementation guidelines, data sharing challenges, lack of coordination among different actors, inadequate policies, and lack of skilled human resources as major gaps. In order to address the these gaps, he suggested the following action points to effectively manage landslide risk in Nepal:

- Develop a harmonized method for comprehensively studying landslides
- Conduct training and capacity building programmes for young professionals
- Improve landslide and risk engineering curriculums in universities
- Create a data sharing platform

Pem N Kandel assured strong leadership from DSCWM to take the outcomes of the workshop forward. He thanked all the co-organizers for their support in organizing this important event. All speakers called for national organizations like DSCWM to take a leadership role in this process, and development partners attending the meeting committed to supporting DSCWM and national partners in this endeavour.

Technical Session I: **Post-Earthquake Landslide Inventories and Interventions**

Session objective: *To share the experiences and problems encountered by institutions conducting post-earthquake landslide inventories in Nepal.*

Presenters: Jagannath Joshi, DSCWM; Deo Raj Gurung, ICIMOD; Dinesh R Bhuju, Tribhuvan University; Colm Jordan, British Geological Society; Judy Oglethorpe, WWF Nepal; CJ van Westen, University of Twente

There were six presentations in this session and all of them spoke of Nepal as highly vulnerable to landslides and other natural hazards, with the situation further aggravated by the Gorkha Earthquake. According to the Post-Disaster Needs Assessment, the event affected 31 out of Nepal's 75 districts, of which 14 were severely affected, resulting in 8,790 casualties and 22,300 injuries. The estimated forest cover loss is 23,375 ha, and loss of ecosystem services is valuated at NPR 34,700 million. Loss of large areas of Langtang larch (*Larix himalaica*), which is only found in Langtang, indicates of the impact of earthquake-induced avalanches on biodiversity. The problem is far from over as the potential threat posed by landslides looms large and more landslides may be triggered in cracked areas, as well as active landslide areas, during the monsoon. With access to markets restricted, people started to exploit natural resources in many areas, for example for fuelwood and construction materials. Therefore, environmental concerns need to be adequately considered in order to build back better.

So far there is only one national level landslide inventory done by the Central Department of Environmental Science of Tribhuvan University (TU-CDES), conducted before the earthquake, while there are multiple post-earthquake inventories done by different teams. The TU-CDES-led landslide inventory mapped landslides above 1 km in area, and each landslide polygon is accompanied by additional attributes such as types, pre-existing land use/cover, topographic details, human presence, and risk. In total, 72 districts were mapped, which identified 5,003 landslides with a total area of 126.34 km^2. From 72 districts, 14 districts were ranked high and another 14 were ranked very high in terms of landslides. Most post-earthquake inventories were done with focus on academic publishing, which restricted the free distribution of data in appropriate formats prior to publication. Thus, despite numerous post-earthquake inventories, access to data in appropriate formats when it was most needed was a challenge.

There was a unanimous call for landslide mapping and inventory in Nepal to develop a comprehensive landslide database, but the lack of a harmonized methodology for landslide mapping was identified as a major gap requiring immediate attention. In addition to the traditional remote sensing based inventory approach, crowdsourcing using mobile apps and social media could also to be explored as a way to integrate field-based information into other information systems. The need for strong engagement with local communities was emphasized during the workshop. Their involvement is critical to ensure ownership and, thus, sustainability. The inventory needs to be dynamic and regularly updated. There are over ten ministries associated with some aspect of landslide risk management, thus a mutually agreed upon standard methodology for landslide mapping is critical to make data relevant to multiple agencies. Inventory development entails looking at technical and institutional mechanisms and arrangements, thus ground work needs to be done before the inventory. Presenters strongly expressed that relevant government departments must take the lead and anchor the activity within the government system so it becomes a regular activity and is mainstreamed into a national mechanism.

Action points from Technical Session I are summarized below.

- Develop a harmonized methodology for landslide inventory in Nepal
- Develop a platform for regular and continual updating of the national landslide inventory
- Establish a working group (inter-departmental or agency) to work on the above action points
- Train relevant people to build up skilled human resource pool
- Work on landslide hazard mapping at the local scale focusing on affected areas to address immediate needs in resettlement initiative

Technical Session II: **Landslide Hazard, Vulnerability, and Risk Assessments and Mapping Methodologies**

Session objective: *To share methodologies and results being used by institutions in mapping landslide hazards and assessing vulnerability and risk in Nepal*

Presenters: Jagannath Joshi, DSCWM; Megh Raj Dhital, Tribhuvan University; Sudan Bikash Maharjan, ICIMOD; Narendra Raj Khanal, ICIMOD; Prem Paudel, DSCWM; and CJ van Westen, University of Twente

Economic losses and lives lost due to landslide in Nepal constitute a significant chunk of the nation's disaster loss database. The need to safeguard lives, livelihoods, and infrastructure though evidence-based planning was echoed by all the presenters. For this, landslide hazard and risk assessments are imperative. While some agencies have completed hazard/susceptibility mapping, they are at a large scale or for specific sites, which is not adequate for local level planning. Some examples prepared using statistical approach from areas in the Chure hills and those affected by the Gorkha Earthquake were presented. However, the case studies presented were large scale and were not relevant for local-level decision-making processes. Presenters noted the lack of a harmonized method for hazard and risk mapping as a major gap, which has resulted in a mismatch between the needs and the products generated. It was stressed that landslide hazard and risk assessment maps at the VDC or watershed-level be developed at scales of at least 1:10,000 and 1:25,000. Landslide hazards are complex, and understanding hazards in the local context is important for producing meaningful products. For example, the damage to buildings and infrastructure is sometime the result of debris flows and not actual landslides.

Between top-down and bottom-up approaches, the former mostly led by experts, a bottom-up approach that ensures community involvement was favoured. It was suggested that a community-based approach in conjunction with the use of GIS tools be considered. The use of Google Earth to capture communities' perceptions was highly recommended. The products generated must ultimately be owned by local communities, and their role in the larger process of landslide hazard mapping and risk assessment needs to be ensured. The final product must also consider the local situation to ensure it is relevant to the ground reality. Landslides are complex processes that are also influenced by other factors in addition to peak ground acceleration (PGA). It was advised that landslide hazard analysis be done with proper understanding of these complex processes and mechanisms.

There was a unanimous call for collaboration on the huge task of landslide hazard and risk mapping at the VDC level. This effort entails data collection, analysis, and dissemination; thus, depending on their role, different agencies may act as data providers, analysis hubs, dissemination centres, and/or capacity building hubs. There is much uncertainty in landslide prediction, and historical can provide some direction, which highlights the importance of creating a comprehensive landslide inventory. The complexity of landslides and landslide hazards was acknowledged. Three things must be considered in hazard assessments: spatial probability, temporal probability, and intensity probability. These must be integrated into hazard mapping efforts.

Although dynamic, physical models generate the most refined outputs, these are not suitable for Nepal as they are extremely data intensive. In the current context, hazard and risk assessments using qualitative methods and the risk matrix approach, indicator-based analysis, and spatial multi-criteria evaluation is possible in Nepal.

Action points from Technical Session II are summarized below:

- Develop a harmonized hazard and risk mapping methodology, which should be done at the VDC or watershed level at scales of 1:10,000 and/or 1:25,000
- Test the methodology
- Establish a working group to work on the above action points

Technical Session III: **Development of a Common Platform**

Session objective: *To discuss and agree on a common methodology and platform for data collection and sharing on landslides in Nepal*

Presenter: Dalia B Kirschbaum, NASA Goddard Space Flight Center

There has been a move recently towards crowdsourcing for data gathering, and Dalia B Kirschbaum and her team have developed a global landslide catalogue (GLC) using crowdsouring principles. It is currently running on Amazon Cloud Instance (JavaScript), an open-source tool with the possibility of scaling to a national context. So far the system has 6,790 landslide reports from 136 countries (2007–2015), and over 25,000 reported fatalities (1,779 events with reported fatalities). The online system allows users to view landslide data in the shapefile format. The inventory is developed through principles based on crowd mapping whereby individuals map landslides online. The online application comes with common tools like zoom and pan. Users can view additional attributes and information like precipitation to compare and contrast. She said any system that targets participation by local communities should have a reporting mechanism in a local language.

A semi-automated mapping approach called Sudden Landslide Identification Product (SLIP) using Landsat is another possibility, but it most appropriate for mapping large landslides. It is based on changes in spectral characteristic of pixels in multi-temporal sets of images. She said her team is collaborating with ICIMOD on furthering some research on landslides.

Technical Session IV: **Landslide Treatment, Rehabilitation, and Mitigation**

Session objective: *To share landslide treatment and rehabilitation approaches*

Presenters: Shanmukhesh C Amatya, DWIDP; Nabraj KC, Department of Roads; Ningsheng Chen, IMHE; Pierre Plotto , IMSRN; Faizul Bari, FAO; Karen Sudmeier-Rieux, University of Lausanne and UNEP/UNIL; and Sanjaya Devkota, TU

There are two primary national organizations with the mandate for landslide treatment: Department of Water Induced Disaster Prevention (DWIDP) and the Department of Roads (DOR). In addition to landslides, DWIDP works on flood risk management. Since landslides are a major problem for road infrastructure, DOR's scope of work includes landslide treatment along road corridors. Both these organizations have successful examples of slope stabilization. DWIDP and DOR are already present in districts to implement landslide risk reduction activities. Both organizations have experience working on civil structures and bioengineering for landslide treatment. The presenters representing these agencies identified the lack of human resources, capacity, funds, and coordination as major challenges.

There are many technical approaches being used to treat landslides and rock falls in other parts of the world. However, the complexity of Nepal's terrain and financial limitations bring into question what can be adopted. Experiences from China show that containing and treating landslides and associated hazards is not easy and require detailed investigations in the field prior to designing structural measures. Emphasis was placed on adopting civil infrastructure in conjunction with bioengineering measures for more effective landslide management. Early warning systems, and community based early warning systems in particular, have successfully saved lives in China (Winjia gully and Aizi valley). Predicting landsides requires requires temporal and spatial granularity that is not possible as a result of large uncertainties, thus it is necessary to remain on guard against mountain hazards.

Rebuilding livelihoods and ensuring food security are equally critical in post-disaster situations. Experience from Pakistan has shown that the development and implementation of integrated watershed management plans with community engagement helped in reconstruction after a natural hazard. The use of bioengineering measures with fast growing and locally useful vegetation species helped manage hazards and supported livelihoods. Since rural populations are reliant on domestic animals, veterinary services are critical. Backyard poultry farming and plant nurseries were useful in terms of providing income generation opportunities to local households.

Action points from Technical Session III are summarized below:

- Civil infrastructure should be used in conjunction with bioengineering for maximum benefit
- Detailed field investigations should prelude the design of treatment measures
- Community early warning systems have proved successful in managing residual risk
- Rebuilding livelihoods and ensuring food security are equally critical, thus reconstruction should focus on these aspects
- Integrated watershed management should be developed and implemented with community engagement
- Capacity building of government agencies on treatment techniques is essential

Technical Session V: **Group Work and Plenary**

Group 1: **Landslide inventory methodology and platforms**

Group members: Prakash Pokhrel, Shanti Basnet, Prashant Ghimire, Deo Raj Gurung, Paolo Frattini, Megh N Kafle, Salina Bajracharya, Pasang Tamang, Kalpana Shrestha, Sanjaya Devkota, Pradeep Mool, Santosh Nepal, Samjwal Bajracharya

Presenter: Shanti Basnet, Department of Survey

A comprehensive landslide database at the national level is essential for understanding landslide distribution patterns and to form the basis for landslide hazard/susceptibility mapping. However, there is only one national-level landslide inventory, although several inventories have been done for localized areas (watershed, along road corridors, districts, etc.). The lack of a standardized methodology for landslide mapping has resulted in several inconsistent landslide databases. In addition to the lack of a standardized landslide mapping methodology, there are not enough skilled human resources to undertake a national-level landslide inventory, which is a major gap. Group 1 recommended the following action points:

- Creation of a working group, which will be responsible for the development of 1) a standard harmonized protocol for landslide inventory work; 2) a moderated, web-based platform for landslide inventory data; 3) development of metadata templates/standards for landslides
- Capacity development, including the assessment of current capacities and development of a capacity development plan

Group 2: **Landslide hazard, vulnerability, and risk mapping methodology**

Group members: MSR Murthy, Suresh Shrestha, Khila Nath Dahal, Indira Maleate, Man Bahadur Cherty, Narayan Adhikari, Sudan Bikash Maharjan, CJ van Westen, Narendra Raj Khanal, Suresh Chaudhary, Dipak Bharadwas, Narayangopal Ghimire, Jagannath Joshi, Raju Sapkota, Stefano Gambini, Prem Bahadur Thapa

Presenter: Jagannath Joshi, DSCWM

Landslide hazard, vulnerability, and risk products are tools that support informed decision making by policy makers and planners. At present the Department of Mines and Geology (DMG), DWIDP, and individual researchers have been producing such products, but the granularity of these products is often not adequate to support decisions at the local level. The group recommended that such products are generated at multiple levels: national, district, and VDC or watershed level. In terms of scale, the products should be at 1:10,000 or 1:25,000 to be of help for local level planning. Since the products need to be relevant at the community level, strong engagement of communities while developing these products is suggested. For consistency in future mapping exercises, it is necessary to develop a harmonized mapping methodology. Group 2 recommended the following action points:

- Formation of multidisciplinary, interdepartmental working group, which should include national and international institutions and individual experts
- Develop landslide risk assessment maps at the VDC level or watershed level with strong engagement of communities
- Develop a simple, harmonized methodology for landslide hazard assessment, which consistently uses available parameters and is cost effective.
- Capacity building of national agencies across different levels (e.g., national and district level)
- Prioritize landslide hazard areas for intervention
- Develop spatially explicit maps for priority areas
- Develop a feedback mechanism to improve landslide products

Group 3: **Landslide treatment and mitigation**

Group members: SC Amatya, Thakur Prasad Magrat, Suresh Chaudhary, Purna Chandra Lal Rajbhandari, Sanjeev Bhuchar, Faizul Bari, Nagendra Sitoula, Laxmi Thagunna, Binod Shah, Diwakar Maskey, Krishna Ghimire, Kamal Jaishi, Hari Prasad Sharma, Bhawani S Dongol, Gautam Rajkarnikar, Pierre Plotto

Presenter: Faizul Bari, FAO Pakistan

Landslide treatment and mitigation are resource-intensive activities, and there is a need to prioritize landslides for treatment based on the level of risk posed, scale of treatment, and potential success of treatment interventions. As a common challenge in countries of the HKH region, the sharing of good practices (both success and failure) should be facilitated so that there is collective learning and gains. Although landslide treatment is a local intervention, appropriate institutional mechanisms, policies, and legislation has to be put in place. It is important to have one government department to anchor landslide treatment activities.

Group 3 suggested the following operational level interventions:

- Land use planning
- Hazard and risk assessment mapping
- Awareness raising
- Reinforce livelihood and food security based on emphasis on maintaining ecosystems
- Capacity building of communities and relevant stakeholders
- Establishment of early warning systems
- Community participation and an integrated approach during the whole project cycle
- Adoption of multi-partnership approach

Many issues are common across the Hindu Kush Himalayas, and collective learning can benefit communities across the region. Thus, to ensure transfer of technology and knowledge, Group 3 recommended the following action points:

- Documentation and sharing of best practices/technologies, both in Nepal and across the region
- Development of new technologies (action research), including climate-smart and indigenous technologies
- Departments mandated with landslide related work should ensure they are up to date in disaster risk reduction approaches
- Scoping of appropriate technologies for Nepal

Workshop Proceedings

Inaugural Session

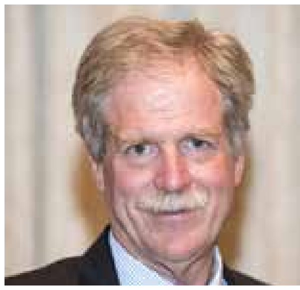
Facilitator: Deo Raj Gurung, ICIMOD

Session chair: Pem Naryan Kandel, Department of Soil Conservation and Watershed Management

Chief guest: Bishwa Nath Oli, Ministry of Forests and Soil Conservation

Deo Raj Gurung, Remote Sensing Specialist, ICIMOD, gave a background of the workshop, which was jointly organized by the DSCWM, United Nations Environment Programme (UNEP), Food and Agriculture Organization (FAO), United Nations Development Programme (UNDP), International Union for Conservation of Nature (IUCN), and ICIMOD. Support from ICIMOD came from the Australian-funded Koshi Basin Programme. He informed the gathering that this event brought together 95 experts including 10 international experts and representatives of 30 organizations (national and international). He welcomed the chief guest, Bishwa Nath Oli, Joint Secretary of the Ministry of Forests and Soil Conservation; session chair, Pem Naryan Kandel, Director General of DSCWM; and David Molden, Director General of ICIMOD.

Welcome remarks by David Molden



David Molden, Director General, ICIMOD, welcomed the session chair, chief guest, scientists, colleagues, and participants to the event addressing the important topic of landslide risk management. Although this workshop focuses on Nepal, landslide issues and the need for better risk management is relevant in all eight of ICIMOD's regional member countries: Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal and Pakistan. He introduced ICIMOD as a regional intergovernmental organization working for mountains and people in the eight countries of the Hindu Kush Himalayas (HKH) by promoting the exchange of ideas and knowledge sharing between these countries to improve the livelihoods of mountain people. He noted that the workshop provides a common platform for participants to learn from each other and gain collectively. He welcomed mountain hazards experts from China to share information on the situation of landslides in the Chinese Himalayas and good practices as lessons for Nepal.

