Relationships among landslides, slope geometry, and river steepness

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Landslide activity in Himalayan region is controlled by a complex interaction among geological structures, earthquakes, geomorphological, meteorological, and hydrological factors.

- Landslides triggered by the 8 October 2005 Kashmir earthquake (Lewis et al., 2007).
- The catastrophic landslide of 16 July 2001 in Phata Byung area, Rudraprayag District, Garhwal Himalaya, India (Naithani et al., 2002).
- The relationship between geology and rock weathering on the rock instability along Mugling–Narayanhat road corridor, Central Nepal Himalaya (Regmi et al., 2013).

The objective of this study is to understand the relationships of some of those factors with existing landslides in geologically, and geomorphologically, least explored far west Nepal using the following methods.

- Spatial analysis.
- Geometric alignment between topography and the geologic bedding planes.
- Fluvial knick zones.
- Quaternary dating of deformed terraces.
Methods & Results
Landslide Inventory
Digital Topographical data

DEM from digitized contours

ASTER DEM (HR 29 mtrs)

SRTM DEM (HR 3 arc sec)

Legend
DEM
Height in meters
- High: 2100
- Low: 520
Slope map from digitized contours

Slope map from ASTER DEM (29 mtrs)

Slope map from SRTM DEM (3arc sec)
Spatial Analysis
Spatial Relationship among Landslides and Major Geological Structures in Nepal Himalayas

Legend
- National Boundary
- Major towns
- Landslides

Elevation in Meters
- High: 8848
- Low: 15

Major Geological Structures
- HFT (Himalayan Frontal Thrust)
- MBT (Main Boundary Thrust)
- MCT (Main Central Thrust)
- RT (Rangarh Thrust)
- STD (South Tibetan Detachment)
Dip amount layer (IDW interpolation)

Dip direction layer (IDW interpolation)
Topography, Geological Structures, and Landslides
Ross K. Meentemeyer, Aaron Moody 1999

\[ \text{TOBIA} = \cos \theta \cos S + \sin \theta \sin S \cos(\alpha - A) \]
\[ \theta = \text{Bedding dip amount } 0-90^\circ \]
\[ S = \text{Slope } 0-90^\circ \]
\[ A = \text{Slope aspect } 0-360^\circ \]
\[ \alpha = \text{Bedding dip direction } 0-360^\circ \]
Deviation angle ($\theta$) layer
\[
\text{con}(\text{abs}([\text{Aspect}] - [\text{DipDir}]) < 180, \text{abs}([\text{Aspect}] - [\text{DipDir}], 360 - \text{abs}([\text{Aspect}] - [\text{DipDir}])))
\]

Apparent dip ($\beta$) Layer
\[
\beta = \tan^{-1}(\tan(\alpha) \times \cos(\theta))
\]

$\theta$ = Deviation angle layer
$\alpha$ = Dip angle layer
Histogram represents the strong correlation among threshold cataclinal slopes and landslides.
Fluvial Knick zones, Landslides, and Geological Structures

Snyder et al., 2000; Kirby and Whipple, 2001; Wobus et al., 2006a; Garzanti et al., 2007

According to above authors the geometry of river longitudinal profiles can be characterized by power law function of drainage area and channel gradient as expressed in the following equation:

$$S = K_s A^{-\theta}$$

$S =$ Local Channel Slope
$K_s =$ Local Steepness Index
$A =$ Upstream drainage area
$\theta =$ Concavity Index
Conclusion

Gamini JAYATHISSA, Dietrich SCHRÖDER and Edwin FECKER 2009
Conclusion continued

• Landslide is the result of a balance between driving forces and resisting forces. To date Nepal (a least developed country in Asia) does not have a database that allows planners and policy makers to understand this relationship to save lives and property.

• Our team at university of Arizona is trying to help Nepal by developing a GIS based, geological, geomorphological, and topographical database to understand the above relationship.