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Generation of Thematic Layers from Spatial Database for Landslide Hazard Management in Part of Garhwal Himalaya

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ABSTRACT - Landslides are one of the important natural hazards of Himalaya. Due to landslides, the Himalayan region often faces geoenvironmental problems posing threats to, both, life and property. The fragile Himalayan ecosystem, which is characterized by weak rocks, various types of geological discontinuities and unfavorable hydrogeological conditions, is more prone to frequent slope failures especially along the rail and road cut slopes and building terraces. During the past few decades, the processes of natural instabilities have been accentuated due to accelerated anthropogenic activities. The hill slopes located in zones of high annual precipitation and/or seismic activity, are more susceptible to landslides. The following study deals with the layer generation for landslide hazard zonation mapping and inter relating the generated layers with actual ground conditions.

Keywords: Aster DEM, GIS, Garhwal Himalaya, LANDSAT, LISS III, RS

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1 Introduction:

Garhwal Himalaya is a very complicated, structurally disturbed part of Alpine-Himalayan orogenic belt where sediments have been compressed about 65% total compression. This has resulted in the formation of steep slopes with deep valleys and unstable escarpment slopes. The National Highway NH-58 that runs from Rishikesh to Mana via Pipalkoti and Joshimath and has always been prone to severe landslides especially in monsoon or little post monsoon season. The constant mitigation measures including the civil engineering repairing works consume the exorbent expenditure every year to improve the slope stability. A major landslide occurred near the village Pakhi in Chamoli district which is being triggered every year to enlarge its outcrop. The area also has several structural lineaments which can be clearly seen on the satellite imageries, indicating structural weakness of the region. The rock mass is also highly sheared and fractured and also weathered upto considerable depths. The area lies in Seismic Zone V. The minute seismic event may act as a triggering factor to a landslide. Also the road traffic load provides a sort of dynamic seismicity that may trigger the slope instability. The general site observations, signatures on satellite imageries, the characterization on generated GIS layers for the same landslides have been discussed in this paper. Along with the same task one more effort is being made to suggest the civil engineering mitigative recommendation.

2.0 Study Area Location:

The Pakhi landslide area lies in Survey of India Toposheet No. 53N/7 along the road NH-58 that descents from Rishikesh to Mana via Chamoli-Pipalkoti-Joshimath-Badrinath, mostly on the left bank of river Alaknanda. Present landslide is located at Latitude $30^0$27’57.6”N and Longitude $79^0$27’27.67”E, near village Pakhi in Chamoli district. The landslide area has very high relief and the lithology-structure controlled flow accumulations running towards Alaknanda mainstream controls the sliding movements. Along a road curvature the length of Pakhi landslide is about 340m with the considerable disturbed elevation. The seasonal temperature variations are 4^0 C to 30^0 C with very heavy monsoon showers. The site is easily approachable from Chamoli by road.

3.0 Objectives:

The present study deals with the observations, analysis and interpretations of remote sensing data, Cartosat-I DEM and various GIS layer output from the same DEM. The observations at the site made during the groundtruthing field visit shall be correlated with some RS and GIS data layers. The interpretative outcome has been brainstormed for finding the causative factors of the sliding movements. After studying the actual site condition and the causative factors, effort will be made to suggest a remedial recommendation. Remote sensing data used includes Band 4, Band 3 and Band 2 imageries of Landsat 7 TM data. High resolution color composite from a

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free web source has also been imported and georeferenced in GIS environment. Also IRS-1D LISS III data has been used for interpretation. Cartosat-I Digital Elevation model has been analyzed and the generated thematic layers have also been interpreted. The inherent objective is to correlate the RS & GIS database with the suitable mitigative recommendation.

4.0 Methodology Of Generating Layers:

The methodology adopted for the flood hazard zonation mapping in the study area, includes the various geoinformatical tools comprising geographical information system (GIS) technology and the satellite remote sensing (RS) techniques. The guideline provided by NNRMS course (Indian Institute of Remote Sensing, Four Kalidas road Dehradun). The generated RS/GIS layers have been interpreted by the conventional photo recognition elements or image interpretation keys along with the generated GIS data base for the decision making i.e. related to the landslide hazard management and mitigation techniques. The software ILWIS was used for analysis.