The earthquake of 25 April brought attention to the issue of landslides. Several organizations were involved in landslide inventorying immediately after the earthquake, including ICIMOD. This workshop presented an opportunity to bring all actors together and to formulate common protocols for landslide work so that it is complementary and avoids redundancy. He stressed the importance of building the capacity of national departments, and that all participants must support the government and each other by coming together during this workshop to address these issues. He concluded his welcome remarks by thanking everyone in the hall and wished everyone a fruitful two days of deliberation.

Opening remarks by Henrik Slotte

Henrik Slotte, Chief of the Post Conflict and Disaster Management Branch of UNEP, stressed that a situation assessment should be done prior to reconstruction, and highlighted the importance of the post-disaster needs assessment (PDNA). He said UNEP has been working with the government, UN family, and various departments in Nepal to ensure environmental matters are part of the reconstruction agenda. He noted that landslides are a new area for UNEP, who has introduced the idea of ecosystem-based disaster risk reduction (EB-DRR) as an approach for managing disaster risk. The EB-DRR approach was discussed at the Third UN World Conference on Disaster Risk Reduction (WCDRR) in Sendai and is in line with the Sendai Framework and global DRR blueprint for the next 15 years. An ecosystem-based approach is useful for landslide disaster risk reduction, because a well-managed ecosystem is an asset in a post-disaster situation, minimizing both hazards and vulnerability.

He noted that UNEP is pleased to be a part of the event's organizing team together with development partners. He expressed hope that this will lead to better collaboration, data sharing platforms, and harmonized methodologies for landslide risk assessment.

Opening remarks by Yam Malla

Yam Malla, Country Director of IUCN Nepal, thanked the chair, director general of ICIMOD, chief guest, and distinguished guests. He expressed happiness in IUCN being a part of this highly relevant and important event. He said that such a workshop was long overdue, and that the earthquake helped all actors come together and realize the need for such an event. He thanked DSCWM for their leadership in work related to the establishment of resource sites to measure the rate of soil erosion and river control measures.

He expressed hope that this event will result in fruitful interaction, generate ideas and facilitate exchange, including bringing important things back on the table and sharing knowledge to take landslide risk management forward under DSCWM's leadership.

IUCN has been working closely with ICIMOD and DSCWM on watershed management, and he expressed hope that experiences from this collaboration could contribute to the discussion during this event. He emphasized the need to translate plans and frameworks into action, and to apply learning and knowledge on the ground. He said engagement with local communities is key in this regard, and linking landslide risk management with livelihoods and food security is imperative. He requested national institutions to take the lead in landslide risk management and to apply knowledge generated through this forum.

He informed the gathering that IUCN worked with the National Planning Commission (NPC) to put together the National Strategic Framework for Nature Conservation, which has been approved by the cabinet. This document which was initiated prior to the earthquake has a component on disaster risk reduction (DRR). Finally, he assured IUCN's continued support and commitment to the cause of improving landslide risk management.

Opening remarks by Eklabya Sharma

Eklabya Sharma, Director of Programme Operations (DPO) at ICIMOD, welcomed the chair, chief guests, experts, colleagues, and participants. He said the fragility of the mountain landscape warrants more conscious efforts to focus on minimizing and managing geohazards while planning and implementing developmental activities. He said that, like floods, the impact of landslides is not confined to the site of origin, but secondary hazards like debris flow and sedimentation intensifies downstream risk.

Highlighting the kind of spatial variability this region represents with an example of Cherrapunjee, which receives almost 12 m of rain annually, he emphasized the need to develop good technologies and approaches to deal with geohazards like landslides. He mentioned that we need to make best use of approaches like mountain geoengineering, bioengineering, and technologies like GIS and RS. Exchange of ideas and sharing experiences from across the region and beyond is therefore important, he remarked.

Misconceptions about geohazards and their causes need to be dispelled with credible research, and these misconceptions should not feed into policy processes. Citing his past research on a species of Alnus, a nitrogen fixing plant used to re-vegetate and stabilize landslide areas despite the differing perception of local people, he stressed the need for good science, and to communicate this science to communities and policy makers.

He said landslides and geohazards are an integral part of ICIMOD's work, as they are directly linked to livelihoods and the sustainable mountain agenda. ICIMOD has identified six transboundary landscapes and follows an ecosystem-based approach to handle disasters and involve local communities. ICIMOD also uses the river basin approach which looks at upstream and downstream areas as a single system to understand linkages. Adaptation is another domain of ICIMOD's work, which looks at the ties between adaptation and disaster risk reduction. Emphasizing a regional framework for data and information sharing, he mentioned the regional flood information system developed at ICIMOD, which provides real-time river water information. He surmised that it is these kinds of technology that we need to implement on the ground to save lives and improve livelihood security.

ICIMOD will also begin working on landslides, so that we can relate them to policy, livelihoods, and adaptation, and to facilitate the sharing of knowledge on landslides between countries of the HKH.

Opening remarks by CJ van Westen

CJ van Westen, University of Twente, thanked the workshop organizers for inviting him to the event. He highlighted the need for a more coherent and systematic approach for landside studies, particularly following the earthquake as many mapping activities are being done by different teams. This consultative process is a good start to work towards developing a comprehensive and consistent landslide inventory. There is an urgent need for such an inventory prior to post-earthquake reconstruction, during which people should rebuild in safe places. For this, there is a need for hazard maps to show where it is safe to build. He hoped that the stakeholders will use this workshop to collaborate and share information to reduce further losses in the future.

Recalling his engagement in earthquake risk assessment for the Kathmandu Valley a decade ago, and work to improve building standards in Lalitpur municipality, he reiterated the need to focus on landslide and hazard risk assessment in Nepal, not just for post-earthquake reconstruction, but for the future.

Workshop objectives and expected outputs by Jagannath Joshi

Jagannath Joshi, Under Secretary of DSCWM, thanked the chief guest, director general of ICIMOD, organizers, government departments and ministries, distinguished representatives from UN agencies, WWF, universities, and other partner organizations, and participants. On behalf of the Government of Nepal and DSCWM, he welcomed everyone to the workshop. He started by drawing attention to geohazards like landslides as a major concern for the security and livelihoods of rural people. Loss of limited cultivatable land in the mountain landscape and downstream sedimentation are serious issues. Landslides activated and re-activated by the earthquake in April 2015 have severely affected people in many districts, he said. Government departments like DSCWM and DWIDP, as well as development partners such as IUCN, WWF, and UNEP, are involved in landslide DRR. He shared information on DSCWM's plan to develop a comprehensive landslide inventory and landslide hazard map, and to mitigate landslides based on urgency. He said that because of a lack of coordination and differing methodologies, the work of many organizations on landslides lack consistency. The DSCWM has realized the importance of a harmonized method and approach for inventorying, mapping, and mitigating landslides through common forum like this to discuss issues and to obtain feedback from national and international experts. This event therefore was proposed by DSCWM and development partners, particularly ICMOD and UNEP, who kindly agreed to support DSCWM.

Objectives of the workshop:

- Bring together a wide range of stakeholders currently involved or planning to get involved in the field of landslide inventorying, hazard mapping, risk assessment, research, or restoration in Nepal
- Present the currently available information on the landslide inventorying, hazard mapping, risk assessment, and restoration measures
- Discuss various scientific approaches to inventorying, hazard mapping, risk assessment, research and restoration measures and recommend the most suitable options
- Create a platform for data sharing and continued collaboration

Expected outcomes:

- Formulation of working groups on developing harmonized methodology for landslide inventory, hazard mapping, and risk assessment
- Networks with international agencies, and avenues and opportunities for support
- Creation of a common platform for data sharing and continued collaboration

Keynote speech: Landslide management in Nepal by Tara Nidhi Bhattarai

Tara Nidhi Bhattarai of Tribhuvan University thanked the chief guest, chair, and participants, and expressed happiness on being able to deliver the keynote message on the highly important and relevant topic of landslide risk management in Nepal.

Landslides (unlike earthquakes) are very local events. Mountainous landscapes like those in Nepal are prone to landslides due to causative factors (e.g., geography) and triggering factors (e.g., rainfall or earthquake). Broadly speaking, landslides can be grouped as either naturally occurring or human induced. In Nepal, with steep terrain and weak geology prone to failure under the slightest disturbance, fragile geology and complex topography are the most important factors. Nepal has a steep topographic profile within a short span, from nearly sea level to 8,848 m, and constituting different zones like the Terai (plains), Siwalik hills, and the high mountains. Nepal is also challenging climatically, with variations from sub-tropical in the Terai to alpine and above the snow line in the Himalayas. In this complex mountain range, he said different types of landslide exists, including those triggered by rainfall and others resulting from weathered basement rock. Landslides are also common in the Himalayas. In addition, anthropogenic activities in the form of deforestation, irrigation, road construction, farming practices, and quarrying are contributing to landslide occurrence. He pointed out that the construction of roads without sound technical assessments of geology, geomorphology, and engineering aspects has been one of the major causes of landslides in Nepal.

He said that the impacts of landslides are wide ranging, from the loss of lives and physical damage to infrastructure of high economic value, cultivated land, forests, and drinking water sources. Impacts on life support systems result in outward migration, causing another form of disaster. The impact extends far beyond the site of landslide origin, as an increased sediment load in river systems poses challenges to hydropower, in particular. Secondary hazards like flood as the result of the outburst of a landslide-dammed river and change of riverbed geometry also have far-reaching impacts in downstream areas, he said.

Effective landslide controls require good understanding of the factors and mechanisms involved in landslide formation, which necessitates detailed study. Thus, field surveys for surface and subsurface investigation are a prerequisite for effectively controlling landslides, he said. Topographical and geotechnical parameters are critical considerations for designing appropriate control measures. He broadly categorized control measures into two categories: structural and non-structural. Awareness raising, land use planning, early warning systems, and sharing of risk through insurance are some examples of non-structural measures. Structural and geotechnical measures include external and internal stabilization measures such as retaining walls, groundwater draining, soil nailing, and rock nailing. These measures are largely unknown in remote areas. Capacity building to develop skilled human resources on different aspects of landslide risk management is imperative for a country like Nepal, thus he spoke of having a centre of excellence for geotechnology.

Narrating his interaction with villagers during recent fieldwork, he pointed out that villagers are concerned about the immediate and future risk from landslide. Local people are helplessly waiting to know if it is safe to return to their settlements, student wants to know if school structures are safe, and people wants to know safe areas to rebuild their homes. He expressed hope that this workshop works toward finding answers to such questions and provides actionable information to those in need.

The following limitations to landslide risk management were identified:

1. Lack of harmonized methodology for landslide inventorying and hazard and risk assessment
2. Lack of guidelines for implementing preventative and mitigation measures
3. Lack of a data sharing mechanism
4. Lack of coordination among agencies working on landslides
5. Lack of relevant policies, plans, regulations, guidelines, and acts
6. Limited skilled human resources on landslide risk management

Based on these, he suggested the following action points to effectively manage landslide risk in Nepal:

1. Develop a harmonized method for studying landslides comprehensively
2. Conduct training and capacity building programmes for young professionals
3. Improve the academic curriculum in universities
4. Create a central data sharing platform

He hoped that this workshop would contribute to the exchange of knowledge, mutual cooperation, and collaborative research for the study of landslides in Nepal and contribute to effective landside risk management.

Figure 2: **Livelihoods of the rural poor are being threatened by earthquake-triggered landslides. A village in Rasuwa District, on the right bank of the Trishuli River**

Remarks by Bishwa Nath Oli, chief guest

Bishwa Nath Oli, Joint Secretary of MOFSC, thanked the chair, facilitator, director general of ICIMOD, organizers, partners, imminent scientists and participants. He highlighted the importance of this workshop for Nepal, where mountains cover 80% of the country, not just in the post-earthquake situation. In Nepal, landslides kill more than 200 people each year. The Gorkha earthquake put people in the hills and mountains under greater risk of landslide. Referring to the PDNA prepared by the National Planning Commission (NPC) together with a multitude of development partners and national agencies, he said that the restoration of forests and ecosystems has been accorded high importance in respect to controlling and managing landslide risk.

In his closing remarks, he thanked experts, scientists, and government departments working on these issues, and expressed hope that this event would lead to improved policy on landslide risk management for the benefit of the people of Nepal. He said that the output of the workshop should benefit ongoing research and policy efforts.

Vote of thanks Pem N Kandel

Pem N Kandel, Director General of DSCWM, thanked the chief guest, director general of ICIMOD, organizers, imminent scientists, and participants for making this important event a reality. He noted the relevance and timeliness of addressing landslides after these issues were heightened by the Gorkha earthquake. Although Nepal is a mountainous country highly vulnerable to landslides, it has not applied a coordinated scientific method for inventorying and assessing landslides, which he said is fundamental for effective risk management. The earthquake of 25 April, which caused estimated damages of USD 340 million, increased landslide risk and accounted for many human, economic, environmental, and infrastructure losses. A third of the total damage was on watersheds, partly caused by landslides triggered by the earthquake, he surmised. Following the earthquake, the risk of more damage and destruction from landslides increased due to destabilized slopes and ruptured basements, due to which rural areas are now at higher risk to natural disasters.

In this context, DSCWM jointly organized this workshop to discuss the issue of landslide inventory, risk assessment, and mitigation in Nepal, which brought together experts in the field to draw up a plan for how to deal with landslide, one of Nepal's most frequent geohazards. DSCWM has endeavoured to conserve soil and water and conduct landslide management to support sustainable livelihoods. He noted that the huge issue of landslides cannot be handled by the government on its own. He highlighted the need to work with development partners and others to conserve soil and water and for landslide management. Finally, he thanked ICIMOD, Jagannath Joshi from DSCWM, FAO, UNEP, as well as national and international experts in attendance, for organizing and supporting the event.

Technical Sessions

Technical Session I: **Post-Earthquake Landslide Inventories and Interventions**

Session objective: *To share the experiences and problems encountered by institutions conducting post-earthquake landslide inventories in Nepal*

Session chair: Pem N Kandel, DSCWM

Facilitator: MSR Murthy, ICIMOD

Initiatives and requirements of government agencies

Jagannath Joshi, Under Secretary, DSCWM, and
Shanmukesh Amatya, Chief, Technology Development Section, DWIDP

The presentation highlighted Nepal as country highly susceptible to landslides. The Gorkha Earthquake of 25 April 2015, which was followed by hundreds of aftershocks, caused thousands of landslides, as well as cracks. A total of 31 out of Nepal's 75 districts were affected by the earthquake; of these, 14 were affected severely (Figure 3).

The Post-Disaster Needs Assessment (PDNA) report prepared under the leadership of the National Planning Commission found that the earthquake caused over 8,790 casualties and 22,300 injuries (PDNA 2015). Many of those deaths were from landslides, which also blocked vital roads and trails, a lifeline to reach out to affected villages. Landslides caused by the earthquake and its aftershocks continue to pose immediate and long-term hazards to villages and infrastructure within the affected area. Potential threats posed by landslides looms large as more landslides may be triggered in cracked areas, as well as active landslide areas. Gully formation and accelerated soil erosion may increase many fold under the influence of monsoon rain, and huge amounts of sediment will be transported to downstream areas, which may cause floods and sediment disasters in downstream areas. Cracked and damaged agricultural land and forest areas will become further degraded. Landslide damming is also a potential threat. As yet, there isn't a complete inventory of landslides or other features indicating potential slope failure.

In order to address these threats, the DSCWM, in consultation with other departments and partners, developed a plan after the earthquake. The plan identified priorities of the department in the post-earthquake situation.

Figure 3: **31 of 75 districts were affected by 2015 Nepal Earthquake**

Source: GON/MOHA as of 21 May 2015

Post-earthquake disaster challenges and gaps

The priorities of the department in the post-earthquake situation were summarized in three categories.

Immediate priorities:

- Identification and prioritization of landslides and crack zones for treatment in the near future and prevention of further landslides

- Construction of safe drainage upstream of prioritized landslide areas and around crack zones to prevent runoff water from entering the landslides/cracks so that they will not trigger another landslide
- Rehabilitation of existing water sources – many water sources have been damaged by the earthquake and landslides, and many settlements are planning to migrate for this reason
- Rehabilitation of drinking water supply and irrigation schemes
- Rehabilitation/improvement of trails and roads

Mid-term priorities:

- Detailed study of landslides including a landslide inventory and hazard, vulnerability, and risk mapping
- Treatment of landslides that pose a direct threat to life and property
- Detailed study of avalanches and glacial lakes
- Mapping of ecosystems and their services
- Reconstruction or new construction of earthquake-resilient, conservation-friendly basic water infrastructure (water source protection and development) and slope stabilization structures, emphasizing bioengineering techniques

Long-term priorities:

- Land use planning based on land capability classification
- Integrated watershed management based on land use plans, focusing on the restoration of ecosystem services, degraded land rehabilitation, natural hazard prevention (landslide treatment, gully treatment), land productivity conservation, water source protection, and development infrastructure protection
- Transformation o3f organizational and institutional setup of government organizations

He also identified gaps needing immediate attention from the scientific and research community to be able to address priorities listed above.

