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Landslide Hazard Zonation Mapping using Remote Sensing and GIS

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Abstract—*Landslides are major hazards for human activities that often cause huge economic losses and property damage. Landslides are the movement of a mass rock debris or soil along a downward slope due to gravitational pull. A variety of movements is associated with landslides such as falling. Many landslides exhibit a combination of two or more types of movements resulting in a complex type .They are triggered by a number of external factors such as intense rainfall, earthquake shaking, water level change, storm waves, and rapid stream erosion. In addition extensive human interference in hill slope areas of construction of roads, urban expansion along the hill slopes also triggers landslide. Identification of landslide hazard zones is a challenge. There are different techniques to determine landslide zones. Geological technique is very rigorous whereas remote sensing and GIS based techniques are quick but often fail to demarcate hazardous zones accurately due to lack of data or ineffective data processing techniques. Thus there is a strong need to evolve a remote sensing and GIS based technique which can quickly and effectively delineate landslide hazard zones.*

The authors studied the landslide hazard zone mapping using remote sensing and GIS based technique for Himalayan region where landslides are very common. CartoSat PAN IRS satellite images at resolution of 2.5 m and LandsatTM multispectral images of Garhwal Himalayan region in Giri valley were used for the study. In this reference some input

Maps such as slope, aspect and relief were derived from DEM (Digital Elevation Model). On the other hand, the maps such as geology maps, geomorphology maps were derived from multispectral Landsat TM images. Overlay analysis method was used then to integrate the above data to identify the landslide spot zone. The overlay analysis methods were used based on the wheightage of respective map. This study mainly aimed at fuzzy algebraic algorithms with overlay analysis to find effectively the landslide hazard zone. It also tried to quantify the hazards due to the landslides for different landslide types.

Keywords*: Landslide, Overlay, Cartosat-1 PAN 2.5m, Landsat TM, Erdas imagine ArcGIS, ILWIS Software.*

1. INTRODUCTION

Landslides are major hazards for human activities that often cause huge economic losses and property damages (Das et al. 2010). Landslides in a strict sense are the movement of a mass of rock, debris or soil along a downward slope, due to gravitational pull. Varieties of movements are associated with landslides, such as flowing, sliding (translational and rotational), toppling or falling. Many landslides exhibit a combination of two or more types of movements, resulting in a complex type (Varnes 1984). They are triggered by a number of external factors such as intense rainfall, earthquake shaking, water level change, storm waves and rapid stream erosion etc (Dai et al. 2002). In addition, extensive human interference in hill slope areas for construction of roads, urban expansion along the hill slopes, deforestation, rapid change in land use contribute to instability. This makes it difficult–if not impossible–to define a single methodology to identify and map landslides, to ascertain landslide hazards (Guzzetti et al. 2005). It thus necessitates a detailed understanding of the physical process, including historical information on their occurrence. Growing environmental concerns in recent years have resulted in quantitative landslide hazard assessment studies (Alexander 2008; Carrara and Pike 2008). The assessment of landslide hazard has become an important assignment for various interest groups comprising technocrats, planners and others mainly due to an increased awareness of the socio-economic significance of landslides (Devoli et al. 2007).

Hazard quantification of landslide is one of the challenging jobs for the Geo-scientists because of the uncertainty associated with its occurrence and its complex mechanism. During the monsoon periods landslides occurring in the study area pose serious threat to the road as well as the vehicles, commuters. It affects directly or indirectly to people as well as natural environment. As the landslides are inevitable their hazard quantification is the best solution to save the people and their properties from danger of landslides. This type of study will help the planners and decision makers to take appropriate action and to reduce the effect by taking preventive measures.

The study to evolve a remote sensing and GIS based technique to extract, compare, and integrate land features to effectively indicate the landslide hazard zone for an area. It used satellite images of Himalayan area which is prone to frequent landslides and processed the data using a sequence of remote sensing and GIS based technique to determine landslide hazard zones and tried to evaluate the potential of landslide there.

2. STUDY AREA

The study area is located in the northern Himalayas. It lies between 30^0 42’ 14”N and 29^0 43’ 39”N latitude and 79^0 5’ 35”E and 78^0 58’57”E longitude. The study area lies in Giri valley, Himachal Pradesh which is mostly mountainous, frequently experience natural disaster such as landslides. Generally landslides occur in the region following heavy rain in month of July and August. Some other landslides are occurred by human activity. Construction and widening of the road along the steep hill slopes are the main anthropogenic cause of the slope instability.

3. MATERIALS AND METHODOLOGY

3.1 Data

Here we used data for Cartosat (2.5m) Resolution with Landsat TM .These data was processed in ERDAS imagine, ArcGIS and ILWIS.Other data to be used SOI topo Sheet .

