ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 7, July 2015

Landslide Vulnerability Assessment of Pauri Garhwal Region in Uttarakhand

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Abstract: This study is carried out to generate the detail temporal landslide inventory and vulnerability assessment of the possible landslide hazardous regions over the Pouri Garhwal of Uttarakhand. In relation to hazards and disasters, vulnerability is a concept that links the relationship that people have with their environment to social forces and institutions and the cultural values that sustain and contest them. The high resolution Quick Bird image is used for landslide mapping in large scale. In addition to that the IRS P6 LISS-IV images are used for improvement of spectral characteristic of the PAN image. This vulnerability is estimated on the parameters which are majorly susceptible to landslides i.e., moderate soil erosion, moderate & deep soil depth, loamy soil texture, excessively drained soil and high slope. This is observed that total 84 watersheds are highly vulnerable for landslide and some are partial areas of Tal nadi, Sukhrao, Paschmi Nayar and Purvi Nayar region of study area.

Key Words: Pauri Garhwal Region, Landslide Vulnerability, Quick Bird Image.

1. INTRODUCTION

Uttarakhand is the twenty seventh state of India with an area of 53,483 sq. km situated in the northern part of India; it is characterized by rugged topography. The Morph tectonic setting at a glance consists of, deep ravines, rivers terraces, ancient and recent flood plains, steeps and gently sloping hills various geotectonic feature such as faults, folds etc. The State of Uttarakhand is plagued by various type of mass movement. The triggering factors are invariably excessive water, earthquakes, and ruggedness etc. Landslides triggered by heavy rain been constant sources of destruction of property and loss of lives. Dormant as well as active slides are threat to human life and property. Their study and monitoring has become imperative to safeguard against destruction by them.

Uttarakhand Himalaya has never been and will never be free from ubiquity of weak geology, slope instability, frequent seismicity, soil erosion etc. mainly due to natural causes and partly as a result of accelerated degradation. These adverse conditions in tandem can exacerbate the existing fragile, vulnerable and multi-functional mountain ecosystem. However, there is ever increasing human demand of natural resources, especially land for urban development and mega dams in an apparently unsustainable manner, making some of the denizens to adapt and survive at dangerous margins. The emerging crisis can be minimized by indigenous knowledge based and modern technological interventions. To safeguard against accelerated degradation and improve the living standard of hill people, the state Government needs to address hill specific issues through systematic and affective integration of the ecosystem service and development, highland and lowland linkages etc. Without a replicable and hill specific development policy, the ever present threat form devastating landslides, earthquake, flood etc. remains an option and opportunities of the progeny in jeopardy.

Landslides in its strict sense are the movement of a mass of rock, debris or earth down slope, due to gravitational pull, and in general are triggered by a variety of external factors such as intense rainfall, earthquake shaking, water level change, storm waves and rapid stream erosion etc (Dai et al., 2002).Conventionally, major landslides in the Himalaya are located in the transitional zone between the lesser and higher Himalaya. The reason being that this zone is dominated by steep slopes, focused rainfall (cloud bursts) and frequent seismicity (Sati et al., 2011). Some of the major landslides in the recent times in this zone are 1970 landslide that induced flash floods in the Alaknanda Valley, the 1978 KanodiyaGad landslide in the Bhagirathi Valley, the 1998 Malpa and Okhimathlandslides in Kali and Madhyamaheswarriver valleys, 2003 VarunavatParvat landslide in Uttarkashi Munsiyari landslide 2009 (Sati et al., 2011).

Remotely sensed data has many advantages for mapping landslides and other natural hazards. The capability of remote sensing data to provide synoptic information over wide areas is a particular advantage (Richards, 1993).Digital remote sensing products are proved to be beneficial in mapping landslides in remote and inaccessible areas due to high resolution (Jaiswal, 2007).Mainly because of its synoptic view and its capability for repetitive observations, optical (visible-infrared) remotely sensed imagery acquired at different dates and at high spatial resolution can be considered as an effective complementary tool for field techniques to derive such information (Hervas, et al., 2003).

But in inaccessible terrain it is always a challenge to carry out landslide mapping (Das, 2007). In rugged forested watershed, canopy cover camouflages the small landslides to a great extent and detecting all landslides from images is a difficult task (Bradinoni et al., 2003).