- Lack of a credible, complete database of landslides and cracked areas
- Lack of a harmonized methodology for landslide inventory and hazard, vulnerability, and risk mapping/assessment
- Lack of appropriate technology for slope protection
- Lack of a credible knowledge base on landslide monitoring, early warning, and rehabilitation and treatment tools and techniques
- Inadequate trained human resources on different aspects of landslide risk management

In alignment with priorities and gaps, he shared information on some of the activities DSCWM has initiated, as presented below:

- Prepared an action plan for landslide treatment and prevention in consultation with other government agencies
- Mobilized all concerned district soil conservation office (DSCO) staff for landslide data/information collection (all concerned DSCO staff are engaged in landslide treatment/prevention and providing services to the local people, as far as possible)
- Coordinated with other government organizations, development partners, academic institutions, professional organizations, and relevant I/NGOs to address the problem effectively
- Developed a preparedness and emergency action plan for landslide treatment (e.g., gabion boxes, nylon boxes, bamboo, and sacs) and arranged for these to be available in the division offices for emergency use
- Made arrangements for landslide disaster data collection
- Initiated satellite imagery analysis for preparation of landslide hazard and vulnerability maps

In addition to these, the Department has conducted a field visit to disaster sites to collect data for the preparation of a status report by comparing satellite imagery before and after quake with field data. Mid-term and long-term mitigation measures will be planned after the rainy season, as per this report.

The Department has also:

- Initiated preparation of a landslide distribution map using stereo images with ADPC/World Bank assistance
- Begun landslide hazard and vulnerability mapping of Gorkha and Sindhupalchowk districts with the help of JICA

Post-earthquake landslide inventory

Deo Raj Gurung, Remote Sensing Specialist, ICIMOD

The Gorkha Earthquake in April 2015 saw people from across the globe come together to contribute to different aspects of the earthquake responses. At the same time there were isolated cases of activities, particularly in the initial days of post-earthquake. Deo Raj Gurung said there were multiple teams doing landslide inventories (e.g., USGS-NASA led team; British Geological Society; Indian Space Research Organization; Indian Institute of Technology; Japan Aerospace Exploration Agency; and Institute of Mountain Hazards and Environment, China), but data was not available to earthquake response teams when it was needed most for coordination. Some of the team involved in the landslide inventory were academic institutions with an interest in publishing data and findings, which led to restrictions in sharing data. ICIMOD helped facilitate immediate access to landslide data in response to urgent requests from government and non-governmental agencies, he said.

In order to attend to urgent demands for a landslide database, ICIMOD mobilized a group of volunteers to visually map landslides using high resolution satellite data (WorldView-1, -2, and -3, EO-1, and GeoEye) primarily made available through the International Charter on Space and Major Disasters. One major challenge was in accessing satellite data, despite ICIMOD's relatively fast internet speed. A team from the SERVIR Coordination Office in Huntsville, Alabama, US had to intervene to clip the scene into multiple tiles without comprising the image quality before uploading it for ICIMOD to access. This partially solved the bandwidth bottleneck issue, but the team also resorted to sharing images on physical drives when someone flew to Nepal from US. He highlighted the absence of mapping guidelines as a major issue, as several volunteers lacked technical expertise on landslide mapping and remote sensing, which resulted in inconsistent datasets. The mapping was initially done offline using the ArcGIS environment, which presented a challenge while working with images not adequately georectified. Once the images were updated on Google Earth, the team made the shift from ArcGIS to the Google Earth environment.

In total the team led by ICIMOD mapped 2,651 landslides using both offline and online platforms; these have been put into the public domain through a website and were distributed in physical drives. It was realized that packaging information based on the kind of user is important, as some users required GIS file formats, while others needed maps showing figures disaggregated by district and village development committee (VDC).

Figure 4: **The Nepal Earthquake 2015 Disaster Recovery and Reconstruction Information Platform provides a single framework for assimilating and disseminating data and information from different quarters**

The following challenges were encountered in the course of mapping and dissemination:

- Lack of guidelines for mapping landslides in Nepal, which resulted in inconsistencies in inventories developed in the aftermath of the earthquake by volunteers, and in the number of reported (varying from 3,000 to 10,000).
- Lack of data sharing mechanisms, platforms, and protocols. In the absence of a standard system, work was mostly done through email communication and physical interaction. Two portals – Nepal Earthquake Portal (www.icimod.org/nepalearthquake2015) and Nepal Disaster Recovery and Reconstruction Information Platform (http://apps.geoportal.icimod.org/ndrrip/) – were later developed (Figure 4) to facilitate the consolidation and dissemination of data and information in the post-earthquake situation.
- In the absence of a feedback mechanism, cross-checks and the integration of field-based information was absent, which is important for tailoring information for specific situations.

Pre-earthquake nationwide landslide inventory of Nepal 2015: An academic exercise

Dinesh R Bhuju and **Prakash Pokharel**
Central Department of Environmental Sciences, Tribhuvan University

Referring to UN Report of 2008, Dinesh R Bhuju said that 49 districts of Nepal out of 75 are prone to landslides. The Himalayas are extremely prone to landslides because of high relief, steep gradient, active geology, and intense monsoon, he said. It is the second most serious hazard in Nepal after epidemics, as reported in the Nepal Disaster Report 2011. Having realized the importance of a comprehensive national-level landslide database, he said that the Central Department of Environmental Science of Tribhuvan University (TU-CDES) undertook a nationwide landslide inventory of Nepal in 2015 as an academic exercise using 13 graduate volunteers (Figure 5). The volunteers were provided with training before being deployed for landslide mapping and inventory development. Landslides were digitized using Google Earth and analysed using ArcGIS 9.3 and 10.1. The landslide data from this exercise is available in both soft and hard copy formats.

Established in 2011, TU-CDES is a self-sustained centre offering Masters of Science and environmental science courses, among others. The mission of TU-CDES is to produce capable human resources in the field of environmental science who can make a meaningful contributions in education, research, and development, and to undertake research on environmental problems in support of science-based decision making. TU-CDES also offers special electives related to landslides, mountain environment, climate change, sustainable development, and, most recently, disaster risk management. So far more than 1,200 case studies and more than 300 theses have come out of the institution.

Landslide patches above 1 km^2 were mapped, with each landslide polygon accompanied by additional attributes such as type, pre-existing land use/cover, topographic details, human presence, and risk. In total 72 districts were mapped (except three districts within the Kathmandu valley), generating 5,003 landslides with total area of 126.34 km^2. The districts with the highest number of landslides were Rolpa (258), Bajhang (212), and Baitadi (176). Mustang District had the highest landside area. Of the 72 districts, 14 were ranked high and another 14 were ranked very high in terms of landslide. Slope-based analysis showed that the maximum number (1,923) of landslides are distributed in mid-slope areas, but up-slope areas had the highest landslide area (36.72 km^2). In terms of aspect, hills with southern aspect are most landslide prone, with 43% of mapped landslides, while northern aspect was found to be least landslide prone. Shrub land and forest land cover types had the highest number of recorded landslides (782 and 779, respectively).

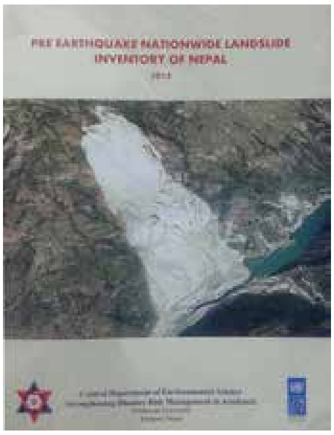


Figure 5: **National level landslide inventory published by Central Department of Environmental Science of Tribhuvan University (TU-CDES)**

The objectives of the pre-earthquake inventory were as follows:

- Document the extent of landslides in Nepal
- Investigate the distribution, type, and pattern of landslides by district
- Enhance the research capabilities of Tribhuvan University and contribute to landslide risk management

British Geological Survey landslide mapping for Nepal

Colm Jordan, British Geological Survey and Durham University

Responding to a request from the Government of Nepal after the earthquake to assess the impacts of the earthquake on housing, infrastructure, rivers, and settlements, the the British Geological Survey (BGS) undertook landslide mapping using satellite imagery. The BGS team also integrated landslide data from an internationally led mapping initiative into the inventory. The outputs of this exercise were landslide inventory maps and a landslide inventory database, which are updated continuously. Various landslide inventories were delivered to Nepal, showing more than 400 landslides on 4 May, followed by a second inventory on 8 May with more than 3,000 landslides. The maps were delivered in PDF format, while spatial data were delivered as shapefiles (GIS files) and KMZ (Google Earth). Landslides were mapped as points (initially), lines (to indicate two or more landslides) or polygons with map grid references, and included additional metadata such as the date and source of satellite images, landslide type, and confidence level. Identification of different landslide components was not possible due to the resolution of the images. Colm Jordan felt the need to standardize the method and database, although the urgency to provide data was more important in this case following the earthquake, which led to variable landslide metadata being used. He said satellites are being specially tasked to collect data on landslides throughout the monsoon. The BGS team is also using social media, including Twitter and YouTube, to troll for any mention of the word 'landslide' (Figure 6). Social media as a source of data and information during overcast conditions when remote sensing is futile is very useful. Social media is therefore an extra tool alongside satellite imagery, and is trustworthy. It is useful and easy to authenticate when reports are accompanied by geotagged photos of the event. In addition to inventory, he said that the BGS team is also implementing activities on the ground and installing in situ monitoring devices in the upper Bhote Koshi area of Nepal.

The BGS team hopes for better coordination among various actors and, more importantly, greater sharing of data. The BGS team is sharing data through online portals, which are being used by such groups as the Logistics Cluster to manage logistics. He recommended putting all information on several portals so that information can be broadly accessed by users from many different points. As a way forward, he proposed standardizing landslide data from different sources, as these data need to come together. We need to look at how the earthquake and the monsoon interact together to affect landslides.

Figure 6: **Example of mapping of social media troll on landslide**

Rapid environmental assessment with focus on landslide and green recovery and reconstruction

Judy Oglethorpe, WWF Nepal

Under the directive of the Ministry of Science, Technology and Environment (MOSTE), a team of local and international experts led by former National Planning Commission (NPC) vice chairman undertook a rapid environmental assessment (REA) after the earthquake with funding support from the Hariyo Ban Program and WWF Nepal. The goal of the REA was to enhance the resilience of earthquake recovery and reconstruction efforts in Nepal by identifying and integrating sound environmental practices. The REA looked at landslide impacts, including damage to settlements, loss of agricultural land, damage to drinking water supplies and irrigation systems, damage to roads, bridges and trails, and damage to hydropower.

Presenting the findings of REA, Judy Oglethorpe reported estimated loss of 2.2% of forest in six districts to co-seismic landslides. Assuming the rate was consistent across severely affected districts, FAO estimated forest cover loss to the order of 23,375 ha (in PDNA). Loss of ecosystem services is valuated at NPR 34,700 million as per the PDNA document. Large areas of Langtang larch (Larix himalaica), which is only found in Langtang, were lost due to earthquake-induced avalanches and landslides in the Langtang valley. The recovery of landslide areas will take time, she opined, especially at high altitudes. While recovery takes place, there is a risk of invasive species in landslide sites, which is already a problem in Nepal, with the risk of more invasive species coming in.

The impacts of landslide on wildlife and natural resources are also significant, she said. Direct loss of animal species like wild boar, Himalayan tahr, snow leopard, barking deer, and musk deer in landslides and avalanches and other geological changes are not uncommon. Loss of habitat and change in water sources also contribute to loss of species. Landslides also indirectly contribute to species loss by blocking access to some areas. The earthquake happened during the breeding season, which is likely to impact breeding habits although the impacts are not immediately known. The loss of high value natural resources has repercussions on livelihoods. Similarly, the disruption of many trekking trails will have adverse impacts on the tourism industry. With access to markets restricted, people began exploiting natural resources in many areas, for example for fuelwood and construction materials.

Figure 7: **Interaction with participants in the Community Learning and Action Center (CLAC), Birendra Community Forest User Group, Baliya, Kailali District.**

The impact of landslides in rivers basins and watersheds manifests as river blockages and increased sediment in rivers, both adding to increased risk of flooding and changes in the river course. She said climate change will exacerbate the risk of further landslides and increased erosion due to more extreme weather events. This will further aggravate downstream sedimentation and flooding. Another way climate change and the recent earthquake may impact people is through changes in water sources. Climate change may have weakened people's ability to withstand the shock of the earthquake. She emphasized that environmental concerns need to be given due consideration to build back better and safer, and more importantly to enhance sustainability. This statement is more relevant to Nepal where highly vulnerable people depend on natural resources for daily needs like food, fodder, and timber. She stressed the importance of sound land use planning at multiple levels, in which development, ecosystem services, and disaster risk reduction are integrated with zoning. Landslide and other hazards need to be integrated, and risks reduced where possible through suitable land use, using ecosystem services associated with forests and flood plains. She highlighted the gaps between policy and implementation, which warrant proper implementation of land use policy. She noted that the discussion during the workshop needs to be integrated and translated into spatial land use planning.

Referring to the urgent need to relocate settlements from high risk areas to safe areas in the aftermath of the earthquake, she recommended selecting sites with enough natural resources and land for agriculture. It is important to avoid areas with high biodiversity value and where there is a risk of human-wildlife conflict. She recommended resettlement in areas that are already connected to infrastructure as Nepal begins to work on long term rehabilitation and reconstruction.

The following recommendations were made to improve landslide risk management:

- Categorize landslides by treatment need types (high cost/low cost) or those that will be stabilized with natural regeneration
- Prioritize landslides by potential risk to settlements, farms, and infrastructure and importance to biodiversity sites
- Undertake detailed site investigation in high priority landslides
- Initiate water management activities before implementing stabilization measures
- Engage communities in landslide management process
- Apply bioengineering techniques as far as possible, particularly for shallow landslides (up to 12 inches deep) using quick-establishing native plant species appropriate to the site

Other recommendations from the REA include:

- Promote the use of safe and green building materials and, as much as possible, promote the reuse of disaster debris (for example, don't dig sand and gravel out of unsafe sites as it will trigger more landslides)
- Ensure strategic road planning and reconstruction through proper investigation and systematic development
- Promote alternative energy and energy efficient methods to take pressure off forests for fuelwood extraction so that forests will be better able to protect against landslides
- Improve water and sanitation and promote integrated watershed management, including ensuring water is available to support biodiversity
- Support alternative livelihoods and environmentally responsible agriculture to reduce landslide risk
- Promote reforestation and sustainably sourced timber for reconstruction
- Promote equity in the recovery and reconstruction process with particular attention to the needs of women and vulnerable or marginalized groups, who are more likely to live in landslide-prone areas
- Incorporate climate change into recovery and reconstruction
- Support policy implementation and enforcement mechanisms
- Build capacity for green recovery and reconstruction and support risk awareness raising activities

A common approach to landslide inventory: Harmonization of landslide inventory mapping for Nepal

CJ van Westen, University of Twente

Landslide is a topic that is relevant to many sectors: roads/rural roads; forests and agriculture; soil, water management, ecosystem services; hydropower; buildings; and tourism. In one of the tributaries of the Bhote Koshi, CJ van Westen counted four hydropower projects damaged by the earthquake. There was a lot of damage to settlements close to the border with Tibet. Earthquake-triggered landslides caused a lot of damage to roads and to agriculture in the affected districts. He cautioned that landslides can be a major concern even when the monsoon is mild; even one high single rainfall event could result in landslides and large debris flows.

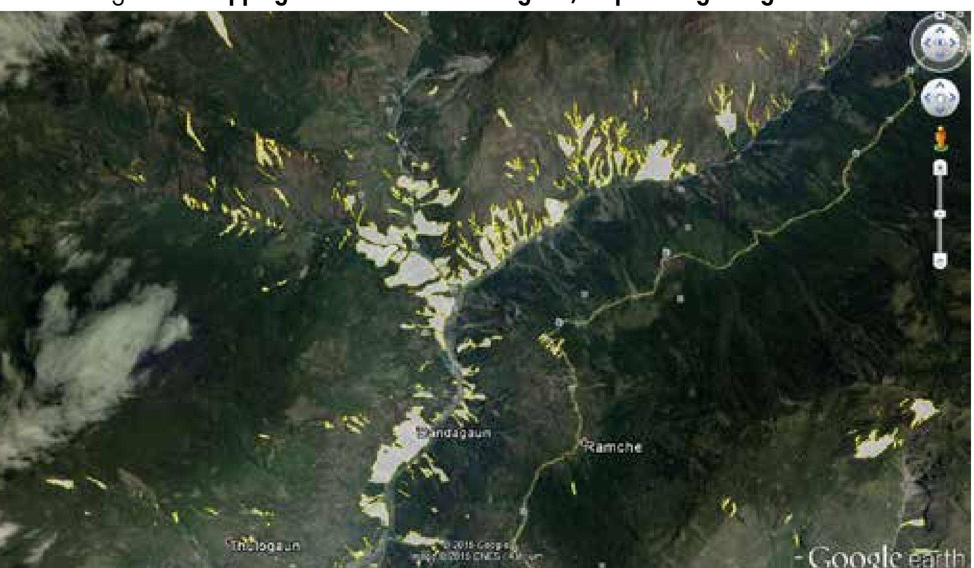
Landslide inventories need to be dynamic, or at least regularly updated, and should not be a one-time exercise. He highlighted the importance of a complete database of historical landslide events in order to do cause and impact analysis, and to be able to foresee and predict areas that might become hazardous using landslide susceptibility and risk maps. Showing the progression of the Jure landslide using historical satellite images, he said monitoring of landslides could provide vital signs, which to an experts' eyes could act as an early warning. Despite clear signs of progression in the Jure landslide observed on satellite images, in August 2014 the whole hill slope failed, killing many people, destroying houses and infrastructure, and blocking the Bhote Koshi River.

Within Nepal there are many organizations associated with landslide studies, although each has a different focus, he said. The ministries involved in landslide studies are listed below.