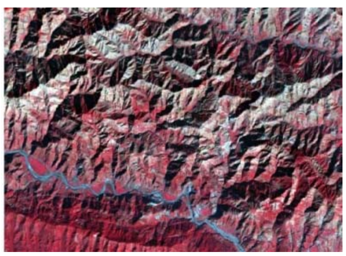

Fig. 1: Landsat image in study area

3.2 Methodology

Landslide hazard zonation mapping is made on the basis of weighing the causative thematic data of landslide such as slope map, aspect map, lineament density map, Drainage map and NDVI. The concerned parameters are considered responsible for landslide. The reasons for giving them the importance are given below.

Slope is most influencing factor for assessing the landslide study for the road corridor. Landslides normally associated with increase in slope steepness and slope length. As a result, there is an increase in velocity and volume of surface runoff.

Aspect plays a significant role in slope stability assessment in the Himalayan terrain, where most of the south-facing slopes are poorly vegetated, resulting in rapid mass wasting on moderate to steep slopes.

Geological discontinuity like Lineaments, are the most significant weak planes which plays a vital role in mass movement processes. So for landslide susceptibility analyses, frequency or the density of lineaments are necessary to prepare because they are likely to be affected by the mass movement process around the lineaments (Purohit et al., 1990). It varies depending upon the nature of terrain, nature of study and overall pattern of landslide distribution in particular area. For the present study, lineaments were extracted from the satellite image interpretation and edge enhancement and filtering techniques as well as field verification.

For preparation of landslide hazard zonation mapping the above land features (slope, aspects, etc.) are required to be integrated. GIS based overlay analysis was used to carry out this integration with proper weights to each of above factors.

The processing involved DEM extraction and digitization of satellite image to generate characteristic slope map, aspect map, drainage map, lineament density map and NDVI (Normalized Difference Vegetation Index) for vegetation index. Based on practiced weightage (Purohit, 1990) the thematic maps were integrated to determine a landslide hazard zonation map. Susceptibility class is then found out based on the susceptibility index of landslide zones. The detail process flow is given below.

Fig. 2: work flow chart

4. RESULTS

4.1 DEM Extraction from Cartosat-1

The digital elevation model was generated by Cartosat-1 stereo pair (Fore and Aft) images. The ground control points (GCP) were collected using Differential GPS (DGPS) survey to refine the coordinate parameters.

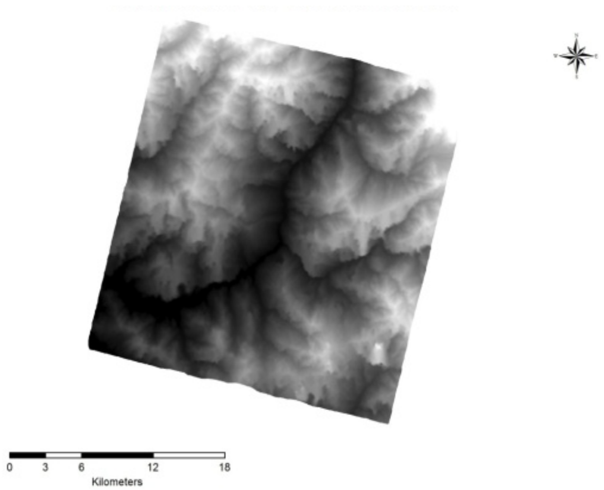

Fig. 3: DEM

4.2 Slope Map

Slope is derived from DEM For the present study, slope (0-76 degree found for whole area) was divided into six classes with 10 degree interval as per slope classification (Kanungo et al., 2006). 25 to 60 degree slope was found in major portion of the region. The classified slope is given below.

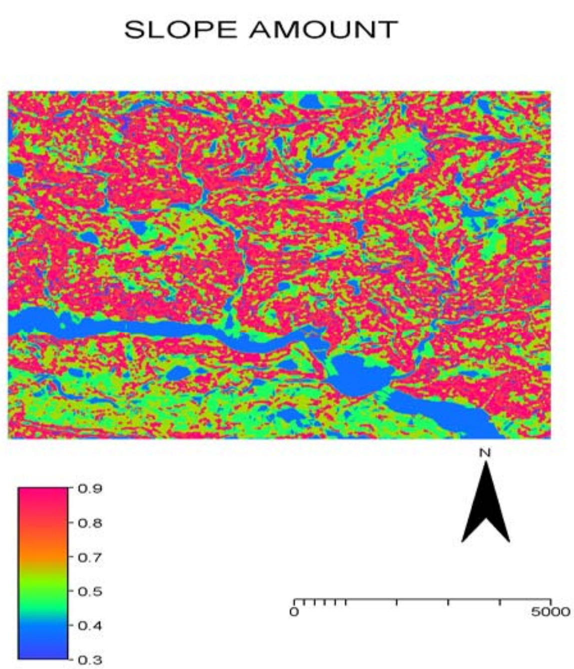

Fig. 4: Slope Map

4.3 Aspect Map

In this study, aspect was divided into eight classes. Such as N, NE, E, SE, S, SW and NW (Kanungo et al., 2006). The classified aspect map is given below.