4.1 Preparation of the basic layers

The readily available Landsat 7 TM data was used with bands 4, 3 and 2 with 30 m spatial resolution. Similarly, IRS 1D LISS III data with 23.5 m resolution was also used. Aster DEM with 30 m ground resolution has also been used as a basic layer. High resolution color composite was also imported in IlWIS environment and georeferenced with respect to Landsat 7 and LISS III data. Also the mobile handset having the offline GPS facility has been specially procured for the ground truthing of web based and generated RS&GIS layers. It has been found to be equally effective tool in comparison with the routine GPS handset available in the market.

4.2 Preparation of Thematic layers

By on screen digitization on basic layers the following segment maps were prepared.

Road Map (Part of NH-58, near Pakhi)
Settlement Map (Fig. 1)
Lineament Map (Fig. 2)
Forest Map
Pre-occurred Landslides Map (Fig. 3)
Lithology Map (Fig. 4)

Settlement, forest, prior events maps were polygonized and rasterized for further analysis.

Digital Elevation Model (DEM) was analyzed for obtaining the following raster outputs.

Elevation Map (Fig. 5)
Slope Map (Fig. 6)
Slope Aspect Map
Slope Shape Map
Flow Direction Map
Flow Accumulation Map (Fig. 7)
Slide Prone Flow Accumulation Map

These rasters really speak volumes about the slide prone or unstable slopes in Pakhi area. Elevation map shows a sliced elevation zone of maximum prior events. Slide prone slopes have been extracted from slope degree map. The slicing range was decided after measuring several slopes near prior events. Slope aspect map was prepared and maybe further utilized in combination with the structural attitudes of the existing strata. The criss-cross concavo-convex slopes in slope shape map indicate a thick soft overburden resting with angle of repose, on sloping bed rock. Flow direction map is a basic layer to develop flow accumulation map. Each pixel in flow accumulation map indicates a number of pixels flowing towards that pixel from upstream locations. The slide prone flow accumulations were extracted from flow accumulation map. The value ranges of slide prone flow accumulations were decided after studying the flow accumulations near pre occurred slide events.

The map showing lithology (web source) was directly imported and georeferenced in ILWIS and used for analysis. This map depicts the outcrops of various lithological units as quartzite, limestone, alternating layers of shales, slates, phyllites and also some isolated patches of unconsolidated or semi consolidated sediments.

Some of the vector and raster thematic layers generated have been illustrated in the pictorial collection.

5.0 Interpretations And Analysis Of GIS Layers:

From the manual interpretation and the comparative observations of different thematic layer combinations one can locate the hazardous sites having unstable slopes where the landslide event maybe triggered in heavy rainfall. The sites of prior events and the sites where slide prone slopes, slide prone flow accumulations, structurally disturbed lithological conditions are found to be susceptible to slope failures. The susceptible locations having vicinity of road, settlement have been considered as landslide vulnerable sites. After such brain storming exercise on various rasters the Pakhi landslide was found to be very vulnerable location where Rishsikesh - Mana highway gets blocked every year even after providing the traditional civil engineering mitigative measures.

6.0 Concluding Remarks:

Remote sensing and GIS or the geoinformatical tools have been found to be very effective in finding out the landslide hazard locations especially slope, flow accumulation, lithology and settlement or Landuse/Landcover map are few of the important GIS layers for this task. All the raster layers including buffer maps of the segments like road and lineaments may further be used in software based statistical analytical methods like Information Value techniques. These techniques automatically extract the vulnerable locations. Pakhi landslide bears structurally disturbed lithological conditions and weathering zones persisting with depth. Weathering conditions are prominent especially along joints and fractures. Smallish to larger joint blocks suddenly dislodge and causes the rock avalanching or debris flows. The mitigative measures like cutting the slopes and providing lined drainages followed by rock bolting and mechanically stabilized retaining wall may mitigate the hazardous situation for longer time. The plantation of Pine, Deodhar, Golden Oak etc may improve the stability factor of slopes and allow the uninterrupted traffic towards the holy places of Joshimath, Vishnuprayag, Govindghat, Badrinath and Mana.