- Ministry of Forests and Soil Conservation, Department of Soil Conservation and, Watershed Management and Department of Forest
- Ministry of Industry, Department of Mines and Geology
- Ministry of Energy, Department of Electricity Development
- Ministry of Physical Infrastructure and Transport, Department of Roads
- Ministry of Science, Technology and Environment, Department of Hydrology and Meteorology
- Ministry of Urban Development, Department of Urban Development and Building Construction
- Ministry of Federal Affairs and Local Development, Department of Local Infrastructure Development and Agricultural Roads
- Ministry of Agriculture and Cooperatives, Department of Agriculture
- Ministry of irrigation, Department of Water Induced Disaster Prevention
- Ministry of Culture, Tourism and Civil Aviation, Department of Tourism

The list is be longer if other players like ICIMOD, NSET, academia, international research groups, and international organizations are also added. Some of these are data providers, some technical experts in spatial data handling, some generate landslide inventories and hazard maps, and some are users of information. It is important to know what these organizations use the data for and what their requirements are. This, he said, requires a lot of coordination and collaboration, as well as the harmonization of activities through mutually agreed upon standards and methods for mapping and assessment. With no harmonized method, outputs from different teams will not be comparable and the larger picture will still be missing. As a starting point he suggested to include a

Figure 8: **Mapping of landslide in Dandagaun, Nepal using Google Earth**



few important parameters like location (point at minimum, polygon as best), date (or relative age), landslide type, dimensions (depth, area, and volume), impact (damage), cause/trigger, and future hazard/risk.

Elaborating on methods for developing a landslide inventory, he spoke of different approaches such as remote sensing based, field based, archived studies, dating method, and monitoring networks. He stressed that the approach one takes is determined by the scale of the exercise, as regional, national, and local scales require different granularity of details which are determined by the purpose. In practice, a desk based inventory is accomplished using digital tools such as image interpretation using satellite data (most commonly Google Earth). Google Earth has a history slicer and terrain information, which enhances ones interpretation of landslide features. Google Earth as a base map is also useful for field based inventorying, and additional tools like GPS are handy for providing geo-locations of the landslides. Figure 8 illustrates the use of Google Earth for mapping landslide in Dandagaun in Nepal.

Developing a national landslide inventory would require revisiting technical, organizational, and data collection aspects, he said. The technical part of the process would include getting the platform ready, finalizing the standard templates for data collection, and establishing data collection tools and procedures. As a starting point, agreement must be met on the landslide attributes to be included and mapped and a minimum set of attributes must be developed, as additional attributes require more work. Organizational aspects include having ground rules laid out to facilitate collaboration among different agencies, as developing a national inventory will be an interagency initiative. Data collection aspects include having guidelines in place for data extraction from different sources: remote sensing based, field based by experts, public reporting, and media reports. He highlighted the importance of having a Nepali version of a crowd sourcing application if it is adopted. Sharing experience from Vietnam, he said it is important to have dedicated staff to work on the landslide inventory instead of treating it as an ad-hoc exercise. Developing a landslide inventory is a highly technical task that requires a pool of skilled human resources with specific technical qualifications, including IT experts, GIS experts, landslide experts, RS experts, social scientists, and local experts. Lot sof human resources must be deployed in districts and VDCs for the collection and mapping of landslide data. Inventory development is a huge exercise, thus it has to be embedded within an organization and institutionally anchored. He highlighted existing landslide inventory and hazard mapping systems from Italy (www.sinanet.apat.it/progettoiffi [Miet Van Den Eeckhaut and Javier Hervás 2012]), and the Caucuses (http://drm.cenn.org), which also includes a public reporting mechanism.

Experience shows that active engagement of local people is key in mapping landslides. Engaging teachers after training them is another approach, as they will have access to information through their students coming to school from different villages. The public reporting system could be embedded in the environmental curriculum of schools so that it is institutionalized. Alternatively, or additionally, other government machinery like the police or army could be used as they are often the first to be deployed during emergencies. The involvement of local people ensures ownership and increases the relevance of information. Authorized reporting is alternative, in which a designated organization in a district maps the landslides, with relevant attributes being fed in by others. The media is good source of information and with little additional responsibility they can be a good source of data. If accompanied by geo-tagged photos and videos, media reports on local events could serve as excellent sources of information. The link for geo-located news items on landslides with photographs in the national database could become an important source of historical information for the media as well.

The following action points were recommended to take the landslide inventory forward.

1. Develop harmonized methodology for conducting landslide inventories in Nepal. This method should build upon the excellent work that has been done in mapping co-seismic landslides and be integrated with information on pre-earthquake landslides
2. Develop a platform for continuous updating of a landslide inventory, which should be web-based and open sourced. The system should be integrated with a public reporting system (using schools, media, police, etc.)
3. Establish a working group (inter-departmental or agency) to generate guidelines for landslide inventory mapping in Nepal that would work out these aspects
4. Train relevant people to build up a skilled human resources pool
5. Work on landslide hazard mapping at a local scale focusing on affected areas to aid in resettlement

Technical Session II: **Landslide Hazard, Vulnerability, and Risk Assessment and Mapping Methodologies**

Session objective: *To share the methodologies and results of landslide hazard, vulnerability, and risk assessment and mapping by institutions in Nepal*

Session chair: Pem Naryan Kandel, DWIDP

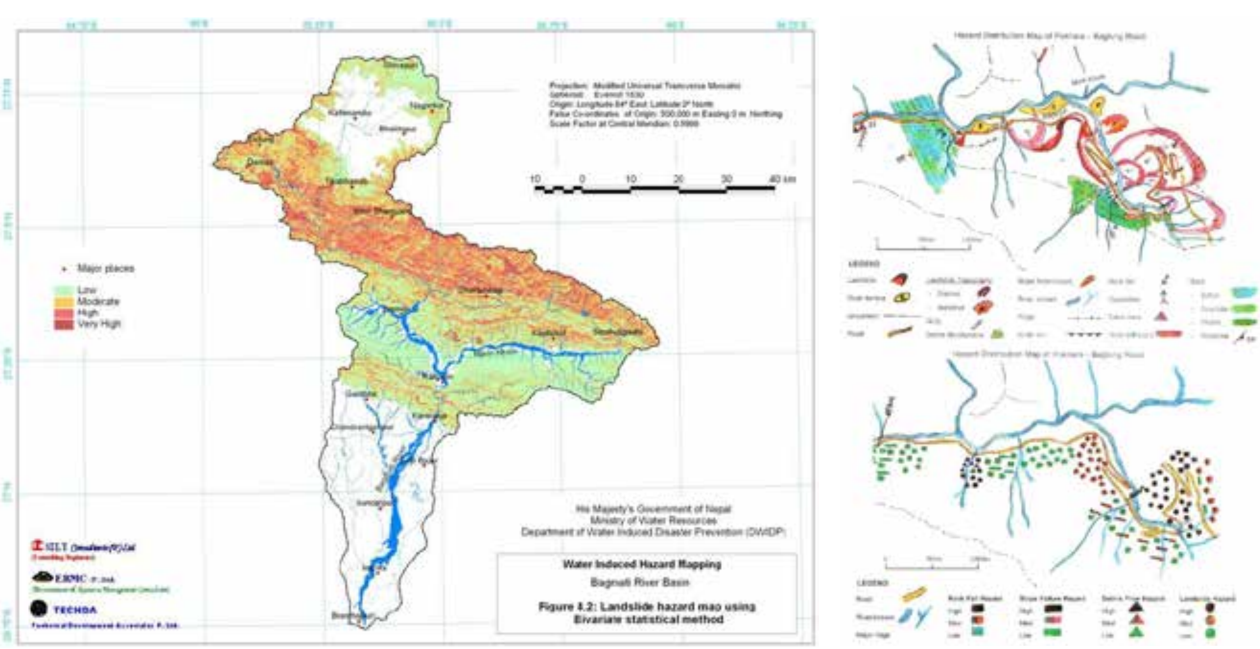
Facilitator: Paolo Frattini, University of Milano Bicocca

Need for landslide hazard, vulnerability and risk assessment and mapping in Nepal

Jagannath Joshi, DSCWM

DSCWM has been working on landslide hazard, vulnerability, and risk assessment and mapping as the mandated national agency for the past few decades. The average number of small and large landslides in Nepal is as high as 12,000 per year (Bhattarai et al. 2002). Landslides can be broadly categorized into two types: human induced and natural. Natural factors include geomorphological processes, geo-physical processes, and ground conditions. Man-made factors include road construction, deforestation, and other activities. Landslide events can be catastrophic, and records show over 300 people are killed by landslides and floods each year in Nepal. The direct economic losses are estimated at NPR 700 million per year, and indirect economic losses would be much higher. One examples of a devastating landslide events is a disastrous debris flow in July 1993 in Phedi Gaon, Kulekhani that took the lives of 56 people. This event was preceded by 535 mm of rainfall in 24 hours. The Matatirtha landslide in July 2002 killed 16 people, and the area recorded 300 mm rainfall in 24 hours. A recent landslide in Taplejung in June 2015 killed 53 people and injured 12. The impacts of such landslides are not confined to the location of origin; they extend further downstream in the form of debris flow. Landslides damage houses, agricultural land, water sources and supply system, forests and biodiversity, roads, irrigation channels, and other physical infrastructure. Sedimentation in areas downstream of landslides can have devastating consequences due to riverbed rise, which in turn contributes to flooding. Secondary hazards also include the formation of landslide dammed lakes which could result in an outburst flood.

Figure 9: **Hazard maps prepared using different methods and scales to serve different purposes**



The government needs to work on landslide prevention through mitigation and control measures and to develop landslide hazard and risk maps to support policy making and sustainable land use planning. Proper planning will safeguard countless lives and physical infrastructure. With long-term rehabilitation currently a high priority on the national agenda, a land use planning tool can help the country build back better. At the local level, such products will help communities identify safe and suitable sites and avoid hazard-prone areas.

However, the lack of a credible and complete landslide database; lack of harmonized methodology for landslide hazard, vulnerability and risk mapping; and lack of trained human resources on landslide risk management are critical gaps. Although landslides cannot be predicted, identifying landslide-prone areas will help in securing lives and development activities through informed decision making, he said.

Earthquake-induced landslide distribution and hazard mapping

Megh R Dhital, Mountain Risk Engineering, Central Department of Geology (CDG), TU

Megh R Dhital presented case studies of post-earthquake landslides from Gorkha District, in which he talked about the relationship between the influences of earthquake-induced ground acceleration and landslide, which was analysed using the Newmark displacement equation. Based on the rock slide distribution map and rainfall frequency map (exceeding 100 mm in 24 hours for 30 years) he confirmed the bearing of rainfall on landslide event. Many landslides/rockslides were found distributed along the ridge or crest, indicating a strong edge effect on co-seismic landslides. Many landslides were formed along the road, indicating that road corridors are prone to landslides. These landslides are found to disrupt vehicular traffic, resulting loss of trade and business. Landslides triggered by the earthquake near the confluence of Mailung Khola and the Trishuli River killed many hydropower workers, illustrating the risk landslides pose to human lives. Most of the landslides and rockslides found in the area were shallow triggered by the earthquake or rain. In many cases, discontinuities in the rock resulted in plane failure or wedge failure. Such landslides and rockslides result in maximum destruction at the lower end of the fall due to momentum. Many old landslides near the Tama Koshi Hydropower and Gongar confluence reactivated by the earthquake. However an old landslide near the Upper Tama Koshi Road was interestingly not reactivated, while many new slides occurred in its vicinity. Along the Arniko Highway there were many cases of failure along the dip-normal-slope.

The case studies did not have good agreement between landslide distribution and the Newmark displacement vector (Figure 10). This suggests there are some other controlling factors that trigger landslides, and opines that hazard mapping using existing information alone is not enough due to the complexities of the process and the interrelationship between landslides and the effects of the earthquake. The internal relief map showed that slopes with higher (more than 50 m) internal relief suffered the most, thus use of internal relief maps in hazard assessments may help.

He concluded by outlining salient features of landslides from his research:

- Mainly resistant metamorphic rocks prevail in the area affected by the Gorkha earthquake
- Peak ground acceleration and landslides do not correlate well
- Mainly shallow rockslides were triggered by the quake, whereas old and deep slides were insensitive to the earthquake
- Newmark displacement and seismically induced failures are not in good agreement. Hence, some other factors, such as slope height, amplification of vibration at the crest, and resonance of shear waves contributed to the landslides seen after the earthquake

Figure 10: **Newmark displacement map of the Bhote Koshi area, Sindhupalchok District with landslide polygons overlaid**

Multi-variate statistical approach to landslide susceptibility mapping

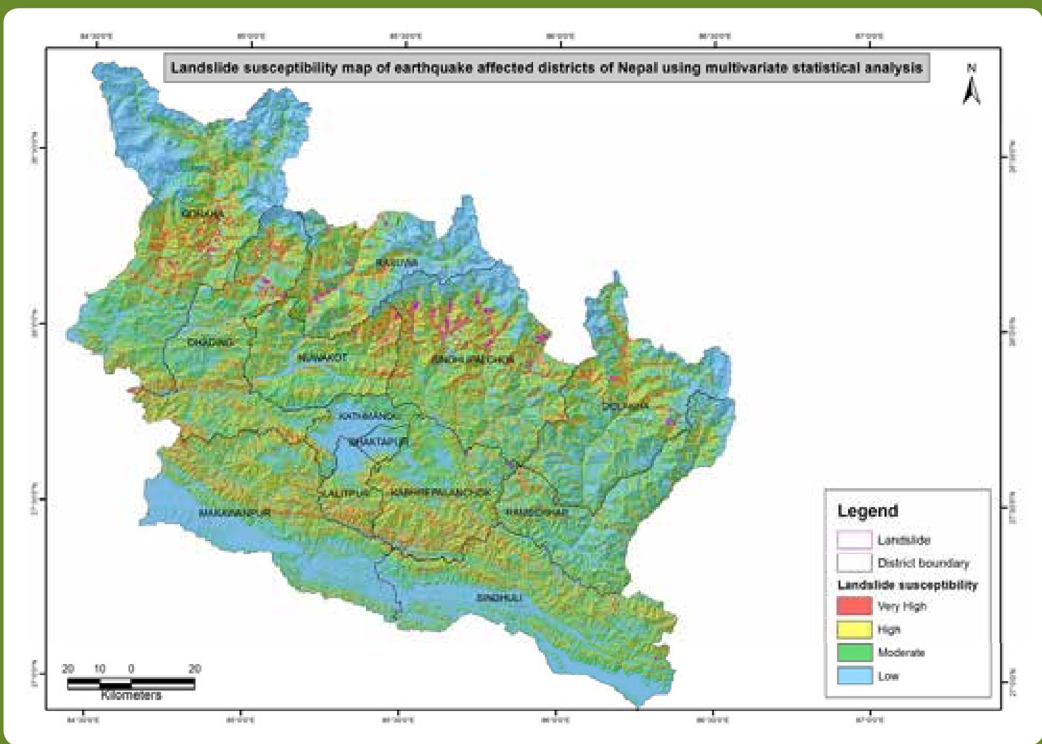
Sudan Bikash Maharjan, ICIMOD

As the post-earthquake response was transitioning from rescue and relief to rehabilitation and reconstruction, demand for landslide hazard maps increased. ICIMOD quickly prepared landslide hazard maps using available datasets to support rehabilitation and reconstruction interventions. The landslide inventory developed by ICIMOD-led international volunteer group was used, which included 1,716 landslide polygons based on pre- and post-earthquake satellite images from different sources (DigitalGlobe, Indian Remote Sensing, Sentinel Asia, and Gaofen). The largest distribution of landslides was found in Sindhupalchowk (523 landslides). The smallest and largest landslide mapped was 30 m^2 and 766,800 m^2, respectively. Most landslides were on slopes greater than 40°. Since topographic representation in hazard mapping is critical, topographic parameters (slope, aspect, relief) were derived from digital elevation models (DEM) generated from 20 m contour intervals. Additionally, other input layers like distance from drainage network, distance from the road network, geology (provided by Megh Raj Dhital), lineaments (faults and discontinuities traced from a geological map provided by the Department of Mines and Geology, peak ground acceleration (PGA), and land cover were used as predictor variables.

The multi-variate logistic regression statistical method using R-package was used, which is a type of generalized linear model (GLM) that relates the probability of landslide occurrences to predictors (causative factors – slope, land cover, aspect, relief, geology, etc.). The result showed that all the variables were significant except for aspect (Figure 11). Landslide probability maps were prepared using ArcGIS 10.3. The probability values ranged from 0 to 1, indicating low to high probability. This in turn was translated into landslide susceptibility maps using quartile scheme (0.25 as low, 0.25 -0.5 high and 0.5–0.75 very high).

Validation of the product was done in two ways: testing landslide datasets and the receiver operating characteristics (ROC) curve. Eighty-seven per cent of the landslides fell within the high and very high susceptibility zones, while areas under curve (AUC) in case of ROC is 0.79, both of which points to the fact that the susceptibility map is acceptable.