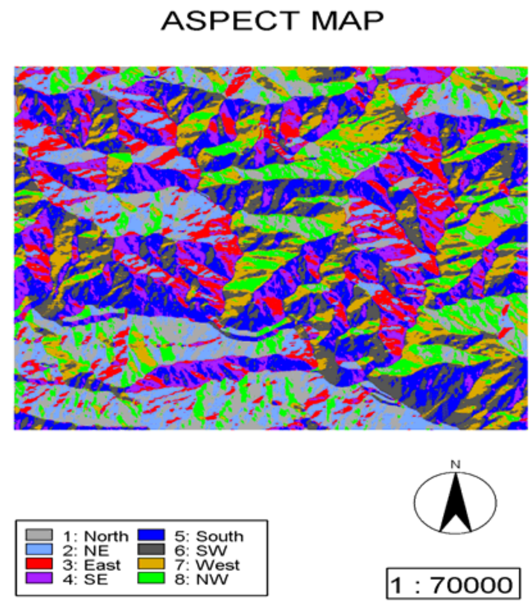

Fig. 5: Aspect map

4.4 Lineament Density Map

The density was calculated by the total length of lineament per grid and the value was converted into a point. According to their values, again it was classified into different classes. The lineament map and the classified lineament map are shown below.

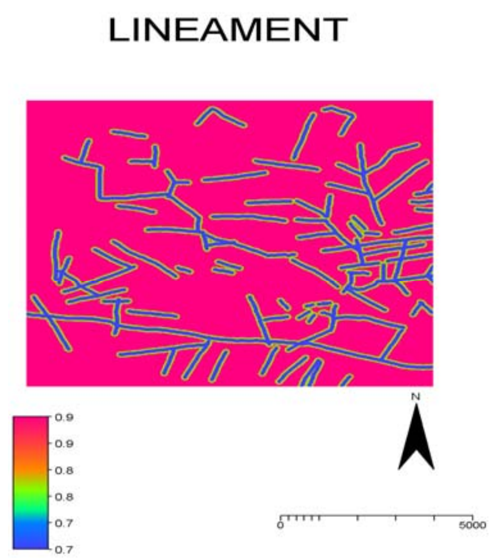

Fig. 6: Lineament map

4.5 Drainage Map

The drainage map was prepared from the satellite images map with ancillary information. The main drainage pattern of the area is having dendritic pattern. With this information, a drainage density map was prepared using the density calculation formula. After calculating the density values, again it was classified into different classes. The final drainage density map is shown below.

