Presentation structure

- Brief overview of Geology and Climate of Nepal
- Rainfall as triggering agent
- Stability analysis
- Rainfall threshold of Landslide for the Nepal Himalaya
- Landslide hazard mapping in Nepal
- Mitigation measures
- Conclusions

Geo-Disaster and Its Mitigation in Nepal

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The Nepal Himalaya

- The longest division of the Himalaya
- Extended about 800 Km
- Starts from west at the Mahakali River
- Ends at the east by the Tista River (India)

Geological Map of Nepal
Simplified North-South Cross Section of Nepal Himalaya

Regional geomorphological map of Nepal

After Dahal and Hasegawa (2008)

Huge difference of elevation in short distance
South is less elevated
North is highly elevated

Strong South Asian Monsoon, 90% annual rainfall occurs within three months

Climates of Nepal
More Concentration of people in Lesser Himalayan Region

Source: DoS, Nepal

Fig Courtesy: ICIMOD

Many landslides

The map does not represent the total number of landslides events in Nepal. However, the landslides included in this map were responsible for damage to infrastructures and/or a number of human deaths.

Distribution of Landslides in Nepal
After Dahal and Hasegawa (2008)

Slope failure inventory – In central Nepal
1993 to 2010, in total 9884 events were identified

New landslides: 655
Old landslides: 9229
4043 Sq km. area of central Nepal

Text Book type landslides in the Lesser Himalaya

Landslide on the right bank of the Bhotekoshi River.
Location: north east of Kathmandu

Many Lesser Himalayan slopes has problem of landslides
A landslide view in Ghatte Khola, Achham, Western Nepal, 2006

Debris flow channeled in steep gully is now found to be very prominent on Roadside Slopes of Nepal.

Ramche Debris flow, killed 15 army personnel

Landslide in the upper part of the Argheli Khola, Achham district

Debris flow channeled in steep gully is now found to be very prominent on Roadside Slopes of Nepal.

Nepal Army searching the Village

Nepal Police searching the Village

The matatirtha landslides at Kathmandu

Recovered Death Bodies

Total 16 people killed

Death body recovered

Nine people died

Recovered Death Bodies

Death body recovered

Death body recovered

Death body recovered

Recovered Death Bodies

Death body recovered

Death body recovered

Death body recovered

Recovered Death Bodies

Death body recovered

Death body recovered

Death body recovered
Threat from Rockfalls!

A remote village in Gorkha, Nepal

Population in landslide risk

Living with landslide

Welcome to Hotel Landslide

Landslide disaster in Nepal

Total people killed after landslide disaster during half period of monsoon:
In 2007: 70 people
In 2008: 50 people
In 2009: 68 people

Geomorphology of the mountain slopes

In 2009: 68 people
After Yatabe et al., 2005

Tansen City of Nepal is on old mega landslide materials

Tansen Mega Landslide

Large-scale landslide in Higher Himalayas
4. Low-cost Environment-friendly or Green Road Method

- Stage construction of 1 to 2 m in combination with bioengineering
- Limited use of heavy equipment
- Only local material used except some gabion wires
- Use of cement discouraged
- No blasting for rock breaking permitted
- Use of harvesting tools for sheet flow – no side drains
- Equipment may be used for gravelling and pavement
- Applicable for construction of highways and feeder roads
- Method is inherently poverty focused and uses poorest people

3. Labor-Based Road Construction Method

- Mostly used for district roads and feeder roads
- Only light equipment used, no heavy equipment used
- Maximum use of local laborers for works
- Limited blasting permitted for rock breaking

2. Conventional Mechanized Road Construction Practice

- Applied in highways, feeder roads and urban roads
- Earthwork equipment used for cut, slope trimming and embankment construction
- Mechanized compaction of backfill and embankments
- Laborers used for minor works – drainage, slope finishing
- Blasting for rock breaking permitted

1. Labor-intensive Method

- Applied for construction of early roads in Nepal
- Labor groups employed as labor contracts, no work contracts
- No heavy equipment used except work tools
- Mostly full cut roads, structures and embankments minimized
- Side casting of surplus material permitted, blasting for rock breaking

Road Construction Practice in Nepal
(Modified after Adhikari 2004)
2. Conventional Mechanized Road Construction Practice