Figure 11: **Landslide susceptibility map of 13 of the 14 affected districts**



Community-based landslide vulnerability and risk assessment: Method and tools

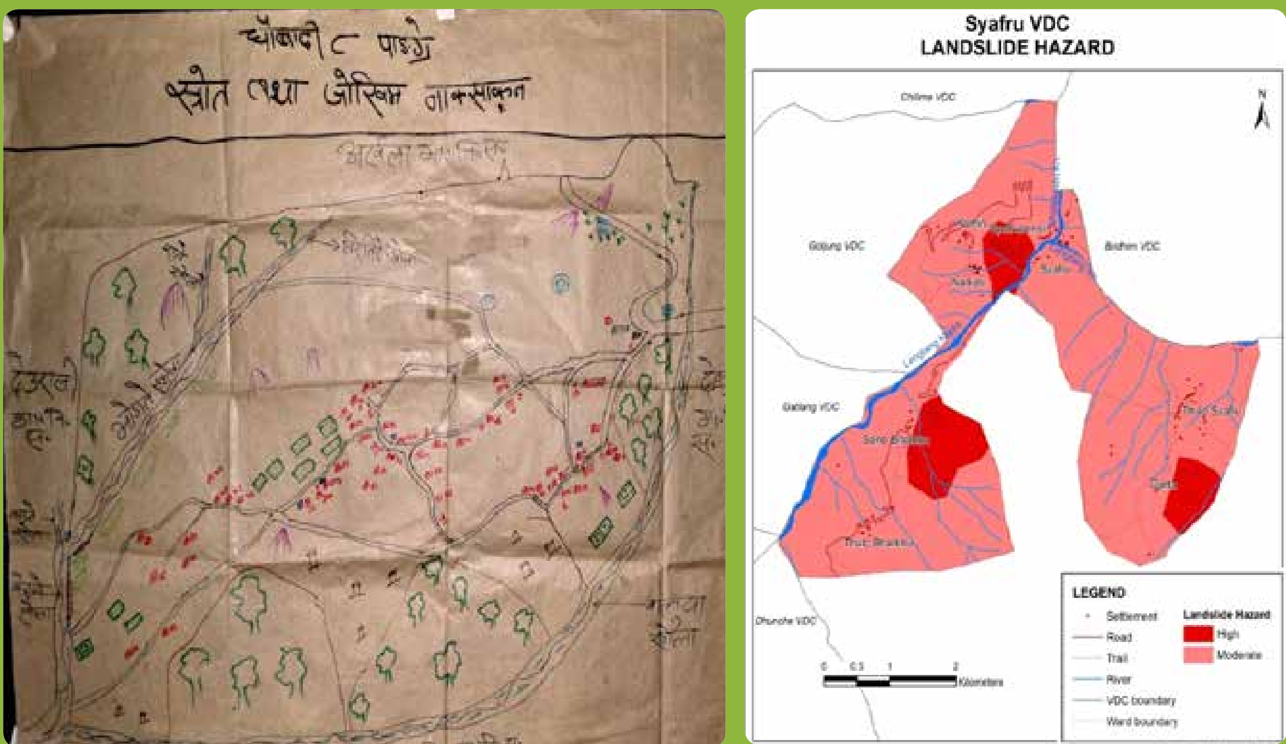
Narendra Raj Khanal, ICIMOD

Bottom-up, community-based approaches are good tools for ensuring community engagement in the exercise. He said communities are primary victims and the first to respond to emergencies when a disaster strikes. The community-based risk assessment approach puts communities at the centre, providing local people with opportunities to participate in identifying and evaluating risk, as well as in formulating and implementing measures to reduce risk. The engagement of local communities and their ownership of the process increases the chances of successful adoption and implementation. This approach eventually empowers communities to better cope with the adverse effects of disaster.

There are tools to assess vulnerability of the exposed communities through the assessment of communities' sensitivity and adaptive capacity. The term exposure in risk assessment constitutes people, property, infrastructure, livelihood support systems, and environmental resources. Communities' capacity to handle hazard and adapt to disaster events is measured by each person's access to assets/wealth, information, technology, skills, service infrastructure, and institutions. Sensitivity to risk is a function of access to food, health, education, transportation and communication, and infrastructure services such as markets. He explained the following risk assessment approaches:

- Hazard approach – hazard of a place and exposure
- Political economy approach – assesses resources and decision-making processes
- Resilience approach – looks at the propensity of social and ecological systems to suffer harm from external stresses and shocks
- Livelihood approach – looks at access to physical, natural, social, and financial capital or assets
- Integrated approach – combined hazard of place, with the social profile of communities
- He outlined the four steps used by social scientists in the participatory rural appraisal (PRA) process:
- Gathering of scattered stakeholders and groups

Figure 12: **Examples of hazard map prepared using a participatory approach**



Source: MoEST 2012

- Collecting of information and data
- Cross-checking and triangulation of information
- Identification of the main problem and preparation of action plans

Since the PRA approach relies on information from communities, the action plan to address the problem is formulated with due consideration of the local situation. He outlined some of the PRA analysis approaches used in disaster risk management:

- Social/ resources/ physical/ hazard/ institutional mapping
- Prioritization of problems/ interests/ needs
- Wellbeing ranking
- Seasonal calendar
- Trend line/ timeline
- Problem tree analysis
- Cause and effects analysis
- Key informant interviews
- Structured or semi-structured questionnaire survey
- Transect walk
- Group discussion

Using modern tools such as Google Earth and Google Maps to imprint communities' perceptions in conjunction with conventional social science techniques will result in better hazard maps.

He outlined the following steps for participatory risk mapping:

- Collection and production of the base map and preparation of other logistics
- Consultation with stakeholders
- Familiarization with the area and rapport building
- Familiarization with the base map
- Preparing the legend for mapping
- Putting community information on the map
- Putting hazard information on the map
- Planning for disaster risk reduction
- Integrating data into a geographic information system (GIS)

Landslide dynamics in Siwalik: Mechanics and management policy

Prem Paudel, Chure-Terai Madhesh Conservation Development Board

The Siwalik hills is a contiguous landscape that runs from east to west across Nepal. Half of Nepal's population is concentrated across this landscape. It is characterized by sparse vegetation and steep slopes, and is linked to both upstream and downstream areas. Geologically, the Siwalik has been divided into three sections:

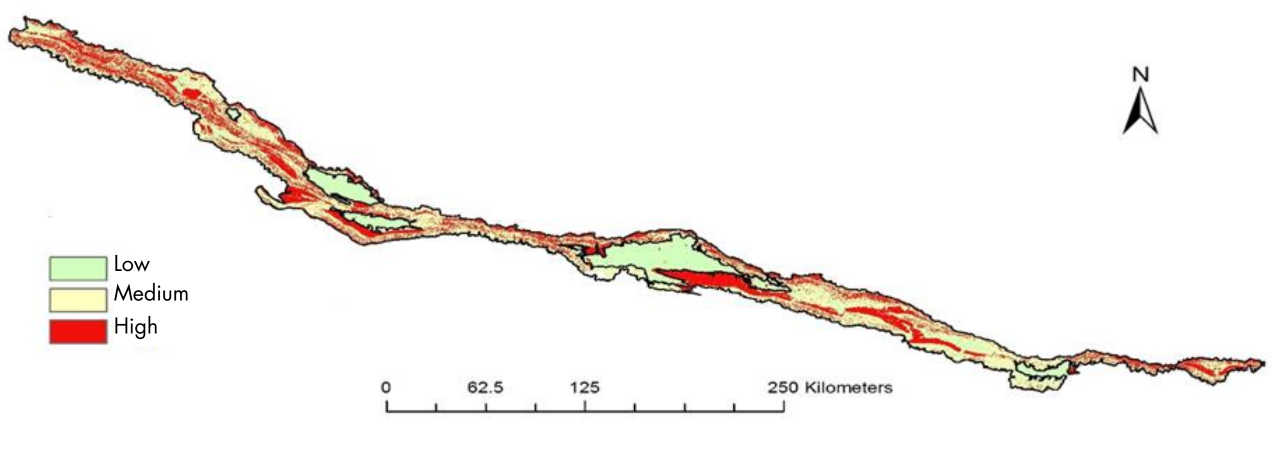
- *Lower Siwalik:* Irregularly laminated beds of fine grained greenish sandstone and siltstone with mudstone (Amlekhgunj, Arunghhola, Barahchhetra, and Rato Khola area)
- *Middle Siwalik:* Medium to coarse grained salt-and-pepper sandstones interbedded with mudstone (Surkhet, Surai Khola, Hetauda, and Butwal)
- *Upper Siwalik:* Conglomerate and boulder beds and subordinately sand and silt beds (Bardibas, Hetauda, Bhalubang, and Chitwan)

Landslides are common in the Siwalik hills and are of different geometry: plane failure, wedge failure, circular failure, and toppling failure. Even the forested landscape is not devoid of landslides, says Prem Paudel, even when forest quality is very good. Factors such as weak geology, steep topography (13% of the area is above 19° slope), high drainage density, deforestation, and high rainfall are some of the factors causing landslides in the Siwalik hills. The high proportion of barren land also contributes to the formation of landslides. The role of vegetation/forest is critical in areas where the mean annual precipitation ranges from 2,500–3,500 mm and the PGA value is 300 cm per second.

He showed some work on landslide susceptibility zonation done under the Chure Area Programme, using the statistical approach (bi-variate and multi-variate) and deterministic model (Figure 13). He stressed having good understanding of the relationship between causal factors and landslide failure so that appropriate weightage can be accorded to individual layers while generating landslide hazard maps. The results of the research are still preliminary and need more product testing, thus there is a need for further research. The identification of site-specific accurate hazard zonation methodology is still challenging. The need for science-based recommendations is required, and perhaps this workshop is the forum to determine the appropriate methodology.

Calling for more collaboration among relevant agencies, he said that individual institutions must work together with academia, the government, and other institutions. Since a landslide inventory is prerequisite for good landslide hazard analysis, he said an attempt to develop a landslide inventory for ten districts must be made. He sought collaboration from research groups to work on landslide mapping and hazard assessment. There are so many unanswered questions on sedimentation processes. As a means to protect the Siwalik slopes from failure and further degradation, the government is trying to limit harvesting of timber by restricting logging.

Figure 13: **Landslide susceptibility map of the Chure hills based on statistical approach**



Harmonization of landslide hazard, vulnerability and risk assessment and mapping methodologies in Nepal

CJ van Westen, University of Twente

Landslide is a natural process and our understanding of the process is very limited, as we do not have good knowledge about sub-surface conditions everywhere (soil depth, discontinuities in the rock, water table, soil type, etc.). It can happen anywhere and everywhere, and where ground conditions are conducive, uncertainties are high. What we are certain about is where they have happened in the past. Therefore, the more extensive the landslide inventory is, the better predictive models will be able to predict where landslides might happen.

Cj van Westen differentiated three terms often used interchangably: susceptibility map, hazard map, and risk map:

Landslide susceptibility is the relative spatial likelihood of the occurrence of a landslide of a particular type and volume.

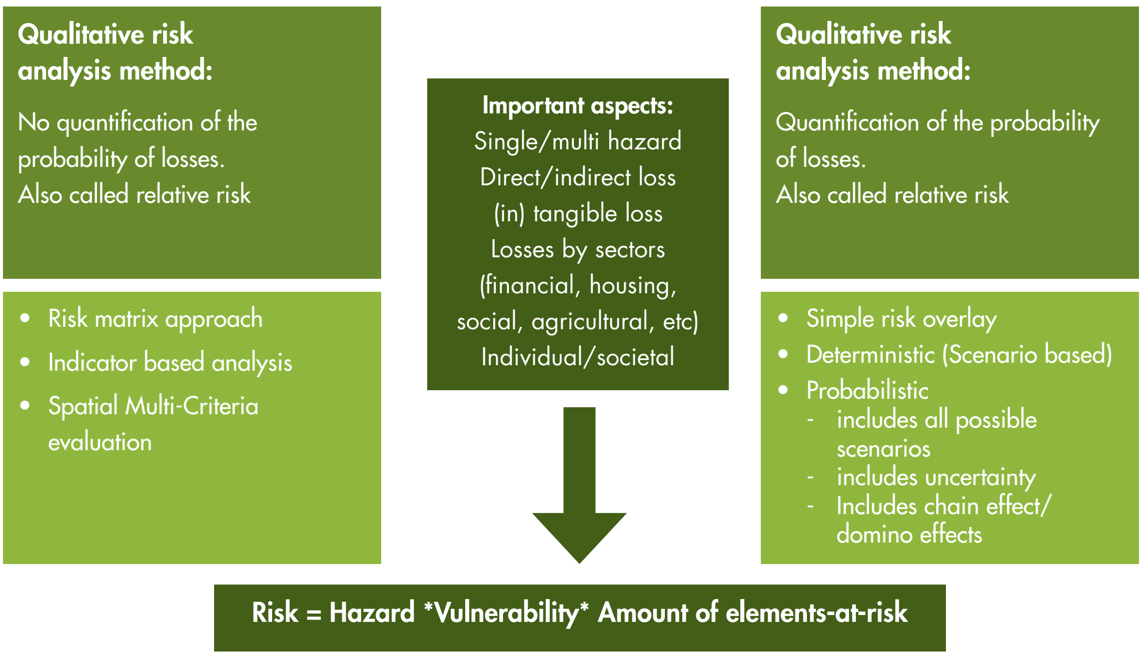
Landslide hazard is the probability of occurrence of a particular landslide type (initiation and run-out, volume, and speed) within a specified period of time and in a given area.

Landslide risk is the expected losses (monetary or in number of buildings/people) due to specific landslide type (initiation and run-out, volume, speed) within a specified period of time and in a given area

It is a complex process, as primary hazards will often result in secondary hazards as in the case of the landslide dam outburst floods resulting from a landslide event. Hazard assessments consider three things: spatial probability, temporal probability, and intensity probability (the chance of a certain height of debris flows). Landslides are not treated in isolation, and treatment must be looked at from a broader perspective. One has to look at causal factors (earthquakes, rainfall) before looking at mass movements. There can be a whole series of events that make hazard assessment difficult. The process can be simplified using models, but models are data intensive, making them impractical over larger areas. The frequency/return period of the hazard event is an important parameter to consider since hazard events with higher frequency will generate higher risk as compared to ones with lower frequency.

There are different methods for susceptibility mapping: based on historical events, direct mapping, expert assessment, statistical analysis, empirical models, numerical models, spatial models (i.e., mathematical models with spatial components), or dynamic spatial models (i.e., mathematical models with spatial and temporal

Figure 14: **Difference between qualitative and quantitative risk analysis methods.**



components)). Process and context has to be understood well, as damage to buildings/infrastructure is sometime the result of debris flows and not the actual landslide. In this regard, debris flow needs to be part of the data layer and included in analysis. In any case, appropriate data need to be ingested for different scales/levels of analysis, without which information derived will not represent the reality and will not serve the purpose. Thus, deciding on an appropriate model is as important as the analysis and output. Methods generally fall under three categories:

- Qualitative methods
- Quantitative methods
- Knowledge driven methods (data drive models, dynamic physically-based models)

The dynamic, physically based models give the most refined output, but are also the most data intensive, which may not suit Nepal.

Quantifying the expected losses is landslide risk, for which knowledge about exposure is imperative. Information about exposure includes the number of elements exposed to a potential landslide, and expected degree of damage (vulnerability) if the event happens. Elements at risk include people, roads, agriculture, and other infrastructure. The focus and objective of the exercise will determine which type of element to be mapped. The need to understand the context and purpose is of paramount importance to make it relevant to decision makers and other users. Risk products can be used for spatial planning, insurance, and emergency planning, but the level of detail required varies for different purposes. In the current situation, a qualitative risk assessment is the best you could get. Use of updated data layers is equally important as environmental parameters are dynamic. Using land cover products from the 1950s do not represent the current situation. Since rainfall is an important triggering mechanism and dynamic, it has to be represented with the latest datasets. Triggering factors and mechanisms need to be properly evaluated in order to understand magnitude and frequency, and they also need to be adequately represented during analysis. In the current context, risk assessment using a qualitative method with the risk matrix approach, indicator-based analysis, and spatial multi-criteria evaluation is possible in Nepal.

The scale at which mapping and assessment is done is an important consideration and is dependent on purpose, objective, and the data available. He said that most of the case studies and examples presented in this forum were done at coarse resolution, and thus the information is not very useful for local-level decision making where concerns are of an operational kind.

He highlighted key points to guide landslide hazard and risk mapping in Nepal:

- Landslide hazard and risk assessment needs to be done before rehabilitation is done, at whatever scale possible
- The hazard and risk mapping exercise should be done at the VDC level at a scale of 1: 10,000 to 1: 25,000 so that it is useful for reconstruction planning.
- In order to optimize time and resources, initial efforts should be limited to areas with people at risk
- Make it simple and understandable
- The map prepared should be harmonized using a standard template/format
- The method should be based as much as possible on events that have already happened without too much guess work
- Assessment is to be done with the integration of as much field data as possible
- As a way forward he proposed following action points:
- An inventory based method using all available landslide inventories plus additional information through local knowledge at the VDC level

Figure 15: **Hazard classification matrix**

		Magnitude: Percentage of the mapping unit that may be affected by landslides		
Frequency:		Large (e.g. > 25%)	Moderate (2–25%)	Small (<2%)
How often will the unit be affected by landslides	Very high (annually)	1: Very High	2: Very High	3: High
	High (1–10 years)	4: Very High	5: High	6: Moderate
	Moderate (10–50 years)	7: High	8: Moderate	9: Low
	Low (< 50 years)	10: Moderate	11: Low	12: Low
	No landslides expected	13: Very Low		

- Use the direct mapping method
- Outline mapping of units from DEM, satellite images, and land use maps should be done prior to field work
- Characterize the mapping units based on a checklist with a series of questions to prioritize for further intervention
- Develop a matrix based hazard classification (Figure 15).

He mentioned the importance of prioritizing landslides for intervention, and suggested developing a checklist or decision tree to guide that exercise. For this he provided some guiding questions:

- Was the area affected by landslide before?
    - When?
    - Where?
    - What type?
    - How large?
    - How was it affected?
    - Are there co-seismic landslides?
    - Can they be reactivated?
    - Are there signs of instability?
- If the area was not affected by landslide...
    - Is the slope steeper than 20 degrees?
    - Is the areas close to steep slopes above?
    - Is the area close to steep slopes below?
    - Is it close to a new road cut?
    - Is it close to natural drainage?
    - Is the land form possibly related to landslide
    - Have there been recent land use changes? Are these potentially harmful in the context of landslides?
    - Is the rock type landslide prone?
    - Is the soil type landslide prone?