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Fig. 1

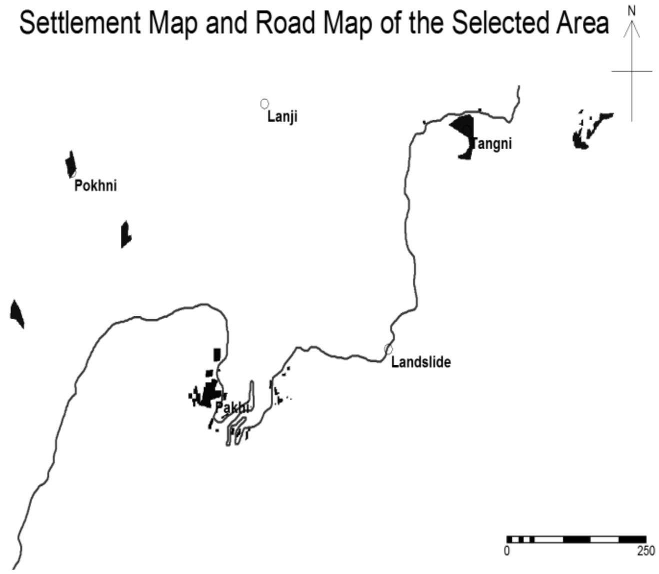
Settlement Map and Road Map of the Selected Area
N
Lanji
Tangni
Pokhni
Landslide
Pakhi
0
250

Fig. 2

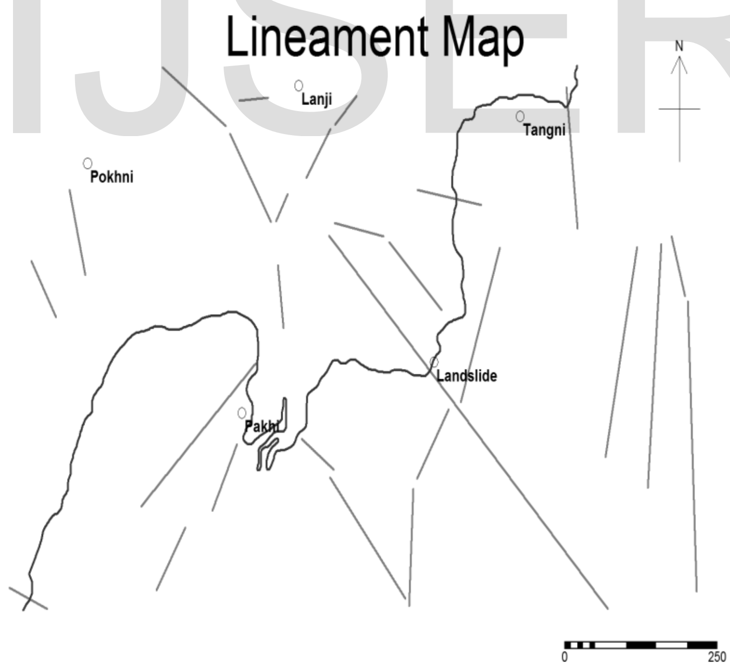
Lineament Map
N
Lanji
Tangni
Pokhni
Landslide
Pakhi
0
250

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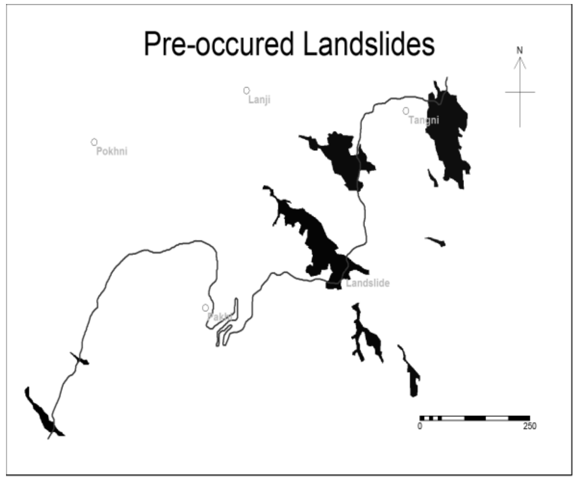
Fig. 3



