Landslide Hazard Mapping and Assessment in Himalayas

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LANDSLIDE HAZARD MAPPING AND ASSESSMENT IN HIMALAYAS

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ABSTRACT

Himalayas offer a good opportunity to study landslides in hard terrains. The region is a well established seismic region of Asia where earthquakes are common occurrence. The on going plate motion and its collision with Asian plate is the main triggering factor for landslides, but there are geological factors that make the slopes susceptible for landslides to be triggered during rains. The Yatra routes of Char Dham the four pilgrimage centers where millions of Hindus go each year for salvation and heaven abode have to face road blocks each rainy season. The border road organization the pioneer organization looking after the roads and their maintenance is beset with so many difficulties and unforeseen geological surprises. The terrain is very rugged and inaccessible. The Himalayas are the highest mountain system on earth and the gravity plays a very important role in landslides. Debris from weak and fragile rocks that are highly fractured due to intense folding and faulting make this terrain very fragile, weak and susceptible to landslides. Therefore a need arose to identify such slopes that are susceptible to landslide hazards. Hierarchical classification of terrain makes the basis of classification of terrain in to slope categories and these basic maps called the facet maps form the foundation of database for hazard assessment. Factors like distance from fault, rock type, density, drainage and fracture density, relief and relative relief and geotechnical factors like dip-slope relationship are taken in ot account to arrive at a landslide hazard Zonation map. Example of such Zonation is presented. The work has a long term approach to landslides and not merely remedial measures in isolation. The identification of slopes vulnerable to slides is one of the main key outcome of the research that has been carried out for the last 20 years or more.

INTRODUCTION

Himalayas the youngest mountain chain on earth and also the loftiest mountain ranges are unique in many ways and its geological set up is responsible for the nature of natural disasters that the range faces. This region which is the backbone of the monsoon rainfall in the northern fertile plains of India where the largest population of the country resides also controls granaries of India as India's budget is a gamble of monsoons (OHK Spate: geography of India). Not only this the mountain range is also a habitat for the wild life sanctuaries and very rare species of animals and flora and fauna due to which the UN has recognized the valley of flower region in Garhwal as a Biodiversity reserve. The significance of the elevation, snow covered mountains and the foothills touching the vast plains of India are some of the characteristic features bordering this land. To the north lies the Tibet plateau the roof of the earth and to the south is the Ganga Plain one of the most fertile lands where largest population of the earth resides with one of the highest density of populations. The Indo Gangetic plains provide the largest granary of India and is also vast reservoir of ground water for its population.
The natural disasters struck this region due to ongoing geodynamic processes which are constantly modifying the landscape of this newly sculptured part of the earth. The present paper focuses on the landslides distribution and attempts to assess the occurrence of landslides in seismically active zones. The recent earthquakes of Chamoli and Uttarkashi and now in Bhutan all suggest the seismic nature of the terrain. On the other hand the Indian Plate is constantly moving north and causing tectonic disturbance eto the existing thrusts and faults. The study carried over two decades of study on landslides has helped arrive at some useful outcomes with respect to the relationship of landslides with geological and geomorphological processes in Himalayas which are discussed.

Earthquake and landslide are two major natural disasters in Garhwal Himalyas. The river blockades like the one at madhymaheshwer Ganga in Chgamoli Rudraprayag district in Higher Himlayas and the Birahi Ganga river during the historical Gona landslide are some of the conspicuous and well known landslide created dams over rivers in Garhwal.

LANDSLIDE HAZARD MAPPING AND ASSESSMENT

The Landslide hazard mapping (LHZ) in Himalayas wa started in 1984 with a few students of the author (Krishna, 1984; Pant, 1986; Gupta, 1990; Ajay Kumar,2001 Amit Pal Singh, 2001;Girish Bairwa 2001 in erstwhile University of Roorkee and first ideas on LHZ were developed on terrain analyses in seventies (Pachauri 1969, 1998, 2001, 2007) prepared based on some of the prominent factors which may be related to land hazards.

There is hardly any plain area in Himalayas as this is a mountainous terrain. Thus slopes which make most of the Himalayas are the first to be identified. Krynine and Judd (1957) and Varnes (1958) and many authors gave types of landslides as well as analyses of wedge failures, which include slope as a major factor in landslide analyses. Therefore we made first what are called the slope maps of the region at 1: 50, 000 scale. One such map is shown in the adjacent Figure 1.

The mapping of landslide hazards involves two steps:
I. Making the basic unit maps and identification of such base units.
II. The score value of each unit.

The first step is incorporated by finding slope categories of the maps is question. The slope map is generated by using contour intervals and the contour distances on the scale of the map. Thus boundaries of each map is created and we end up getting a slope area whose limits are known to us.

The following slope categories are used in the mapping:

Escarpment/Cliff
Very Steep Slope
Steep Slope
Mod Steep Slope
Less Steep Slope
Mod Gentle Slope
Gentle Slope
Very Gentle Slope

These categories are shown I n the map and these we call the facet map of an area. (Fig.1).