DOI 10.17148/IJARCCE.2015.47125

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2. OBJECTIVES OF THE STUDY

The present study has the main objective to develop a methodology for the determination spatial and temporal probability of a landslide in Pauri district of Uttarakhand state. Preparation of detailed temporal landslide inventory in Pauri district concentrating even on a small landslide perceived as critical and mapping of possible risk zone for landslide in the future.

3. STUDY AREA

The selection criteria for the study area was based on the following conditions a) availability of landslide b) authentic location information of slides along the route and along the river c) and finally a genuine problematic situation that is need to handle with a scientific methodology. The study region is shown in figure 1.

Garhwal Himalaya is well known for its fragile landscape and frequent geological hazards, among which landslides are the regular threats over this region. The selected study area is the Pauri district which is located between 29°20'-29°75' N latitude and 78°20' E longitude. Total area of the district is 5230 sq kms. Pauri stretches from the Ramganga River that separates Pauri-Kumaon border in the east, and to the Ganga demarcating the western border. The road corridor passing through a highly rugged terrain and suffering from frequent landslides especially during every monsoon season.

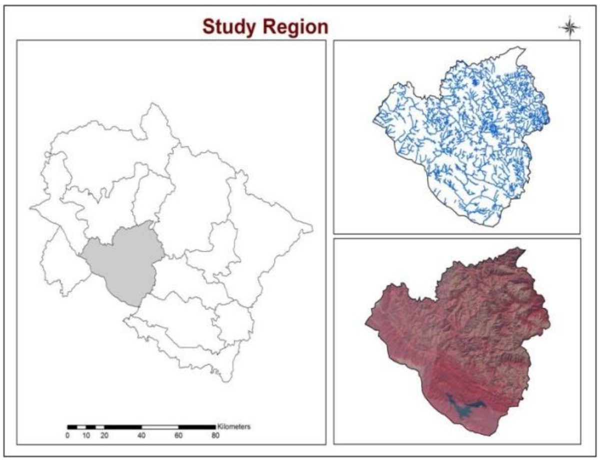

Figure 1: Location map of study area

4. MATERIALS AND METHODS

The Quick bird satellite datasets and IRS-LISS IV datasets are used in the study. The specifications of the dataset used are shown in the table1.Survey of India top sheets of a scale of 1:50,000 were used for reference purpose and in identification of human occupants in the study area. The selected grids, scale and projection system used are shown in the Table 2.

4.1Digital Remote Sensing Data

Quick bird images are the high resolution image used for landslide mapping in large scale.

Satellite Name	Resolution type	Projection type
Quick bird	0.6 m	UTM, WGS 84
LISS IV	5.8 m	UTM, WGS 84

Table 1: Satellite dataset used in the study

Sheet No	Scale	Projection System
53J/12,53J/16,53N/4, 3K/5,53K/9,53K/13,53 K/10 and 53K/14	1:50,000	Polyconic

Table 2: Grid in the scale and projection used

In addition to that the IRS P6 LISS-IV image is used for improvement of spectral characteristic of the PAN image which in turn helps in better identification of the image features (Metternicht and Zinck, 1998; Pickup and Marks 2000; Meyer et. al., 2001)

Various radiometric enhancement techniques had to be applied before Geometric correction, the contrast enhancement techniques improves the visual analysis (Jensen, 1996) and (Lillesand and Kiefer, 1999)

Due to the non availability of the three season data in the study region, old data has been used and prior to that through visual image interpretation the homogeneity of the area. The visual quality of image obtained from Pan-sharpening of LISS 4 image enabled detailed interpretation of landslides and associated environmental features. This data has is mainly being used in mapping of landslide in the field as well as during the preparation of digital database on landslides by screen digitization.

4.2 Field Survey

The field survey was conducted for the fulfilment of the objective. The main objective was to identify the landslide location of the slides in the study region for corresponding size verification and type recognition and field mapping of slides respectively.

4.3 Approach Used:

A step by step approach has been used for identification of highly vulnerable area for landslides in the study area. The detailed approach used in this study is shown in figure 2. The Following approaches was used for vulnerability analysis.

