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Gis-Based Landslide Hazard Zonation Mapping Using Weighted Overlay Analysis In The Part Of Tehri Dam Area, Tehri Garhwal, Uttarakhand, India

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Abstract:

A basic study for the demarcation of landslide hazard zones using Weighted Overlay Analysis in ArcGIS software, have been done for the part of Tehri Reservoir region, Tehri Garhwal District, Uttarakhand. India. The objective of this present study is to prepare landslide hazard zonation map in the study area. Total 198 landslides have been recognized using world view-2 satellite image. In this study five causative factors have been taken such as slope, aspect, geology, drainage and land use/ land cover. Remote sensing data and ancillary data have been used to prepare landslide inventory map and thematic layers for hazard zonation mapping. Slope, aspect and drainage map have been derived from the ASTER DEM satellite data. Geology map has been taken from the Geological Survey of India. Land use/ land cover map has been prepared using World view -2. The results of this study shows the three zones such as high, medium and low. Out of the total area 2.74 percent area is under high hazard zone, 0.386 percentage of area is under medium hazard zone and remaining 96.87 percentage is under low hazard zone. The result of this study also reveals that most of the landslide have been occurred in the steep slope as well as very near to drainage areas. The final map will be helpful for the local people, engineers, planner for mitigating the hazard and also demarcate the highly vulnerable and low vulnerable zone in the study area.

Key words: weighted overlay analysis, GIS, landslide, hazard zonation, Tehri dam.

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1. Introduction

The geo-environmental factors such as geology, meteorology and manmade factors plays an important role for occurrence of landslide, or landslide is the result of these combine factors. The most influencing factors of landslide are geology, geomorphology, soil, land use/ land cover and hydrological factors which are discussed by Varnes (1984) and Hutchinson (1995). There are many triggering factors for landslide. According to Varnes, 1984, zone can be defined by dividing the surface of the land into areas and ranking that areas on the basis of degree of potentiality of landslide on the slope. The landslide susceptibility zone is defined by the spatial chances of occurrence of landslide due to geo-environmental factors (Brabb, 1984). Both the term landslide hazard zonation and landslide susceptibility zonation have been greatly used in the study of landslide (Anbalagan, 1992; Pachauri and Pant 1992; Nagaraan et al.2002, 2005; Arora et al. 2004; Sarkar and Kanugo 2004; Ayelew and Yamagishi 2005; Kayastha et al. 2013).

Since a few decades Remote Sensing and GIS plays an important role in hazard mapping study in hilly terrain which is inaccessible. Remote Sensing data such as satellite images provide the landslide information. With the help of remote sensing data and GIS software, the landslide zonation map can be done with causative factors. For extracting the attribute data or spatial data, GIS is the best platform. GIS also help in integration and analysis of data. The Weighted Overlay Analysis using ArcGIS software has been applied in this study to identified the landslide hazard zone on the basis of weight value of each causative factors and prepared the landslide hazard zonation map in the study area.

1.1Statement of the problem

The world biggest Tehri Dam, height is 260.5 m is constructed in the junction of two rivers such as Bhagirathi and Bhilangana in the part of Lesser Himalayan region. A long reservoir about 67 km situated near the side of the dam. There are so many studies have been done on this dam and indicated that the dam has the inverse effects on the geo-environmental system of the study area. Around the reservoir there are so many small villages. Due to the slope adjustment during drawdown situation of the reservoir, villages which are situated on the steep slope have been made unstable and damage to the farmland areas of the study area. The slope, aspect, geology and drainages are called geo-environmental factors which make the slope instable in the hilly terrain. For this above situation, the landslide hazard zonation mapping is needed for reducing the loss and damages in the study area.

1.2Objective

The aim and objective of this present paper is to create a Landslide Hazard Zonation Map in the study area.

2. Study area

Geographically the study area located in between 30° 22' 40" N latitude and 78° 28' 7.50.4" E longitude. The Tehri Dam is one of the biggest dam in the world. The height of the Dam is 260.5m. It is situated in the Garhwal district of Uttrakhand State of India. It is a part of the Lesser Himalayan terrain. The main river of this area is Bhagirathi and Bhilangana and in these two river valleys, the huge reservoir formed. The maximum and minimum storage level of the reservoir are 830m and 740m. The causes of instability problem in that area is the saturation of the side slope due to low water level. There are some certain factors which causes instability problem such as interference of human on the bank of the reservoir, materials type of slope, cover of vegetation and geometric features of the slope of the rock in the study area. These type of condition are more suitable for inviting landslides in that area. Because of these landslide, the construction structures such as building like school, offices, roads and other civil structures in the study area. Figure 1 showing the stud area.