Advantages of facet maps in LHZ

The advantages of a slope facet map are numerous. First they are easy to make and hardly any Software is required and no trained manpower is needed in this case. However if we insist for a software to do this than the Envi Image software for textures may be the useful ones.

This facet map is made from contour data manually. However some argue that a DEM may be used to make such a slope map and that can be tried also. But the results are not the same.

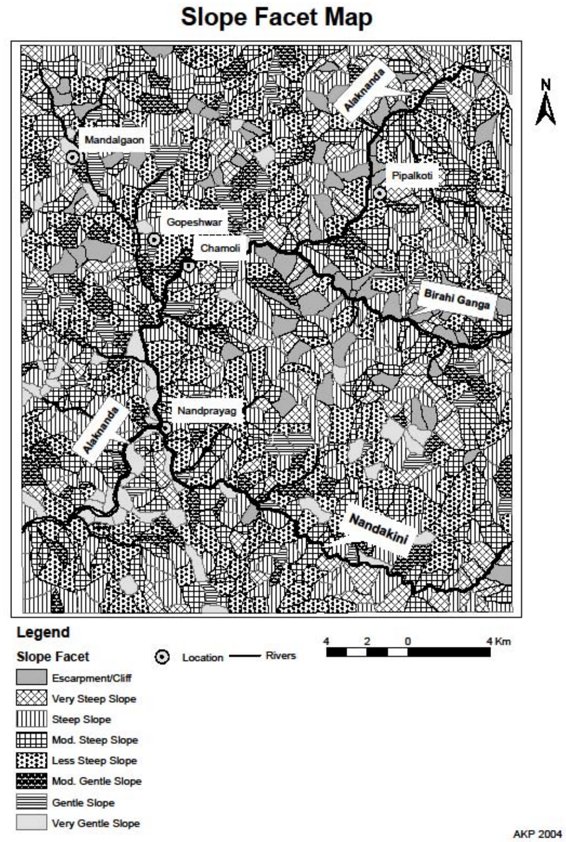

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Fig.1, Slope facets as listed in text and drainage system of the area around. Chamoli. The streams are all a part of the Alaknanda river system which is called Ganga further downstream at Rishikesh.

The factors and scoring of facet scores:

The facets are taken as base units in which all the landslides are first plotted and a correlation found. Once a correlation has been established that base don the degree of correlation of the factor in question, the weights are used and a score of each category arrived at and a LHZ map as shown below is obtained. The following factors are used:

Distance from the fault
Distance from the drainage
Relief
Rock type
Dip slope relationship
Geotechnical data using dip direction, amount and slope

The relationship between drainage lines and landslides or rather distance to landslides is a significant observation. This is due to the fact that drainages especially the first order drainages are often developed along fracture planes which become pathways for the rain water to follow. It has been found that there is a fair coincidence between the slides and drainage lines which is reflected in the buffer zone analyses of drainage lines. The buffer zone of 200 meters is a good distance for accounting most of the cliffs and slides which suggests a downgrading and vertical cutting of rivers due to rise of Himalayas is a significant factor. This is a part of erosion process in Himalayas. A buffer zone can easily be generated using Arc Info and relationship of cliffs and slides found.

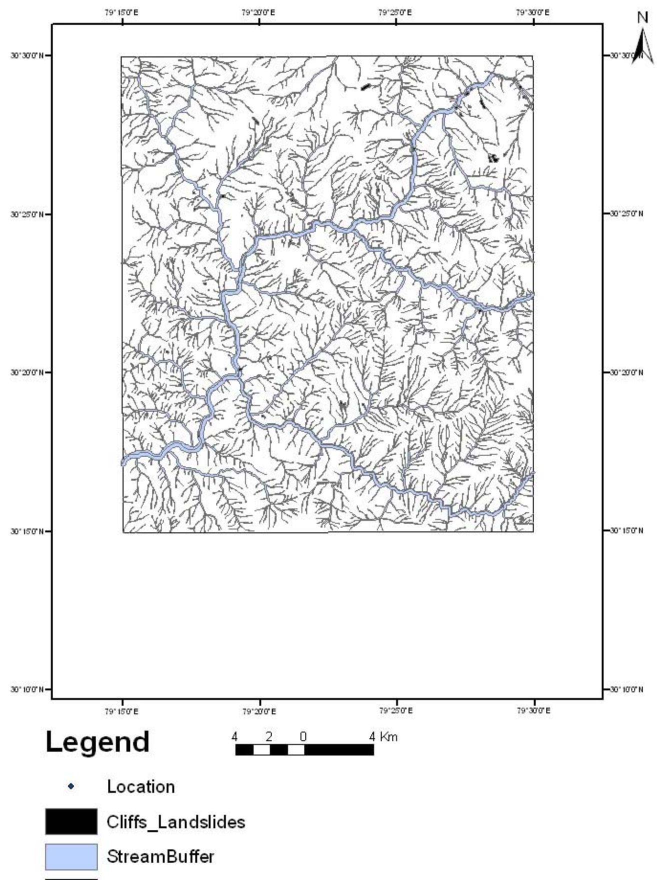

Figure.2 The figure shows cliffs and landslides in the region developed in proximity of drainage lines. The black dots show that more number of slides develop by drain sides due to tectonic erosion due to rise of Himalayas specially in Higher Himalayas. However landslides occupy spaces between them.