Tools that can be used to gather this information are:

- Image interpretation
- Field work
- Close interaction with local people
- Generation of multi-temporal inventory

These products need to be widely distributed in order for them to be put to use. A dynamic online platform with query, download, and print functions is one option. Queries based on districts or VDCs with community profiles will be useful additions to the system.

To conclude, the following recommendations were made:

- Establish a working group to establish guidelines
- Learn from other Asian countries that face similar problems of data limitations
- Organize a workshop with international experts to discuss methodology
- Test guidelines in selected areas
- Plan training
- Use a national landslide platform to
    - Support public reporting of landslides (perhaps later also other hazards)
    - Share landslide inventories
    - Share susceptibility and hazard maps
    - Share publications on landslide in Nepal
    - Keep track of landslide work being done in Nepal

Technical Session III: **Development of a Common Platform**

Session objective: *To discuss and agree on a common methodology and platform for data collection and sharing on landslides in Nepal*

Session chair: MSR Murthy, ICIMOD

Facilitator: Deo Raj Gurung, ICIMOD

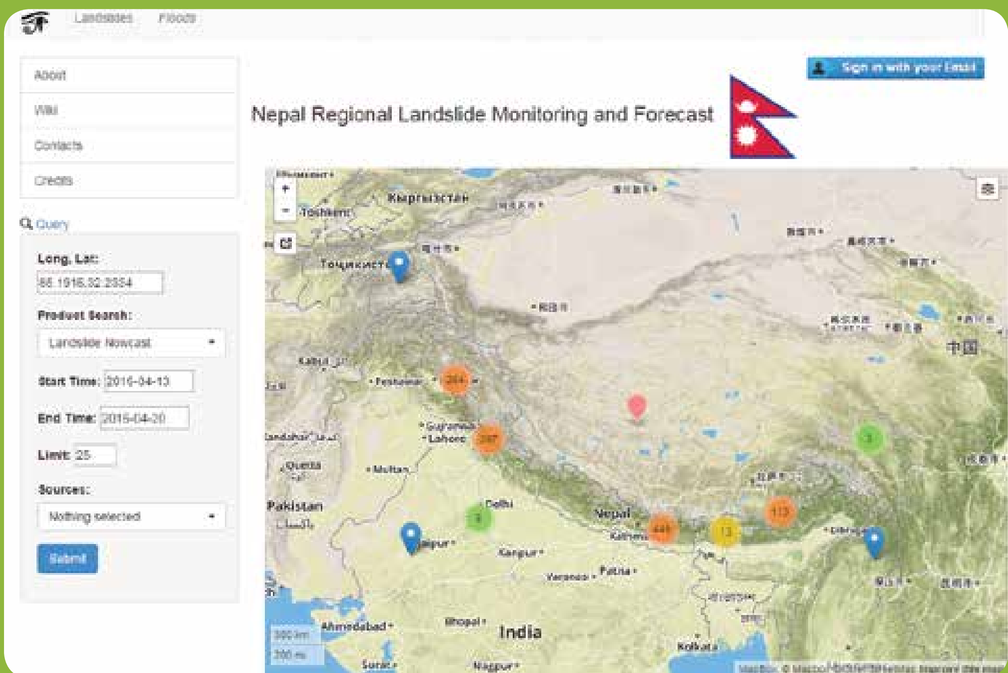
Developing a common methodology and platform for data collection and sharing: Global landslide catalogue

Dalia B Kirschbaum, NASA Goddard Space Flight Center (via Skype)

Motivated to know where and when landslides have occurred in the past so that we know where they will happen in the future, Dalia B Kirschbaum and team developed global landslide catalogue (GLC) and a common methodology. There are few local inventories and fewer systematic approaches for conducting broader hazard analysis. These landslide databases underpin all landslide assessment and mitigation efforts. The system the team has developed at NASA bases the inventory on media reports and contains information on the date, time, location, impact and landslide types, which are catalogued and made available online (http://ojo-streamer.herokuapp.com/). Currently it is running on Amazon Cloud Instance (JavaScript),), which is an open source tool with the possibility of scaling to a national context. If a core group across the country can be identified, the database could be easily transitioned to a mobile app for use locally. So far this inventory is based on English media, thus it may miss out on those events reported only in local media. A more local reporting mechanism is needed to overcome this bias. So far, the system has 6,790 landslide reports from 136 countries (2007–2015), and over 25,000 reported fatalities (1,779 events with reported fatalities).

The online system allows users to view landslide data in the shapefile format. An online landslide editor that allows users to edit is available online but is currently only available in a prototype stage. The inventory is developed through principles based on crowd mapping whereby individuals map landslides online. The online application comes with common tools like zoom and pan. A rainfall-based landslide susceptibility map is still under development. Users can view additional attributes and information like precipitation to compare and contrast. She said any system that targets participation by local communities should have a reporting mechanism in a local language.

Figure 16: **Screen shot of prototype Nepal Regional Landslide Monitoring and Forecasting system**



She spoke of other ongoing landslide inventorying exercises in Nepal, particularly in the post-earthquake phase, including the volunteer working group led by NASA and USGS. After the earthquake, NASA mobilized a group of volunteers to map landslides using satellite images. Images were analysed and pre- and post-earthquake data was looked at to identify landslides. They mapped 4,300 landslide points (which were actually the location of the deposits). They coordinated with other groups (British Geological Survey and ICIMOD). She outlined three main challenges identified in this approach:

- No uniform cataloguing methodology
- The inventory used deposit zones, not initiation points
- Points, not polygons, were used
- No collective place to share what we learned about these landslides
- A lot of time was spent on image analysis

A semi-automated mapping approach called Sudden Landslide Identification Product (SLIP) using Landsat is another possibility, but it is mostly for mapping large landslides. It is based on changes in spectral characteristic of pixels in multi-temporal sets of images. This approach needs to be validated manually, and can be used after a big event like the Gorkha Earthquake.

The Nepal Hazard Prototype Website (Figure 16) is online and can produce regional scale information on different hazards for Nepal using different data (landslide monitoring and forecasting).

Concluding, she noted that NASA is are working with ICIMOD on recalibrating the rainfall threshold and the near real-time hazard model. She added that NASA is also collaborating with ICIMOD and other groups on the potential formation of landslide inventory projects to ultimately construct a national landslide inventory. For this guidelines and strategies for collection are needed so that people who want to contribute can.

Technical Session IV: **Landslide Treatment, Rehabilitation, and Mitigation**

Session objective: *To share landslide treatment and rehabilitation approaches*

Session chair: MSR Murthy, ICIMOD

Facilitator: Purna Chandra Lal Rajbhandari, UNEP

Landslide treatment in Nepal

Shanmukhesh C Amatya, DWIDP, and Jagannath Joshi, DSCWM

Introducing Department of Water Induced Disaster Prevention (DWIDP), Shanmukhesh C Amatya said the organization is still comparatively young, having been established in 1991. The erstwhile Disaster Prevention Technical Centre (DPTC) was renamed as DWIDP in 2000. In 2002, the river training domain was merged with disaster prevention, and since then DWIDP's mandate has covered landslide and water-related disaster prevention activities. Landslide and flood are two major disaster types experienced annually in Nepal. Flood is rampant in the Terai, which covers 17% of Nepal's area, while the remaining 83% of the country is prone to landslides. In 2013/14, 18% of the 436 lives lost to floods and landslides were attributable to the latter. In addition to loss of life, landslides are also associated with damage and destruction of houses, sedimentation of reservoirs, damage to fertile land, and damage to infrastructure (road, bridges, etc.). A single landslide in Jure in August 2014 killed 156 people and destroyed 40 houses in Sindhupalchowk District.

He differentiated between different types of landslide in Nepal:

- Deep-seated landslides (slowly moving)
- Shallow-seated landslides (slope failure – fast moving)
- Debris flows (flow type)

Figure 17: **Treatment of Sisneghari landslide in Kathmandu District using bioengineering techniques**

Government agencies (DSCWM/DWIDP) are trying to reduce the damage and destruction caused by landslides by implementing structural control/mitigation measures (engineering technology, bioengineering technology) and non-structural mitigation measures (e.g. Roving seminar, audio-visual for local residents, early warning systems). DSCWM has been involved in treating mostly shallow-seated landslides by adopting approaches like catchment treatment (land use improvement in the catchment), water management (drainage management – surface and subsurface), bioengineering/structural techniques (fascines, palisades, retaining walls, check dams, etc.), excavation and filling, toe protection, and protection of the landslide-prone area from livestock. He provided examples of DWIDP's efforts, including work on the Tinthana landslide in Kathmandu, which was treated with surface drainage work, horizontal drainage boring to reduce water pressure on the landslide, and anchoring, and stabilization of slope failure in Dhungre, Bhanjyag, Sindhuli using rock bolting, managing surface drainage, sabo dams and masonry retaining wall. DWIDP has also done debris flow treatment, for example at the Sisneghari landslide treatment site, Matatirtha debris flow (using a series of check dams in 2004, then green cover in 2008), Kabilas landslide (using gabion check dam and slit type dam), Kerunge landslide (using retaining wall), Pipaltar landslide (gully treatment), and Sisneghari landslide (using bioengineering, Figure 17). He said that DWIDP also conducts awareness training and implements early warning systems for communities at risk. Concluding his presentation, he looked forward to learning about recent technology and innovations in landslide risk management from the workshop.

Landslide Rehabilitation and Mitigation

Nabraj KC, Engineer, Department of Roads

Nabraj KC introduced the Department of Roads (DOR) and landslide treatments done by the department, noting that the total strategic road network in Nepal is 14,500 km. DOR has 32 division road offices, and geoenvironment and social units support the division offices. Each division has a nursery for bioengineering work. The division offices undertake small-scale landslide treatment and are also responsible for clearing landslide debris along highways and road networks during the monsoon using machines and manpower. DOR is mandated with stabilizing slopes along the road corridor, and has published a book called Roadside Engineering on the techniques used to stabilize slopes, including using civil engineering techniques, bioengineering techniques, gabion walls, check dams, reforestation, gabion bolsters, retaining walls, grass planting, cardamom planting, seeded grass, diagonal grass, jute netting, brush layers, and shrubs to control debris flow. Examples of landslides treated by DOR include the famous Krishnavir landslide west of Kathmandu. He highlighted the following issues and challenges faced by the DOR:

Figure 18: **Civil engineering and bioengineering were used together to stabilize the famous Krishnavir landslide west of Kathmandu**

- Coordination with other agencies
- Lack of funds
- Lack of skilled manpower
- Need for detailed study of highways after earthquake
- Need to address climate change

Developmental characteristics of landslide and debris flow in the seismic zone of the southeast Qinghai-Tibetan Plateau and hazard management approaches

Chen Ningsheng, Institute of Mountain Hazards and Environment (IMHE), Chinese Academny of Sciences, China

Chen Ningsheng said that, like Nepal, China is also prone to earthquakes. The earthquake belt in China is 100,000 km^2, which comprisesof 5.7 billion tonnes of loose deposits. In the Longxi-Hongkou area, 445 km^2 fall under the earthquake belt, comprising 60 million cubic metres of loose deposits. In August 2010, the Hongcun gully area, measuring 5.35 km^2, experienced precipitation of 163 mm, and on 14 August a landslide resulted in the death of 17 people while 59 people were missing, and 8,000 people were forced to evacuate. In China there are 23 earthquake belts along which 16 debris flow belts lie and which accounts for 69.6% of all landslides in China. Landslide is found to strongly correlate with drought, which contribute to the development of cracks that trigger failure.

He said that although the locations of the Wenchuan Earthquake and Gorkha Earthquake were in different parts of the Himalayan belt and at different elevations, both events triggered many landslides. The impact area of the Wenchauan Earthquake, being in leeward side of the Himalayan belt, is drier than the Gorkha earthquake impact zone. Therefore, debris flows are a greater concern for Nepal. He said identifying and mapping loose deposits are key to debris flow research, as loose deposits/soil are more prone to landslides during earthquake, even under slight tremors, which can turn into debris flow. Humidity and soil moisture substrate is another key factor in determining landslide risk, as it debilitates the cohesive bond between particles as a result of increased pore pressure. The higher the humidity, the higher the pore pressure, and the weaker the inter-particle bond.

During the Wenchuan Earthquake, landslides along with collapse were responsible for about 30% of total killed. Many large-scale debris flows and rock falls were generated following the earthquake, impacting downstream stretches (Table 1). About 1,000 geohazard sites had been brought under control between June 2008 and June 2010 at a cost of RMB 10 billion, using about 50,000 skilled workers and 10,000 engineers and scientists. Netting (active and passive) was widely used to contain rock falls, but were not found to be effective, although active nets performed better than passive. However, installing active nets was more difficult. Check dams and other engineering structures were not effective, as small to medium-sized structures could not prevent the impact of large debris flow (Figure 19). Hazard reoccurrence cannot be neglected and is expected to be around for years in the form of heavy erosion, which will bring about changes in downstream river morphology as a result of intense deposition/siltation. This can impose multiple impacts on the communities downstream. He stressed the need for good planning based

Table 1: **Summary of debris flow after the Wehchaun earthquake**

Date	Location	Debris flow sites	Total volume (10,000 m^3)	Biggest volume of a debris flow site(10,000 m^3)
24 September 2008	Old town of Beichuan county	70		Weijia gully 100
18 July 2009	An county	20		30
13 August 2010	Mianyuan river basin	20	1,000	Wenjia gully 450
	Yinxiu town	21	200	Hongcun gully 75
	DujiangyanLongxi and Baisha river	44	301	Bayi gully 130
19 August 2012	Peng county, Baishui river	12	60	Haihuiqiao gully 20
10 July 2013	Wenchuan county-Yinxiu	100	1,000	Qipan gully 80

Figure 19: **Weak civil structure as seen in Yikeying gully, Li county is not effective to contain large volume of debris**

on adequate understanding of event characteristic and physical processes, or else investments will be futile and unsustainable. In the long run, we need a high quality highway with a tunnel and bridge that does not follow the river valley.

Sharing success stories on community-based early warning system from China in landslide risk management, he said casualties were much less in the case of the Wenjia gully, which occurred on 13 August 2010 with estimated debris flow volume of 3.1 million cubic metres. The event still killed 12 people, injured 39, and damaged 479 houses. CB-EWS was also successful in saving 573 lives in the Aizi valley, although 40 lives were lost. He said we should remain on guard against mountain hazards as uncertainly about the landslide and debris flow occurrence is high.

Nepal is no different in terms of natural hazards. The Jure landslide in August 2014 killed close to 160 people. The Gorkha Earthquake and aftershocks triggered about 20 large landslides and 15 debris flow sites along the Sino-Nepal highway, disrupting vehicular traffic and trade. In addition to landslide, Nepal also witnessed GLOFs in the past, which are equally catastrophic and detrimental. In July 1981, a GLOF was triggered, destroying a power station in the Sun Koshi River and killing 200 people. The 60 km highway along the river was totally destroyed, causing economic losses of approximately USD 300 million, which was 20% of the national gross economic income of that year.

In conclusion, he said that mountain landscapes like the Hindu Kush Himalayas are prone to different types of natural hazards. Hazard mapping and inventory is fundamental to understanding the distribution of hazards by type in order to safeguard lives and infrastructure. Along the Bhote Koshi River, there are on an average 100–150 persons/per square kilometre living along the river, and most of the houses are at elevations less than 13 metres from the river bed, which is the estimated height of the GLOF in 1981. In order to pursue disaster friendly development, land use planning is crucial. Control measures are also necessary, especially after an earthquake. However, structural work should be done properly with adequate investigation. Early warning systems (including community-based early warning systems) are also essential to manage residual risk. The prediction of landslides and debris flows resulting from earthquakes and extreme climate events is still a research topic.

Gravitational movement: Landslides and rockslide studies

Pierre Plotto, Head Manager, Engineering for Earth Management and Natural Risks (IMSRN), France

Pierre Plotto recalled Cruden's definition of a landslide: a movement of a mass of rock, earth, or debris down a slope. It starts with a slope failure and in many cases translates into mud flow and stream flow. Other forms of failure are rockslides and granular flows. He said rheology explains how the transition from solid stable form to free flow and to water flow happens. Landslide is a complex interplay between different causative factors. Among the dominant types of landside, rotational landslides are not common. They are often found along road corridors and are comparatively small in size, which means treatment is usually possible. Any landslide risk management intervention needs detailed investigation of contributing factors. Surface and subsurface geology and soil need to be investigated through appropriate survey instruments. Sliding planes along with underground water

Table 2: **Surveys types for different landslide characteristics and parameters.**

Landslide characterization parameters	Types of survey
Geology on surface	Topography, photogrammetry, morphology
Geology at depth	Core drillings, inclinometry, geophysics
Friction angle and cohesion	Soil sampling and lab tests, back analyses
Underground waters	Hydrogeology, piezometry, hydro-chemistry
Landslide dynamic, triggering process	Geology, history, monitoring

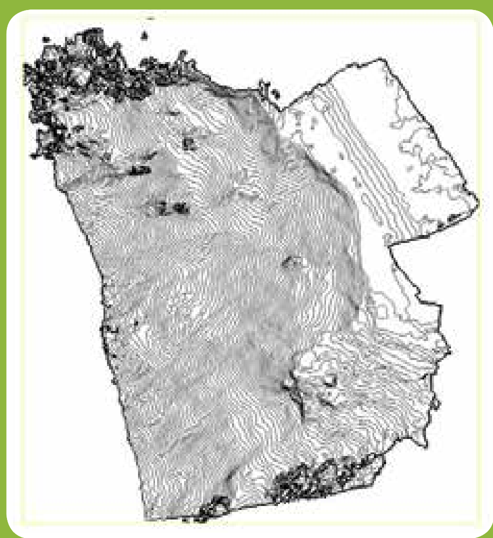
are important features to be investigated, usually done through geophysical survey. Hydrochemistry studies are also done to trace subsurface flow. Remote sensing as a mapping tool is also widely used in landslide study/research. High resolution and unmanned aerial vehicle (UAV) imagery with stereo mode, which is capable of generating high resolution DEMs, have proven useful for topographic surveys. Table 2 provides a summary of landside parameters and the types of survey entailed. Detailed investigation (geomorphological mapping, geological mapping, drilling, geo-physical survey, penetrometric tests, soil tests, stability analysis, and chemical analysis) is imperative for the design of effective mitigation/control measures.