We even capture course of River, Dhulikhel-Nepalthok Road

Very dynamic setting and construction practice of donor agency – JICA

3. Labor-Based Road Construction Method

Basic rules of engineering even suggest that the site is suitable for Tunneling. But…

3. Labor-Based Road Construction Method

Road Construction Practice, Sanfe-Martadi Feeder Road (1998)

4. Low-cost Environment-friendly or Green Road Method

4. Low-cost Environment-friendly or Green Road Method

Cut and Fill
Low-cost Road Construction Method

Source: Green Roads in Nepal: Best Practices Report
Butchering of Himalayan Slopes – An example of cruelty on Himalayan environment in the name of “Lost Cost”

Roads after construction and one set of monsoon

Failure at contact between rock and soil

Ruptured artery

Frequently we read in the News Paper about the blockade of the road
Problems in Road

Jomsom-Kagbeni-Muktinath Road
km 1+200

Debris flow
Annual Rainfall 200 mm

A National highway after debris flow

Jan 4, 2003
2003 January

Butwal-Tansen Road, near Siddhapada

News of national newspaper, October 9, 2004

Rockslide buried nine passengers
Rainfall thresholds of landslides for the Nepal Himalaya

World map showing area for which data for rainfall threshold of landslides are available

This gap has been filled

Rainfall and landslide incidence – an example

Extreme rainfall of July 19-20, 1993, in Tistung, central Nepal
Comparison of the landslide triggering; a) rainfall intensity–duration and b) normalized rainfall intensity–duration thresholds from various studies with Dahal and Hasegawa (2008) for the Nepal Himalaya.
Floods are common issues in Terai.

Floods in Rapti River, 1993 flood disaster in central Nepal.

Floods in Terai

Koshi flood in 2008

River damming Seven hour

Landslide Damming and flooding
Successive development of the Tsho Rolpa Glacial Lake from 1957 to 2000

The photograph shows the site of civil structures of Namche (Thame) Small Hydel Project, which were completely destroyed by the GLOF (photograph taken on 4 August 1985, WECS 1987)

Map showing the location and type of damage along the Dudh Koshi due to the GLOF of 4 August 1985 from Dig Tsho Glacial Lake (Vuichard and Zimmerman 1986)
Glacial lake outburst flood (GLOF) and Damage

Destruction along the path of a Glacial lake Outburst Flood in Nepal

One hydropower was damaged

Destruction along the path of a Diksho Glacial lake Outburst Flood in Nepal

1255-Flash flood in Seti River, Pokhara – May 5, 2012

Field Inspection Survey

[Map showing the Seti River and surrounding areas with labeled points and arrows indicating inspection routes.]

[Photos taken by a photographing boy]
**Avalanche Area**

(Video: 2012.5.5, 9:00AM)

Surface area: 10 sq.km.
Volume: Approx. 1x10^6 m^3

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Possible zone of small rock fall which triggered snow avalanche

Source area of Avalanche

Transportation Zone of Snow avalanche and flow direction

Peaks of Glacial flour (rock flour)

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Rock fall and snow avalanche

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Annapurna IV

Avalanche area before:

Slope after the avalanche

Rock fall and snow avalanche

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Flow path of snow and debris

Seli gorge

---

Devastated Kharpani (Tadapani) area

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Completely washed out road section

Main settlement area with a bus stand and shops

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Traces of debris on the bridge

Damaged suspended trail bridge with traces of damage

Present situation of the damaged trail bridge

Devastated Kharpani (Tadapani) area

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About 30 m from riverbed

About 22 m

About 15 m

About 10 m
Earthquakes in Nepal

Earthquakes of Magnitudes in Richter Scale & Approximate Recurrence Interval (yr)

<table>
<thead>
<tr>
<th>Magnitude</th>
<th>5 to 6</th>
<th>6 to 7</th>
<th>7 to 7.5</th>
<th>7.5 to 8</th>
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<tbody>
<tr>
<td>No. of Events</td>
<td>41</td>
<td>17</td>
<td>10</td>
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</tbody>
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Earthquakes of Magnitudes in Richter Scale & Approximate Recurrence Interval (yr)

- Year
- Earthquake Magnitude
- Deaths
- Homes Destroyed
- Remarks

- 1755: East Nepal 8.1 (M S)
- 1755: North India 7.0 (M L)
- 1755: Kumaon 6.5 (M L)
- 1755: Nepaul 5.5 (M L)
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Kathmandu is a large mountain valley. Valley has thick lake sediment.