- ❖ Pre-processing of satellite data.
- ❖ Creation of different thematic layers such as Road, Drainage, soil type, soil texture, was prepared.
- ❖ Detailed landslide investigation/mapping and monitoring.
- ❖ Identification of highly vulnerable areas in the study region.

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4.3.1 Satellite data Preparation

Satellite data preparation is done in three steps, a) pre-field satellite data processing b) field survey and c) post-field vector layer generation on landslides and other related geo-environmental factors essential for carrying out the study.Satellite data was prepared for field identification and mapping of landslide.

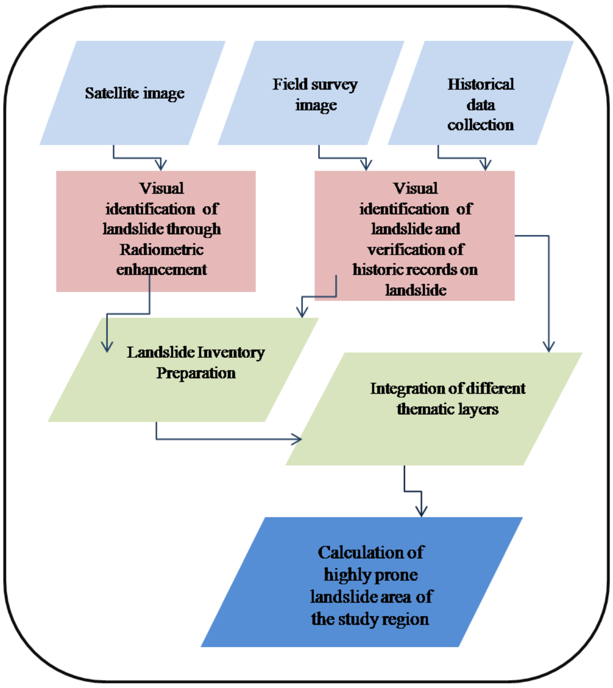

Figure 2: Methodology flow chart

To find relationship between all parameters the attributes under the maximum value of all parameters should be intersected for a common area, which will indicate highly prone area for landslides

Figure 3: Relation between all parameters

5. RESULT AND ANALYSIS

5.1 Drainage

The study area is drained by several rivers that are Eastern Nayar, Western Nayar, Bino, Ramganga, Koh, Malini, Henwal, Sateri, Vidasani; all are the tributaries of the Ganga. The major rivers in the study region are fed with numerous small first and second order streams from both sides. Rivers and streams are loosening the nearby soil which may also trigger landslide, so this factor is examined.

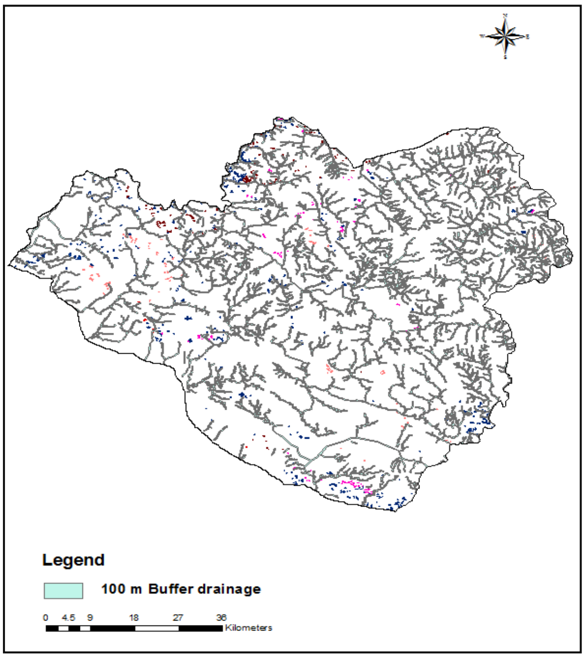

Figure 4: Showing the existing landslide in the hundred meter buffer of drainage in the study region

So as to examine the proper effect a 100m buffer of drainage is taken into account, and only 18 percent was in the buffer zone region while 81 percent landslides was in the non buffer zone area.

5.2Drainage Density

Groundwater is the most important single factor in triggering landslide events. Rising water tables and rising water pressures are contributory to most slope failures; the majority of landslides occur during rainstorms.