Seismicity and landslides

The Chamoli earthquake of March 2003 which was of 6.5 M and the epicenter of which lay in Chamoli near Gopeshwer, was surveyed and the isoseismic lines marked using damage surveys of the region and published reports suggest the isoseismic lines of the highest value encompassed a good amount of slides of the terrain. In fact not all slides were related to Chamoli earthquake because several slides existed before the earthquake came but most of them were retriggered and reactivated therefore IRS Satellite images did show some new but generally reactivated landslides in the area.

A score system worked out by Pachauri and Pant (1992) was used to apply on the terrain here as rocks are similar and part of the Lesser to Higher Garhwal Himalayas. The scores were divided in to five categories and a LHZ zone map arrived at a shown in the following figure. Four zones are shown in the Figure 3 where elevations are also shown with different colors.

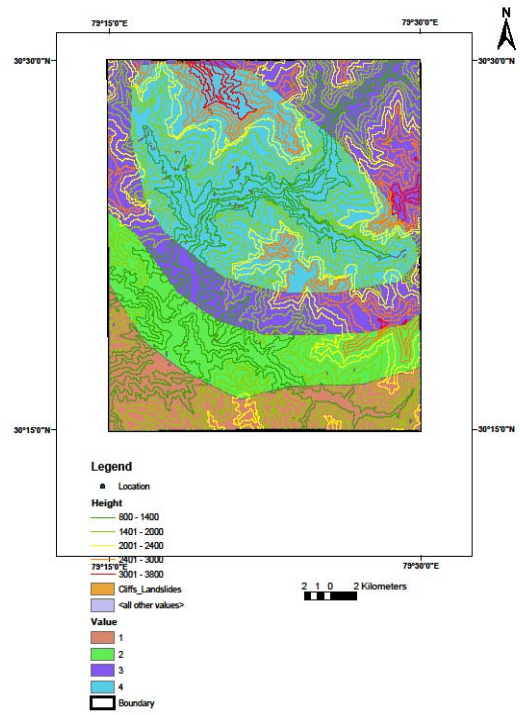

Figure. 3. Seismic zones of Chamoli earthquake and landslides in the isoseismals, the highest being in the inner zones.The levation range from 800 to 3000 m contour interval is 200 meter between contour lines.

LHZ maps and their advantages

The LHZ maps could be made and shown in green to red colors depicting go to stop signals from safest to vulnerable slopes. These are though tentative but they are very informative and first order maps for planning stage. These can be used for land use planning as well as road alignments. However before entering into any land use, one has to check them in the field and find out in the area of study as to where such slopes are really susceptible for landslides. The zones are suggestive and show the method of assessment of landslide possibility. There is a possibility that very high hazard zones are the ones that require prior treatment and attention and that these slopes are more vulnerable to slides given the slope, rock type and other factors as established.

The example of a LHZ map is shown here in Figure 4 with several colors of zones from high (red) to low (green). Zimmermann et al (1986) made similar maps in Nepal but these were representative of general category and not based upon the score system in each slope.

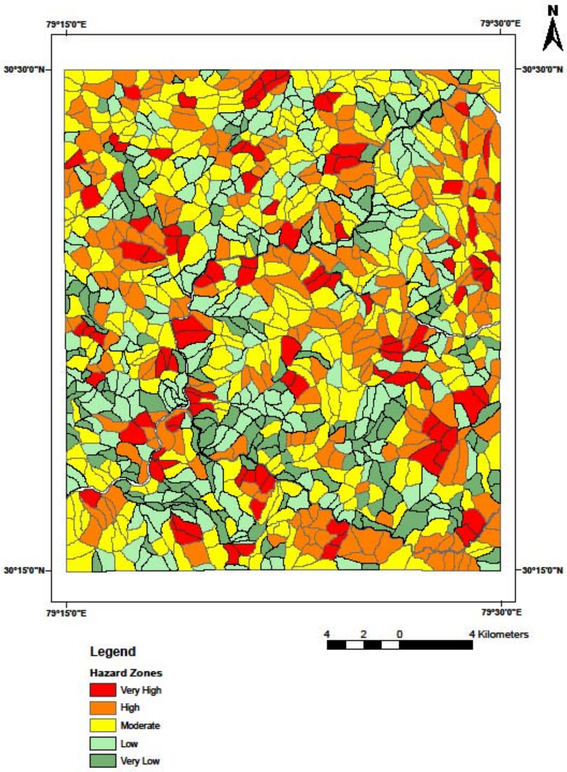

Figure 4. The Landslide Hazard Zonation map of the area based upon slope mapping and scores.

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