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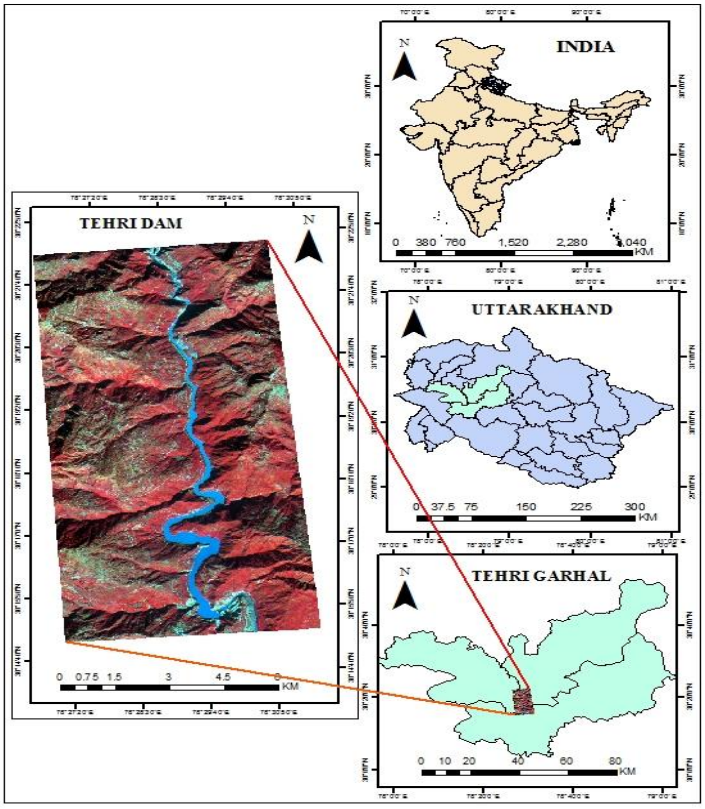

Figure1: Study Area

3. Database and Methodology

In the present study only secondary data have been used to prepare the LHZ map. A base map has been prepared satellite image and ArcGIS online base map. Ancillary data such as geology and invention of landslide have been collected from the different sources such as Geological survey of India. ASTER DEM with 30m resolution satellite data has been downloaded from the USGS Earth explorer. Slope, aspect map has been prepared from the ASTER DEM image. Drainage map has been extracted from the World view 2 satellite image. Using ArcGIS buffer tool, the drainage buffer with 75, 150, 225 has been performed to show the distance from landslide and drainage. For land use land cover classification LISS IV with 5.8 resolution has been used and processed in ArcGIS software. Total four supervised classifications such as settlements, forest, waterbody and cropland has been done. After that all the thematic layers have been reclassified in ArcGIS 10.3 software.

Five in depended causative factors such as slope, aspect, geology, drainage, land use/ land cover and one depended factor such as landslide have been used to demarcate the LH zone in the study area. Each factors have given weighted according to their impacts. The weightage value which is given to individual factors is the summation of all the factors. The higher value of weight indicates the higher impacts and low weight value indicates the lower impacts on landslide zones. The weight value has been given according to their occurrence in the particular study area. All the weighted value has been integrated through weighted overlay analysis in ArcGIS software.

4. Results and Discussion

The study area part of Tehri Dam reservoir is prone to landslide since a decades and many landslide has occurred in this area. In the recent time due to the impact of landslide, damage to properties, loss of life has increased. The present study draws an overview of the important causes of landslide in the study area. Figure 2 shows the landslide location of Tehri Dam area.

4.1. Slope:

Slope map of the study area has been classified into five categories from 0 to 77 degrees on the basis of landslide influence. High gradient slope most prone to landslide and low gradient slope less prone to landslide in

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that particular area (Anbalagan, 1992; Gupta et al. 1999; Saha et al.2005). Five classes of slopes such as 0-16(very low), 16-25(low), 25-33(moderate), 33-44(high) and 44-77(very high). Slope map has been derived from the ASTER DEM with 30m resolution. In this map, maximum landslide occurred in the highly slope area in comparison to very low and moderate slope area (figure 3).