Kathmandu Valley consists of Lake sediment:
- Well consolidated lake deposit
- Semi consolidated lake deposit
- Loose lake deposit
- Magnified seismic energy

Illustration of earthquake energy advancement in soft sediment.

Very few geotechnical study.

Living with Risk

Please think what will happen if great earthquake hit Kathmandu!!

Illustration of earthquake damage in Kathmandu.
Shake map of the Sikkim-Nepal Border Earthquake of September 18, 2011 (modified after USGS)
Mitigation and Management practice

People’s perceptions towards debris flow risk…

Same either developed or under-developed countries

The predictive modeling approach for landslide hazard study

- Heuristic qualitative approach:
- Statistical quantitative approach: Black box model
  - Data driven multivariate statistical analysis and
  - Experience driven bivariate statistical analysis.
- Deterministic approach: hazard analysis in true sense, highly white box model

Hazard and susceptibility mapping practice for landslides and flood hazard mitigation
Management of landslide hazard zones

Community participation

- Till date no definite initiation from government, only few works
- The hazard maps should be brought into the knowledge of local people in order to aware and motivate them in proper land use and disaster management practices.

Landslide hazard map prepared in Nepali language to use in community level

3 colour map

The three colours presented in maps could energize people’s feeling towards Siwaliks degradation and aware them to manage.

Landslide hazard map of Basbari-Badegau VDC

9”X 6” poster in each ward in front of school buildings

Flood hazard map- Koshi River

Fig. 18. Flood hazard map of the Sagmu-Koshi catchment area.
Engineering approach of geo-disaster mitigation

Low cost technology in roadside slope protection

Network of French Drains km 69+000 Arniko Highway
16 years ago

Good approach to draining (French drain) rather than catch drain

Low cost slope management system

Draining (French drain)
km 69+000 of Arniko Highway French Drain is draining well

Japanese Sabo-dam copied in Nepal

IIUSTRATION OF STRUCTURAL MEASURES

Bioengineering on Problematic slope

Photo source: J Howell

Famous Baglung loop before and after bioengineering, western Nepal

Rainfall pattern of the Koshi Highway Eastern Nepal

Photo source: J Howell

Stable slope in the area of maximum rainfall because of bioengineering structures

(Adopted after Howell 1991)
Stabilized slope in combination of civil engineering and vegetative system.

Coir netting in roadside slope at Balephi-Jalbire Road (0+500 km), Sindhupalchowk.

Effectiveness of Bioengineering to in our roadside slopes

Balephi-Jalbire Road, km 0+500.

Tree Plantation

After Drainage and Bioengineering Measures

Krishnabhir landsides

Towards Stabilisation 2004
Krishnabhir is also now continue process of stabilization by the help of bioengineering and structural measures through Rock bolting Cantilever Structure km 31+950, Arniko Highway

Protection from Bank Cutting, but extensive shallow failure problems on uphill slope after extreme rainfall of 2002, Banepa-Sindhuli Road, Bhakude-Nepalthok Section

Community participation in river training work – use of locally available materials

After six years
Thanks to nature!!
Concluding remarks

- Highly dynamic physical processes dominate the mountainous terrain of Nepal, and therefore, mitigating geo-disaster is a challenge.
- Monsoon rainfall is the main trigger of landslides and floods in Nepal
- Construction, maintenance and rehabilitation of infrastructure under the unique Himalayan condition require innovative and more pragmatic approach compared to less critical terrains in other parts of the world.
- Land management code should be implemented in coordination with landslide and flood hazard zonation map of the area
- “Low cost” infrastructure is not always right for low income countries like Nepal

Concluding remarks contd.

- Over the years, Nepal has gained both good and bad experiences in geo-disaster mitigation:
  - in design and survey of geo-disaster mitigation programs,
  - in the fields of hazard and risk assessment,
  - in low cost rural road engineering – how much bad and how much good
  - in community based river training work, and
  - in slope maintenance incorporating indigenous techniques.
- The governmental agencies involved in geo-disaster management must change their status from implementer to facilitator.
- Government should enhance institutional capacity building at local level to enable local bodies to undertake the immense responsibility of geo-disaster mitigation.
- Positive people perception for geo-disaster mitigation and community participations in mitigation program are very important for geo-disaster management in Nepal

Welcome to Nepal

Thank you very much for your kind attention!!