There are different slope stabilization methods determined based on the results of field investigation, and most fall into two categories: off-loading weight from slide head, and reinforcing (abutment) slide bottom to counter downward force. Other common approaches to stabilize the slide is by anchoring the mass to firm basemen by means of nailing, water management, and bioengineering.

Similarly, there are different approaches to control rock fall, which can be broadly classified as active protection (before it falls) and passive protection (after fall). Active protection includes stabilizing unstable blocks by anchoring, netting, etc. As far as passive protection is concerned, structural measures like dynamic barriers, rock fall dykes, rock fall galleries, or a system of brakes are used to absorb energy of the falling rock and contain it. However, the trajectory of the falling boulders needs to be calculated using modelling tools prior to designing passive protection measures.

Monitoring and early warning are cost-effective approaches for minimizing damages. These require a monitoring mechanism to be in place so that early indication of potential failure can be detected well ahead of failure and a warning can be issued. Monitoring and early warning is often done when the need to mitigate is not urgent and/or mitigation is physically and financially challenging.

Figure 20: **High resolution terrain model (DEM) using Lidar and unmanned aerial vehicle (UAV) are becoming popular tools to study surface processes, including landslides**



Landslide Prevention and Stabilization Strategies and Best Practices from Pakistan

Faizul Bari, Watershed Management Expert, FAO Pakistan

Sharing experiences of developing and implementing a landslide rehabilitation strategy and action plan after the 2005 Pakistan Earthquake. The 7.6-m earthquake caused many fatalities and damage. Over 10,000 landslides and landslips were recorded. The earthquake affected a total of nine districts and killed 73,000 people. The largest impacts of the event were felt on irrigation systems, agriculture, food security, and the livelihoods of affected people.

Upon request from the government, FAO prepared a detailed inventory and damage needs assessment and formulated a rehabilitation strategy and action plan that included landslide stabilization projects. Landslide stabilization projects were formulated for 17 selected watersheds, and watershed management committees were established and communities were involved to ensure sustainability. Integrated watershed management plans were prepared with the help of communities to address landslides and to support other activities crucial in helping local people rebuild their livelihoods. As part of this project, hazard mapping and risk and livelihood assessments were conducted with the active involvement of communities.

Local people were trained on how to address certain types of landslide, particularly in bioengineering methods. The plantation of fast growing species (Popular and Robinea) mixed with pines was promoted. He highlighted the importance of planting trees and plants of value to local people, preferably food or fruit bearing plants, and using species found locally. Local people, especially women, were trained to plant nurseries, which help them generated extra income. In addition to plantation, field terracing, brush layering, and check dams were used in conjunction with bioengineering.

Rebuilding livelihoods was equally important as hazard and risk management, so activities like the installation of a wheat demonstration plot was useful in helping people increase their productivity, thus improving their livelihoods and food security. Fruit saplings were also distributed. As livestock rearing is important in the earthquake-affected areas, veterinary services were included in the project. Backyard poultry farming was encouraged, which helped women in particular. An impact assessment of the project conducted in 2012 found the following :

Figure 21: **Rehabilitation of landslide sites in Bagnota using local materials**

- Watershed management committees formed after the earthquake were still functioning
- The watershed had been well protected and landslide sites were fully rehabilitated
- Agricultural productivity had been enhanced by the project
- Additional income, especially for women, was generated from agri-based micro-enterprises promoted through the project
- Communities were found to be more resilient as a result of project activities
- The evaluation recommended the up-scaling and replication of the project

He said there are good lessons in Pakistan's post-earthquake rehabilitation strategy for Nepal to drawn from, some of which are mentioned below:

- Work with the local communities
- Incorporate local food security and livelihoods aspects as an integral part of the rehabilitation strategy

- Follow an integrated approach
- Adopt a multi-partnership approach
- Enhance government department capacity
- Conduct long-term planning to make the community more resilient to natural disasters

With successful experience in landslide stabilization in post-earthquake Pakistan and its global mandate with strong local and regional partnerships, FAO support requested from the Government of Nepal was provided in the following areas:

- Conducted preliminary stocktaking of landslides in Nepal
- Prepared and shared a concept note
- Committed funds for preparatory activities
- In an advance.d stage of negotiations with potential donors

As a way, he noted the need for a detailed damage needs assessment in collaboration with partners to support:

- Resource mobilization
- Selection of critical watersheds
- Constitution of watershed management committees
- Preparation of integrated watershed management plans
- Provision of training to staff and watershed management committee members
- Implementation of the action plan

Ecosystem-based Approaches and Landslide Treatment

Karen Sudmeier-Rieux, University of Lausanne and UNEP/UNIL, and **Sanjaya Devkota**, Tribhuvan University

Making a joint presentation, Karen Sudmeier-Rieux and Sanjaya Devkota talked about ecosystem-based disaster risk reduction (EB-DRR) and its relevance in the Nepal landslide context, and shared some ideas on managing shallow landslide treatments.

Severely deforested landscape in the Alps in the 1900s resulted in downstream flooding, which raised public appreciation of upstream forest canopy to protect them from flooding. Such an event raised awareness on the important value of protected forests to protect us against several types of natural hazards, based on which the concept of EB-DRR evolved. EB-DRR emphasizes looking at the basin as a whole system, including upstream-downstream linkages and the land uses in the watershed. Therefore, the importance of reforestation, land use planning, guidelines for protecting and managing forests, and looking at forestry and hazard management as an interdisciplinary approach, was realized. The ecosystem-based approach used in conjunction with engineering interventions has yielded good results against many natural hazards, including landslide.

The presentation emphasized the importance of protecting forests to ensure the flow of ecosystem services, because healthy ecosystems address risk by contributing to hazard mitigation, vulnerability reduction (by providing livelihood resources), and exposure reduction through land use planning.

Landslides are caused both naturally and with anthropogenic activity. Citing Laban (1976), it was noted that 74% of landslides are natural, 26% are due to anthropogenic activity, and 5% are due to road construction in the case of Nepal. It is consistent with a report by TU-CDES based on a nationwide inventory of landslide, which reported 5.5% of landslides were due to road construction. The road network in Nepal has increased a lot in the last decade and will continue to increase, and with it so will the risk of landslides. In the Phewa Lake watershed, there were 5 km of earthen rural roads in 1979, which increased to 430 km in 2013. One-hundred and eighty-eight small landslides were recorded in 33% (142 km) of the roads surveyed in the Phewa Lake watershed. Road construction contributes

Figure 22: **Road construction in Arukharka VDC, Syangja District, in western Nepal is seen destabilizing hill slope and resulting in ensuing hazard**

to the release of 500 m^3/km (or 210,000 m^3 in total) of sediment in the watershed annually. At UNEP, the team monitoring roads observed that the construction of road network causing significant risk of landslide. The need to look at the small, but cumulative landslides, which affect livelihoods but often go under reported, was highlighted.

After the earthquake, people started rebuilding on their own without knowing which areas are safe. We need to help communities build back better by empowering them with simple techniques such as community-based bioengineering to stabilize slopes, which will ultimately improve people's livelihoods. Taking an integrated watershed management approach that focuses on ecosystem services for livelihoods, hazard mitigation, and climate change adaptation should be the way forward. As relocation and reconstruction is currently high on the agenda, hazard assessment is critical to identify safe locations for reconstruction. Community-based bioengineering for shallow landslides and rural road slides is to be pursued, which will also have livelihood benefits. Slope protection measures fall under two categories: non-living approaches (low-cost civil engineering techniques), and living approaches (bioengineering or bio-technical techniques). Although bioengineering is an old practice and is continuously evolving through research, information is not disseminated to the field. It is found that local people in the communities believe that simple bioengineering approaches is not successful and prefer engineering approaches. But the presentation disproved the notion and stresses that bioengineering is effective, with a lot of research on the effectiveness of plant species and root structures in controlling erosion and landslide.

Information was shared on the Ecosystems Preserving Infrastructure and Communities (EPIC) project,which is being implemented by UNEP in central Nepal. The EPIC project is working on the following components:

- Community awareness about low-cost bioengineering
- Livelihood enhancement activities
- Capacity development
- Integrating EB-DRR into national and global policies
- Quantifying ecosystem services

The following action points were suggested as a way forward:

- Integrated water resources management: Combining land use planning for reconstruction, bioengineered landslide mitigation with livelihoods support and overlapping biophysical and hazard mapping.
- Budget and quality control over local road building processes
- Enforcement of the allocated budget for bioengineering, with dedicated budget for bioengineering during the construction of roads
- Capacity building of DSCO officers and nurseries to include bioengineering and species for livelihoods

Technical Session V: **Group Work and Plenary**

Three groups were formed to take up the following aspects of landslide risk management:

Group 1: Landslide inventory methodology and platforms

Group 2: Landslide hazard, vulnerability and risk mapping methodology

Group 3: Landslide treatment and mitigation

Group 1: **Landslide inventory methodology and platforms**

Group members: Prakash Pokhrel, Shanti Basnet, Prashant Ghimire, Deo Raj Gurung, Paolo Frattini, Megh N Kafle, Salina Bajracharya, Pasang Tamang, Kalpana Shrestha, Sanjaya Devkota, Pradeep Mool, Santosh Nepal, Samjwal Bajracharya

Presenter: Shanti Basnet, Survey Department

There are very few landslide inventories in Nepal and only one national inventory done by TU-CDES. Several inventory activities were undertaken following the earthquake by different groups (NASA-USGS, ICIMOD, BGS, ISRO). These inventories are all based on the remote sensing approach and do not follow common inventory protocol, which has resulted in inconsistent outputs. The lack of standard, harmonized methodology and protocols for landslide inventory in Nepal has been identified as a major gap. The group noted that clarity on the requirements of user groups is needed while developing the standard methodology. The group also identified lack of capacity in different levels of government departments and the need for capacity building. In addition to remote sensing based inventory approaches, the group also discussed the importance and potential of crowd sourcing approaches as instruments for landslide inventory development. The group also noted that there is no single government agency with a complete mandate of landslide risk management.

The group members agreed on the following action points as the way forward:

- Creation of a working group responsible for:
    - Development of a standard, harmonized protocol for landslide inventory
    - Development of a moderated platform (web-based) for landslide inventory
    - Development of metadata template/standards for landslides
- Capacity development
    - Assessment of capacity
    - Development of capacity development plan

The group identified organizations and institutions involved in landslide inventories and suggested action points:

- Tribhuvan University – university curriculum
    - Disaster risk management and integrated water resource management are elective subjects at the moment, which can be developed into a full-fledged coarse
- Tribhuvan University – Geology, Geography, Institute Of Engineering (IOE), Institute of Forestry (IOF)
- Kathmandu University – Environmental Engineering
- Nepal Landslide Society, Himalayan Landslide Society, Nepal Geological Society, Nepal Engineering Society, Disaster Preparedness Network Nepal (DPNET)
- DSCWM, DWIDP, DOR, DMG, DOLIDAR, DOE, DHM, Survey Department – There should be one leading government organization to look after landslides

Group 2: **Landslide hazard, vulnerability and risk mapping methodology**

Facilitator: CJ van Westen, University of Twente

Group members: MSR Murthy, Suresh Shrestha, Khila Nath Dahal, Indira Maleate, Man Bahadur Cherty, Narayan Adhikari, Sudan Bikash Maharjan, CJ van Westen, Narendra Raj Khanal, Suresh Chaudhary, Dipak Bharadwas, Narayangopal Ghimire, Jagannath Joshi, Raju Sapkota, Stefano Gambini, Prem Bahadur Thapa

Presenter: Jagannath Joshi, DWIDP

The group deliberated the objective of hazard, vulnerability, and risk assessments, which are listed below:

- Support planning – infrastructure/watershed management
- Inform local people and make them aware of the risk scenario
- Reduce loss of life/property
- Make communities resilient to disaster
- Land use mapping/land use zoning

In order to focus interventions in areas of high importance with limited resources, the group identified sites where risk mapping should be targeted:

- Hydropower sites
- Recurring landslide sites
- Earthquake rehabilitation and reconstruction sites

The group identified important elements for risk assessment, including generating actionable information and engaging users and communities. The group suggested that landslide hazard, vulnerability, and risk mapping be done at multiple levels: national, district and community. At the district level, district disaster relief committees (DDRC) are involved in coordinating disaster-related activities. At present, the Department of Mines and Geology (DMG) and DWIDP produces maps, but they are not regularly updated. The maps produced by DMG are mostly at a scale of 1:50,000, and 1:25,000 for some areas, and DWIDP has data for ten watersheds at 1:25,000 scale. These initiatives are done in isolation, and they follow different methodology without coordination. Four ministries in the Government of Nepal are dealing with some aspect of landslides: Ministry of Industry, Ministry Forests, Ministry of Irrigation, and Ministry of Physical Infrastructure.

The group also identified the following gaps:

- No harmonized systematic method or framework for integrated hazard management
- Mismatch between output and users' needs
- Risk information is not well integrated with local planning
- Lack of institutional clarity

The group recommended the following action points as a way forward:

- Formation of a multidisciplinary working group, which should be interdepartmental and include national, international institutions and individual experts
- Develop landslide risk assessment maps at the VDC level or watershed level with strong engagement of communities
- Develop a simple, cost-effective and harmonized methodology for landslide hazard assessment using available parameters
- Build the capacity of national agencies across different levels (district, national)
- Prioritize landslide hazard areas for intervention
- Develop spatially explicit maps for priority areas
- Develop a feedback mechanism to improve the product

Group 3: **Landslide treatment and mitigation**

Group members: SC Amatya, Thakur Prasad Magrat, Suresh Chaudhary, Purna Chandra Lal Rajbhandari, Sanjeev Bhuchar, Faizul Bari, Nagendra Sitoula, Laxmi Thagunna, Binod Shah, Diwakar Maskey, Krishna Ghimire, Kamal Jaishi, Hari Prasad Sharma, Bhawani S Dongol, Gautam Rajkarnikar, Pierre Plotto

Presenter: Faizul Bari, FAO Pakistan

The group felt the prioritization of landslides is the first step towards mitigation, which can be done based on different modalities as indicated below:

- Community focus – considering communities under threat or infrastructure of priority to communities
- Infrastructure focus – considering high-value infrastructure

Interventions have to be at both the policy/strategic level and operational level. Policy/strategic level interventions should facilitate the process by drafting an appropriate policy and a specific act dealing with landslide, and a formal coordinating agency must be identified to act as as an institutional anchor. Operational level interventions should include all players – public, private, civil society, and community – and could include:

- Land use planning
- Hazard and risk assessment mapping
- Awareness raising
- Reinforcing livelihoods and food security by maintaining ecosystems
- Capacity building of communities and relevant stakeholders
- Establishment of an early warning system
- Community participation and an integrated approach throughout the project cycle
- Multi-partnership approach to be adopted

Collective learning can benefit the entire HKH region, thus to ensure the transfer of technology and knowledge, the group suggested the following action points:

- Documentation and sharing of best practices and technologies both in the country and in the region
- Development of new technologies (action research), climate smart technologies, and indigenous technologies
- Mandating that departments be educated in disaster risk reduction
- Scoping of technology appropriate for Nepal

The group suggested that while coordination is to be done by the Ministry of Home Affairs, implementation has to be done by line ministries/departments/authority (Ministry of Federal Affairs and Local Development). Some ideas shared by the group to secure financial resources include:

- Preparation of rehabilitation and recovery projects/programme for both government and donor funding
- Arrange a donor conference, for funding as well as expertise and experience

The group noted that there should be a framework in place to monitor progress and, if required, suggest adjustments.

Closing Session

Session chair: Bhartendu Mishra, National Planning Commission, Government of Nepal

Facilitator: Deo Raj Gurung, ICIMOD

The closing session started with a summary of workshop resolution read by Jagganath Joshi, Under Secretary of DWIDP, which was followed by closing remarks by guests on the dais.

Closing Remarks by David Molden, Director General, ICIMOD

David Molden thanked the chief guest, chair, and participants for attending. He noted the incredible amount of energy put into this topic, adding that the key word is harmonization in several different aspects, including data collection and people working together. He reiterated the positive outcome of 30 different organizations coming together and agreeing to form working groups. He called for capacity building and for young people to get out in the field. Under its role as a knowledge sharing organization, ICIMOD would be able to provide a platform to support this under the leadership of the government.

Closing Remarks by Muralee Thummarukudy, Senior Program Officer, DRR, UNEP

Muralee Thummarukudy recalled his visit to Nepal in June, during which many organizations were talking about landslide without coordinating with each other. Some landslides attracted all, and some where understudied. This workshop was an opportunity to work together, and he expressed happiness with the resolution. He hoped that some progress would be made by different working groups by November, and that they will contribute to capacity building. He committed his continued support and expertise to implement the workshop resolution. He said UNEP's focus remains on the ecosystem-based approach. Thus, in addition to looking at landslides at a local level, he noted that it is equally important to look at the landscape level. He thanked all the participants and experts who contributed, and looked forward to the next event at the end of November.