4.2. Aspect:

Aspect map of the study area has been prepared from the ASTER DEM with 30m resolution to show the slope direction. Chances of landslide depends on the impact of aspect. Sun rays determined by the face of the slope which is related with temperature condition of climate. Aspect map of the study area has been classified into ten classes such as flat, north, northeast, east, southeast, south, southwest, west, northwest and north. Effect of aspect occurs in the Himalayan region very clearly. The slope face of south direction is warm, wet and with vegetation cover. The north direction slope face is dry, cold and glacial covered. In the Himalayan region most of the landslide happens in the south direction face of slope (figure 4).

4.3.Lithology:

Lithological map has been collected from the Survey of India and prepared on the basis of study area. In the study area there are total seven geological formations and all are different from each other. Such as Rautgara, Mandhali, Chandpur and Nagthat, formation. Among them Chandpur formation is more vulnerable to landslide due to presence of phyllites and quartzites which is most weathered rocks. In the north-east and few in western part of the study area Rautgara types of rock is found which is rich in slates, quartzite and volcanoes. In the middle portion of the rautgara formation Nagthat formation has occurred, consist of little amount of phyllitic, fine grained and limestone. In the western part of the study area covered by Nagthat formation which is rich in green, white and purple coloured quartzites, limestone and siltstone. In the north and southern part of the study area, less amount of Mandhali types of rock is found. In this rock no landslide has been observed (figure 5).

4.4. Drainage:

Drainage map of the study area has been derived from the ASTER DEM satellite image using ArcGIS software. Through DEM drainage density map has been prepared and the number of drainages or density has been observed till 5^{th} order stream. There is a powerful relationship between drainage network and landslides. Due to erosion by the drainage in the hilly terrain, bank of the river gets cut and the side slope become steep which is most suitable factor for occurrence of landslide. To find out the landslide prone area, the drainage buffer has been done in ArcGIS software with 75, 150 and 225m distance. The figure 6 shows the drainage and landslide distances. Most of the landslide are occurred very close to drainages in the study area.

4.5. Land use/land cover:

For landslide hazard zonation study, land use/ land cover is one of the most important parameter. In this terrain classification, there are four classes, such as settlement, crop land, forest and waterbody. These map has been prepared derived from the satellite image of 15 m resolution. For this supervised classification has been done in ArcGIS. Changes of land use land cover plays an important role in landslide occurrence. Areas with thick or dense vegetation cover prevent the landslide and less number of landslide has occurred in this area. Inversely less vegetation invites the landslide. Most of the landslide has occurred in the built up area or construction area (figure 7).

4.6. Landslide Hazard Zonation Map:

In this present study Overlay Weighted Analysis has been applied to demarcate the Landslide Hazard Zone in the study area, based on the weightage value of each causative factors such as slope, aspect, geology, drainage and land use/ land cover. The LHZ map is a useful tool for managing or reducing or mitigate the landslide hazard in the study area. Total 198 landslides have been depicted by using satellite image for this study. Fig 8 showing the Landslide Hazard Zonation Map. Most of the landslide occurred near to drainage. This map divided into three zones such as high, medium and low. Out of the total area 2.74 percent area is under high hazard zone, 0.386 percentage of area is under medium hazard zone and remaining 96.87 percentage is under low hazard zone.

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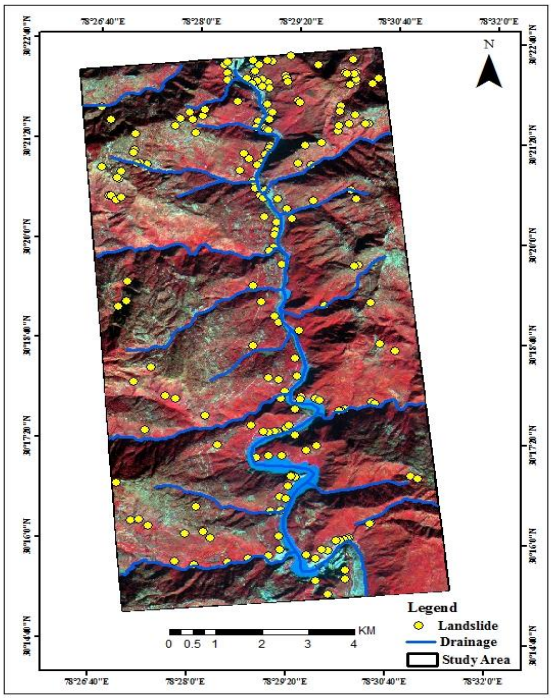