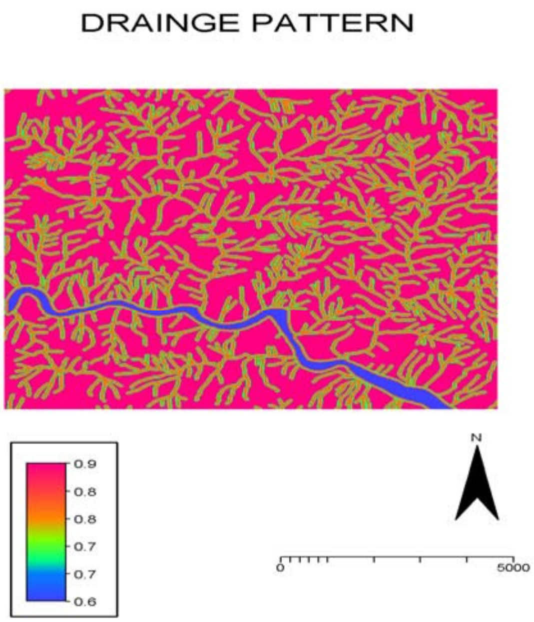

Fig. 7: Drainage map

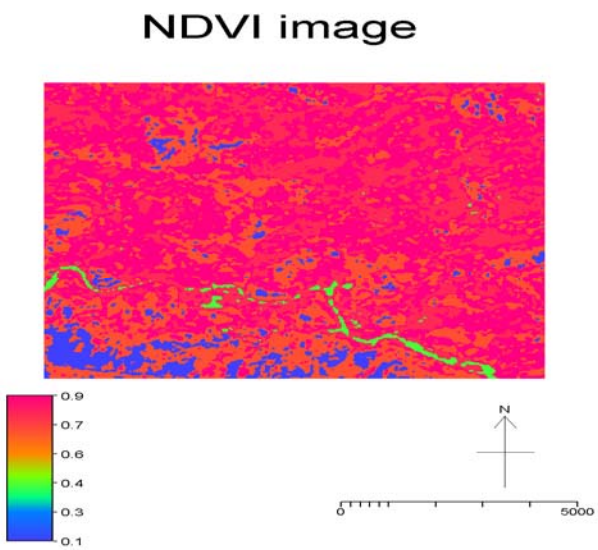

Fig. 8: NDVI map

4.6 Landslide Hazard Zonation Map

Landslide hazard zonation map is prepared by integrating the effect of various triggering factors. Weightage is assigned to the factor considers. The weights are assigned as show in the table.

Table 1: Weightage for thematic maps

S. No.	Theme map	Measure	Maximum Weightage
1	Slope map	Degree of slope	30
2	Aspect map	Direction of map	15
3	Lineament map	Lineament density	15
4	Drainage map	Drainage density	15
5	NDVI Image	Vegetation Index	25

Susceptibility index of the susceptible zonation is calculated by multiplying the multiplication factor of rank with the weightage assigned for each theme.

Susceptibility Index= Multiplication Factor of Rank

X Weightage

Then the summation of susceptibility index of each theme could give the susceptible value for individual polygons. Based on the susceptibility index the susceptible zonation was classified in to six groups (veryhigh, high, moderate, semimoderate, low, very low) and ordered in accordance to their triggering capacity.

Table 2: Susceptibility Class

Susceptibility index	Susceptibility Class
0-0.0023	Very Low
0.0023-0.0762	Low
0.0762-0.1502	Semi moderate
0.1502-0.2241	Moderate
0.2241-0.2981	High
0.2981-0.3720	Very High

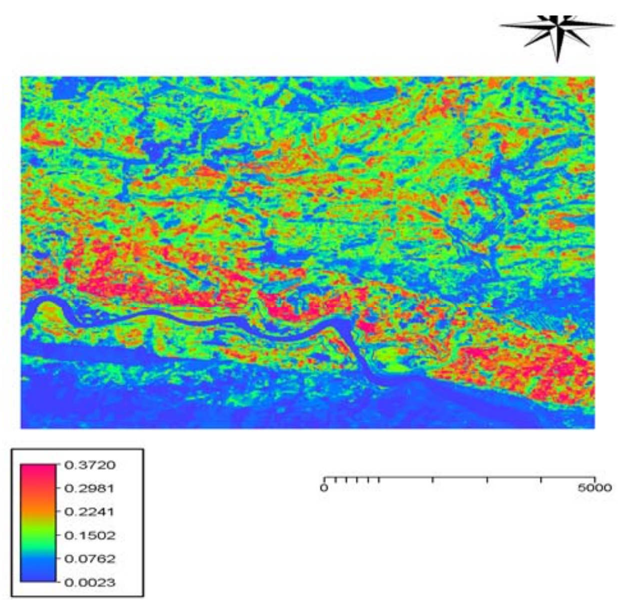

Fig. 9: Landslide hazard map

5. 5. DISCUSSION

Digital elevation model, lithology, land cover, lineament, drainage pattern, slope amount were used to successfully indicate the hazard zones. Susceptibility index could also helped to compare the potential of landslide hazards for different zones.

Based on the susceptibility index the landslide susceptibility levels were classified in to six classes. The susceptibility index increased when landslide susceptibility levels were increased for a particular area. The areas which were susceptible to landslide were calculated and is given in Table 2.The southern portion of the area is highly vegetated where the extent of landslide prone area was very low .South east part showed highly landslide susceptible zone. Similarly, south west parts also found to be highly susceptible to landslide. North of the area on the other hand showed moderate landslide susceptibility.

6. CONCLUSION

The remote sensing and GIS based techniques could successfully extract the hazard zones in Himalayan area. The technique processed satellite images to do it. Processed thematic maps containing slope, aspects, lineament, drainage and NDVI were integrated in GIS environment using Fuzzy logic. The technique could effectively indicate the susceptible hazardous regions for landslide. The final landslide susceptibility levels ranged between 0.0023 to 0.3720; representing the areas with the lowest landslide susceptibility (0.0023), and the highest landslide susceptibility (0.3720) in south east.

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