Closing Remarks by Prem Kandel, Director General, DSCWM

Prem Kandel thanked the chief guest, chair, director of ICIMOD, and the participants, and congratulated all the participants for making the workshop a success. He expressed satisfaction with the concrete recommendations and activities outlining the way forward, and remained hopeful about future follow up. He reminded the gathering that it was only after the earthquake that we realized the importance of a harmonized method and coordinated approach between the organizations in the government working on landslides. Being vulnerable to different types of natural hazard, Nepal's current development trajectory is not that sustainable. For example, rural road construction is accelerating the frequency of landslide events, and the National Planning Commission (NPC) must realize this and take measures to improve the sustainability of development activities. The recent earthquake increased the vulnerability of Nepal. The PDNA estimated damages of USD 340 million. With regard to landslides, DSCWM is one of the lead organizations, but there is fragmentation and isolation. He expressed the need to develop guidelines and revisit institutional mechanisms. He thanked NPC Member Bhartendu Mishra for attending the closing session, and expressed gratitude to the organizers and experts for making this workshop successful.

Closing Remarks by Bhartendu Mishra, National Planning Commission

Bhartendu Mishra thanked the organizers for inviting him to the closing session of this important event. Nepal is a mountainous country and vulnerable to earthquake and climate change. The Gorkha Earthquake reminded everyone of the damaging influence of natural hazards. The problem of landslides is long-standing and will continue to be a challenge in the future. He felt enlightened listening to the resolutions that came out of two days of deliberation and discussion on important topics such as landslide risk assessment and mitigation in Nepal. The topic is very important, which is why the PDNA emphasized landslides. He also appreciated ICIMOD's support to the NPC in bringing out the Livelihood Recovery Strategy in the aftermath of the earthquake. He hoped that the workshop will bring out useful action points to solve the issues Nepal faces pertaining to landslides.

Vote of Thanks by Purna Chandra Lal Rajbhandari, UNEP

Purna Chandra Lal Rajbhandari began by thanking the chair, director general of ICIMOD, and the participants and experts who gave their time to this important event. He also thanked the speakers who came from outside of Nepal and those who made presentations via Skype. He thanked the director general of the DSCWM for his guidance and support. From ICIMOD he thanked Deo Raj Gurung and Kanchan Shrestha, who worked tirelessly to prepare for the workshop. He thanked FAO and other partners for their time and contributions. He hopesd that the outcomes of the workshop would be put together for future reference. He thanked rapporteurs for tirelessly taking notes, which will be ultimately compiled into a compendium to document the deliberation, discussion. and outcomes of the workshop.

Resolution and Summary

A total of 95 participants attended the workshop, including 10 international experts and representatives of 30 organizations (national and international). The participants from the consultative workshop on landslide inventory, risk assessment and mitigation in Nepal, held in ICIMOD on 28 and 29 September, have acknowledged that:

- Nepal is seriously affected by landslides, with an average of 200 people killed per year and many buildings, agricultural land, forest resources, roads, hydropower projects and tourism facilities destroyed or threatened by landslides each year.
- The 2015 Gorkha Earthquake generated thousands of new landslides, leading to massive destruction in the earthquake affected districts.
- As part of the reconstruction planning, there is a great need for hazard maps at the local level, to guide the District Development Committees in taking decision that would reduce future risks.
- Up to now there have been no harmonized initiatives for generating information on the location of landslides, or on how this information can be used for landslide hazard assessment.
- There are several government organizations that require landslide information in order to support decision making at the local level, and the department of Soil Conservation and Watershed Management together with the Department of Water Induced Disaster Prevention has been given the mandate by the Government of Nepal to coordinate the landslide inventory and hazard assessment in the country. For that, they will need the support of other government organizations, academia, INGOs, international organizations and development partners.

The DSCWM and other government organizations realized the need to develop a harmonized method for landslide inventory mapping and the need for a web-based platform for collecting and sharing landslide information. ICIMOD has extensive expertise in utilizing spatial data platforms, and they have also taken the lead in the collection of landslide data after the Gorkha Earthquake. Tribhuvan University has carried out a pre-earthquake landslide inventory and the Department of Mines and Geology has been involved in rapid landslide assessments at problem sites in the country.

The workshop participants agreed that the various agencies should work together in building a national landslide inventory, using a harmonized method for data collection and data storing, which would be hosted in a web-based platform. Also the possibilities for linking this with a public reporting system for landslides should be investigated, both using social media as well as using a target reporting system (e.g., using schools and news media). Existing initiatives, such as the DESINVENTAR database, maintained by NSET should be taken into account in this. The most logical organization to host the platform would be ICIMOD, and it should be evaluated whether an existing landslide inventory platform (e.g., under SERVIR or other ongoing project) could be utilized or whether a specific platform should be developed. The platform should allow the collection of landslide data as points and polygons with relevant attributes (which are still to be defined), should contain a public reporting component and a social media component. Data should be open and downloadable. Also, the hazard maps should be made available through this web-portal, as well as a list of organizations active on landslide work in Nepal, and a repository of documents related to landslides. The users of the landslide inventory platform are government organizations, academia, I/NGO's and international organizations. Data collection should come from remote sensing image interpretation, involving international organizations, such as ICIMOD, the British Geological Survey, University of Durham, NASA, University of Michigan, University of Lausanne, University of Twente, University of Milan Bicocca, Mountain Research Institute (CAS), JICA, and other organizations. Field data collection should be carried out by staff from the Department of Soil Conservation and Watershed Management, Department of Hydrological Induced Disaster Prevention, Department of Mines and Geology. Other government organizations should be instructed to report landslides through the online landslide reporting tool. University students should also be actively involved in landslide inventory data collection in the field. In addition, the results of the community based landslide inventory and hazard assessment, to be carried out by the District Soil Conservation Offices, should be integrated into the platform.

The workshop participants also agreed that a harmonized landslide hazard mapping approach should be adopted which should be:

- **Local:** should be done at the VDC level at a scale of 1:10,000 to 1:25,000, so that it is useful for (reconstruction) planning and should directly involve local communities
- **Fast:** before people start to reconstruct in unsafe areas
- **Focus on built-up areas:** first it should be limited to areas with people at risk (Main aim: is reconstruction safe at this location?)
- **Simple:** the method should be relatively simple
- **Harmonized:** many people should be able to do this using a guideline
- **Evidence based:** the method should be based as much as possible on factual evidence (past landslides, steep slopes,
- **Field based:** given the limitations in terms of input data, the majority of the information should be collected locally, with large involvement of local population

The method should be inventory based, using all available landslide inventories plus additional information through local knowledge at the VDC level. Hazard mapping should be done by the district soil conservation officers, and district officers of the Department of Hydrological Induced Disaster Prevention, using a direct mapping method, in close consultation with the communities.

The method should be as follows:

- For a given district, the process starts with outlining mapping units from Digital Elevation Models, satellite images, land use maps and the landslide inventory, prior to fieldwork, by staff from the DSCWM, DWIDP, and DMG. These will be printed on Google Earth images and supplied to the DSCO for that district.
- The DSCO should work per community and in close communication with the communities to characterize the mapping units based on a check-list with a series of questions in the form of a checklist or decision trees.
- The hazard should be described in a matrix-based hazard classification, showing a combination of frequency and magnitude.
- The resulting hazard map per district would then be digitized and incorporated into the landslide platform.

The work should be carried out in the field by the local District Soil Conservation Offices and the district offices of the Department of Hydrological Induced Disaster Prevention. They should be trained on how to use the method by staff from the departments. Geologist from the DMG would be asked to advice on specific problem sites. University students should also be used in carrying out the hazard assessment, also using additional modelling approaches.

Prevention and Mitigation

It is important to categorize the landslides that require mitigation. This should come from the national landslide inventory and local hazard assessment. Priorities should be given both at the community level as well as for large infrastructure. The landslide stabilization should be seen in the overall context of livelihood and food security. The priority will be the community-preferred landslides so that their livelihood and food security is secured. There should be a formal coordination agency to take the lead role. The operational level should be public, private, civil society and community. Proper land use planning should be done, in which hazard and risk assessment is an integrated component. Awareness raising is an important component of this. It is important to reinforce livelihood and food security based on the available ecosystem services. Capacity building is required. Establishment of an early warning system at the local level is essential. Community participation is very important and an integrated approach should be adopted in the project cycle.

Technology transfer and adaptation:

- Documentation and sharing of best practices/technologies both in the country and in the region
- Development of new technologies (action research), climate smart technology as well as indigenous knowledge
- Departments to be mandated to educate in the DRR
- Scoping of the technology in the Nepalese context

Who will do the recovery work? There will be a coordinating structure at federal level and line departments will be the implementers. The Ministry of Home Affairs (MoHA) will be responsible (lead agency) for rescue and relief and the Ministry of Federal Affairs and Local Development or a dedicated authority will be specifically responsible for landslides.

Secure financial resources:

- Preparation of rehabilitation and recovery projects/programme for both government and donor funding
- Increase in budget allocation
- Donor conference

Monitoring and evaluation by developing and adopting M&E framework.

The following activities are proposed as a follow-up to the workshop:

- Establish a multidisciplinary working group (interdepartmental, national, international institutions, individual experts)

The working group should have the following sub-groups:

- Landslide inventory platform
    - Evaluate approaches for similar methodologies and platforms in other countries
    - Develop and test guidelines for a harmonized landslide inventory
    - Select or develop a landslide web-based platform
- Landslide hazard assessment
    - Evaluate approaches for similar methodologies carried out in other countries.
    - Develop and test guidelines for a harmonized landslide hazard assessment
    - Integrate this component in the web-based platform
- Landslide treatment and mitigation.
    - Evaluate approaches for similar methodologies carried out in other countries.
    - Priorities should be given both at the community level as well as for large infrastructures. The landslide stabilization should be seen in the overall context of livelihood and food security. The priority will be the community-preferred landslides so that their livelihood and food security is secured.
- Capacity building
    - Work out a capacity building strategy in close collaboration with the other sub-groups
    - Carry out training courses at local level

It will be evaluated whether the working group could be under an existing landslide related society, such as the Nepalese Geological Society, Nepalese landslide society. It can also be a consortium of government and non-government organizations, where one organization is designated as coordinator.

The organizations involved in the organizing the current workshop will take the initiative to establish the working group, finalize its TOR, and realize the working group outputs. The TOR for these sub-groups should be established before mid-November 2015.

Annexes

Annex I: **List of Participants with Affiliation**

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Annex II: **Detail Workshop Programmme**

09:00 – Arrival & Registration

Inaugural Session (09:20–10.30)

Facilitator:	Deo Raj Gurung, Remote Sensing Specialist, ICIMOD.
Session	Chair: Pem Narayan Kandel, Director General, Department of Soil Conservation and Watershed Management (DSCWM), Government of Nepal.
Chief Guest:	Bishwa Nath Oli, Joint Secretary, Ministry of Forests and Soil Conservation (MOFSC), Government of Nepal.
Safety briefing	Chandra B Kansakar, Senior Officer, Staff Relations and Security, ICIMOD.
Welcome Remarks	David Molden, Director General, ICIMOD.

Opening Remarks:

- Henrik Slotte, Chief, Post Conflict and Disaster Management Branch, UNEP.
- Yam Malla, Country Director, IUCN, Nepal.
- Eklabya Sharma, Director, Program Operations, ICIMOD.
- CJ van Westen, University of Twente.

Workshop objectives and Expected outputs Jagannath Joshi, Under Secretary, DSCWM.

Key Note Speech	Tara Nidhi Bhattarai, Tribhuvan University.
Remarks by Chief Guest	Bishwa Nath Oli, Joint Secretary, MOFSC.
Vote of thanks and closing remarks	Pem N. Kandel, Director General, DSCWM.

End of inaugural session.

10.30–11.00: Group photo and refreshment

Technical Sessions – Day I

28 September 2015

Technical Session I: **Post-earthquake landslide Inventories and interventions.**

Session Objective: To share the experiences and problems encountered by the institutions in post-earthquake landslide inventory in Nepal.

Session Chair: Pem N Kandel, DG, DSCWM

Facilitator: MSR Murthy, ICIMOD

11:00 Initiatives and requirement of Government agencies - Jagannath Joshi, DSCWM and Shanmukesh Amatya, DWIDP

11:15 Post Nepal Earthquake landslide inventory - Deo Raj Gurung, ICIMOD

11:30 Pre-earthquake Landslide Inventory of Nepal 2015: An Academic Exercise - Dinesh R. Bhuju, Central Department of Environmental Sciences, Tribhuvan University.

11.45 Landslide Mapping in Nepal: the impacts of the Gorkha earthquakes and the monsoon – Colm Jordan, British Geological Survey.

12.00 REA with Focus on Landslide and Green Recovery and Reconstruction - Judy Oglethorpe, WWF-Nepal.

12:15 A common approach to landslide inventory: Harmonization of the landslide inventory mapping for Nepal - Prof. CJ van Westen, University of Twente.

12:30 Discussion.

13:00 Lunch Break

Technical Session II: Landslide Hazard, Vulnerability & Risk Assessment and Mapping Methodologies.

Session Objective: To share the methodologies and results by the institutions in mapping landslide hazard, vulnerability and risk assessment in Nepal.

Session Chair: CJ van Westen, Univ. of Twente

Facilitator: Paolo Frattini, University of Milano Bicocca

14:00 Need for Landslide Hazard, Vulnerability & Risk Assessment and Mapping in Nepal- Jagannath Joshi, DSCWM.

14:15 Earthquake induced landslide distribution and hazard mapping - Megh R Dhital, Mountain Risk Engineering/CDG, TU.

14.30 Multi-variate statistical approach for landslide susceptibility mapping - Sudan Bikash Maharjan, ICIMOD.

14.45 Community Based Landslide Vulnerability and Risk Assessment: Method and Tools - Narendra Raj Khanal, Consultant, ICIMOD.

15:00 Coffee break

15.15 Landslide dynamics in Siwalik: Mechanics and management policy - Prem P Paudel, Under Secretary, President Chure Tarai Madhesh Conservation Development Board.

15.30 Harmonization of Landslide Hazard, Vulnerability & Risk Assessment and Mapping Methodologies for Nepal - CJ van Westen

16.00 Discussion

16:30 Group formation for second day exercise on harmonization of (i) Landslide Inventory methodology and (ii) Landslide hazard, vulnerability and risk mapping methodology (iii) Landslide treatment and mitigation.

17:00 First day wrap-up

Technical Session – Day II

29 September 2015

Technical Session III: Development of Common Platform.

Session Objective: To discuss and agree on a common methodology and platform for data collection and sharing on landslide in Nepal.

Session Chair: MSR Murthy, ICIMOD

Facilitator: Deo Raj Gurung, ICIMOD

09:00 Developing a common methodology and platform for data collection and sharing - Global landslide catalogue - Dalia B. Kirschbaum, NASA Goddard Space Flight Center.

Technical Session IV: Landslide Treatment/ Rehabilitation Mitigation.

Session Objective: To share landslide treatment and rehabilitation approaches.

Session Chair: MSR Murthy, ICIMOD

Facilitator: Purna Chandra Lal Rajbhandari, Consultant, UNEP

09:20 Landslide treatment in Nepal – Shanmukhesh C. Amatya, DWIDP & Jagannath Joshi, DSCWM.

09:35 Landslide Rehabilitation and Mitigation- Nabraj KC, Engineer, Department of Roads

09.50 Developmental characteristics of landslide and debris flow in the seismic zone of southeastern Qinghai-Tibetan Plateau and hazard management approaches - Chen, IMHE, China.

10:05 Landslides and rockslides studies, modelling and mitigation - Pierre Plotto, IMSRN, France.

10:20 Land slide prevention and stabilization strategies, with best practices from Pakistan - Faizul Bari, FAO Pakistan.

10:35 Ecosystem based approaches and landslide treatment – Karen Sudmeier, University of Lausanne and UNEP, and Sanjaya Devkota, Tribhuwan University.

10:50 Coffee/tea break

Technical Session V: Group work

Session Objective: To deliberate and discuss on each of the three aspects of landslide risk management, and arrive at action plans to improve landslide risk management in Nepal.

Session Chair: CJ van Westen, Twente University

Facilitators: Samjwal Bajracharya, ICIMOD, and M. R. Dhital, TU

11:10 Three groups will be formed and take up each of the following aspects of landslide risk management:

- Group 1: Landslide Inventory methodology and platforms.
- Group 2: Landslide hazard, vulnerability and risk mapping methodology.
- Group 3: Landslide treatment and mitigation.

13:00 Lunch break

14:00 Prepare group presentation using power point.

14.30 Plenary - Group presentation (10 min presentation and 10 min Q&A).

15.30 Coffee/tea break.

Closing Session

16.00 Resolution and way forward - Jagannath Joshi, DSCWM
16.20 Closing remarks - David Molden, Director General, ICIMOD.
16.30 Closing remarks - Muralee Thummarukudy, Sr. Program Officer, DRR, UNEP.
16.40 Closing remarks - Pem N. Kandel, DG DSCWM.
16.50 Closing remarks - Bhartendu Mishra, Member, NPC, Government of Nepal
17.00 Vote of thanks - Purna Chandra Lal Rajbhandari, Consultant, UNEP.

Rapporteurs for the event:

- Dhirendra Pradhan, Planning Officer, DSCWM
- Ajay Karki, Asst. Planning Officer, DSCWM
- Susan Sellers, Consultant, ICIMOD

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