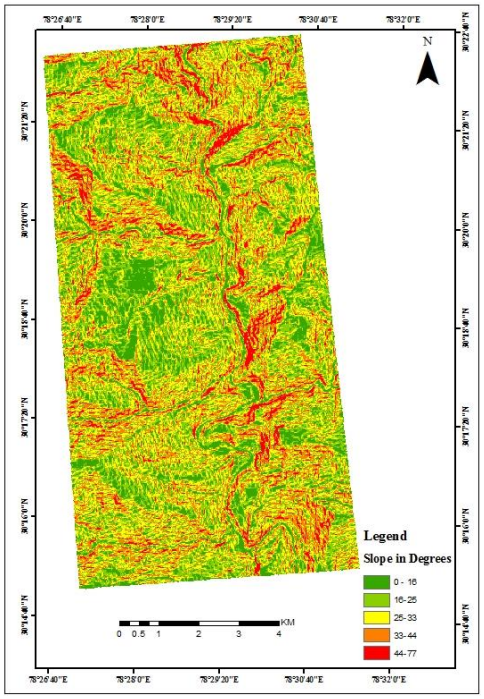
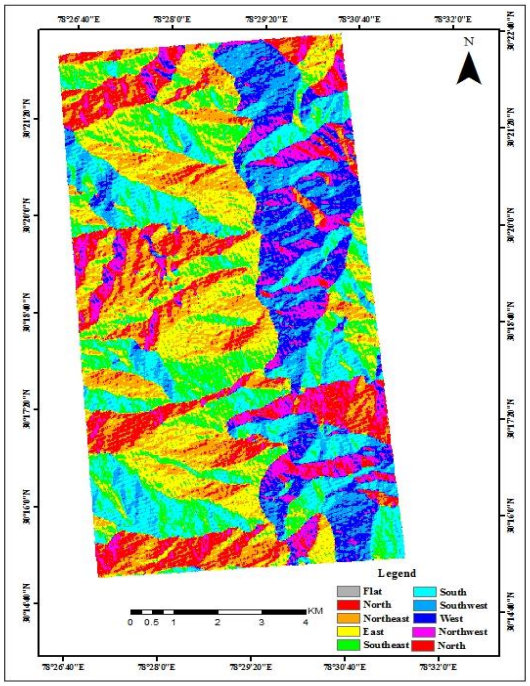


Figure 2: Landslide Location MapFigure 3: Slope Map



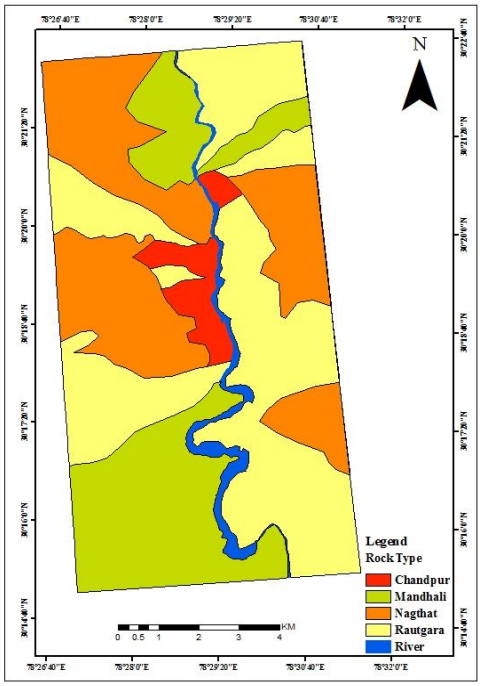


Figure 4: Aspect Map Figure 5: Lithology Map

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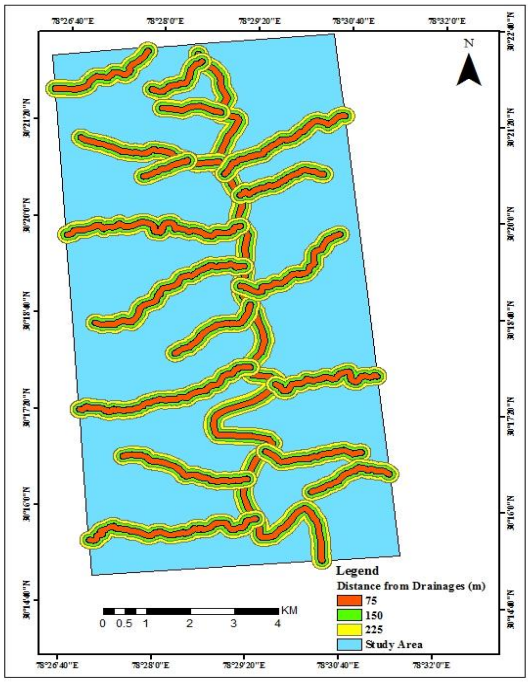