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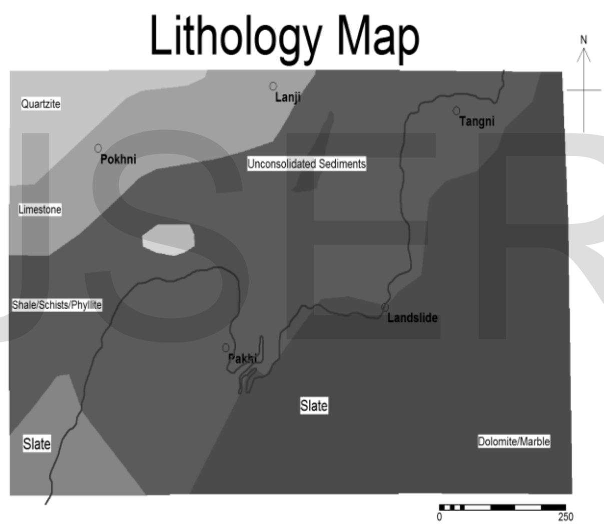
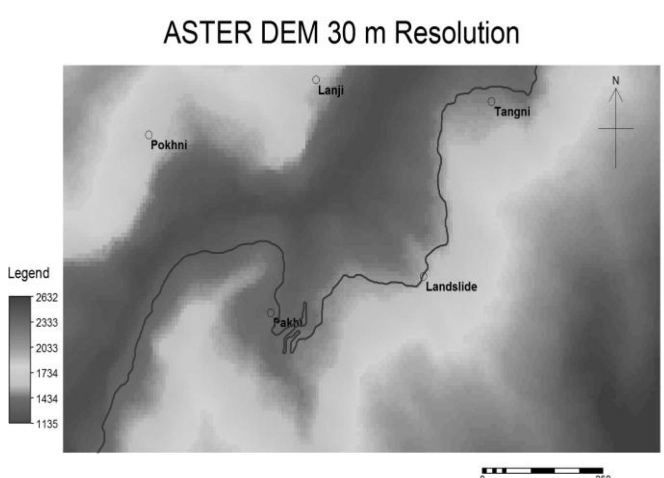


Fig. 5



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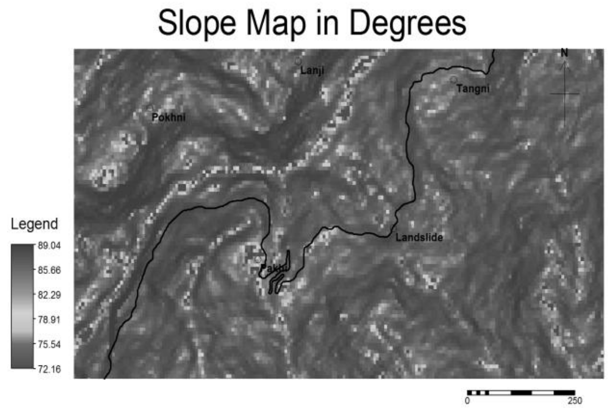
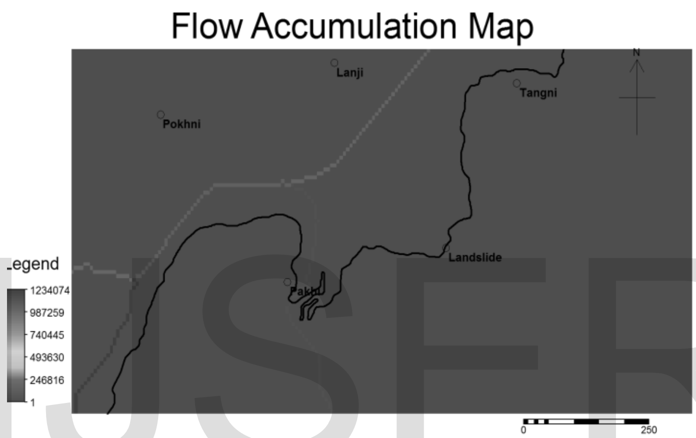
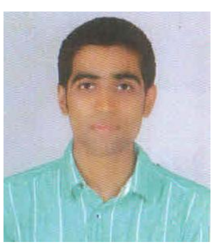


Fig. 7





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