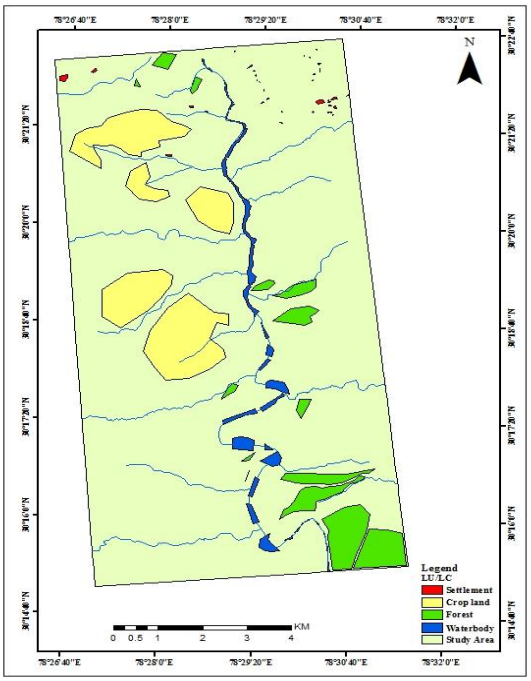

Fig 6: Drainage Buffer Map Fig 7: LU/LC of the Study Area

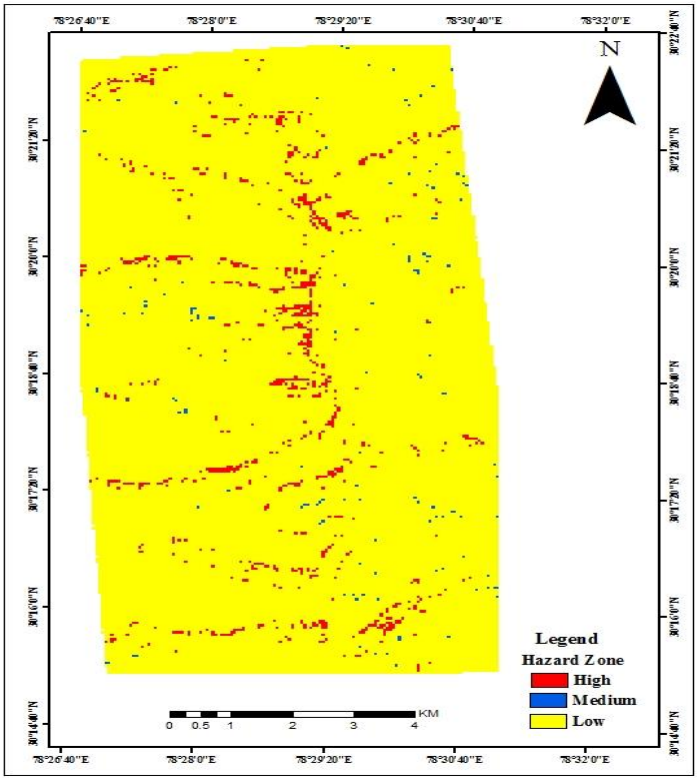

Figure 8: Landslide Hazard Zonation Map

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5. Conclusion

There are number of landslide hazard zonation methodology. Among them Weighted Overlay Analysis is one which is very easy method for hazard zonation and it has been applied using ArcGIS software. In this present study the most important four independent factors have been taken such as slope, aspect, geology, drainage and land use/ land cover. All the factors have been given weightage value according to their impact on the landslide in the study area. for this zonation mapping 25 for slope, 20 for aspect, 20 for geology, 15 for drainage buffer, 10 for LU/LC and the remaining 10 is given to dependent value such as landslide. The results of the study show that the slope is the most causative factor for landslide because more number of landslide occurred in the steep slope of the study area. The final map will be helpful for the local people, engineers, planner for mitigating the hazard and also demarcate the highly vulnerable and low vulnerable zone in the study area.

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