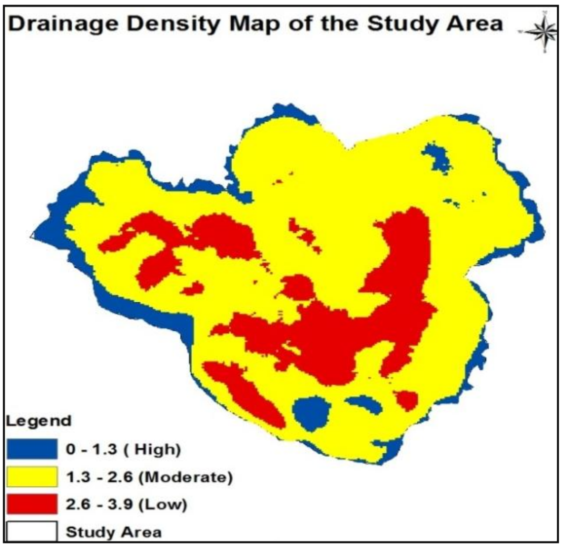

Figure 5. Showing the drainage density of the study area

The study area is characterized by moderate drainage density along with mostly high slope, it indicates a high degree of landslide.

5.3Road

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Humans make landslides more likely through activities like deforestation, overgrazing, mining and road-building. Landslides are much more likely to occur in mountainous areas that have been clear-cut for roads. You've probably seen signs warning of rock fall if you've ever driven through the mountains. The drop-offs with loosened soil you see on both sides of the road require much less water to set off a landslide than natural drop-offs.
So to predict the effect of road we built a 100m buffer around the road and found that out of 1257 Landslides 497 landslides are triggered due to roads.

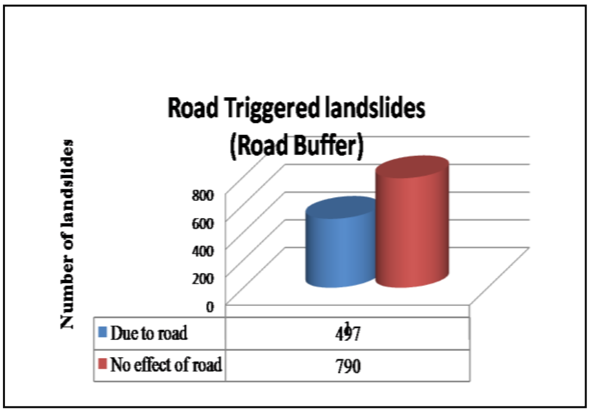

Figure. 6 Showing the existing landslide in the hundred meter buffer of Road in the study region

5.4Soil Texture

Wide range of variation in soil type can be observed in the entire study region. The soil cover is existing as a thin layer along the slopes. Depending upon it altitudes and geomorphic situation the change in soil characteristic is noticeable in the area. Very steep slopes are mostly left without any soil cover. Different soil texture contribute different occurrence of landslides. Mainly five different texture of soil found in the study region such as loamy, fragmental, calcareous, sandy and rocky.

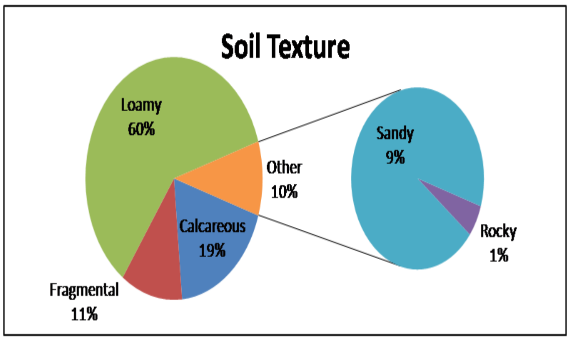

Figure 7. Showing the existing landslide in different type of soil texture

5.5Soil Erosion

Soil erosion is one of the major parameter for landslide studies. The rate of soil erosion is very high in such areas where the soil is mostly sandy in nature, slope is high and rainfall is frequent. Thus, with the increase of soil erosion, the susceptibility of an area to landslide also increases. Soil is characterized by either severe erosion, moderate erosion or slight erosion.

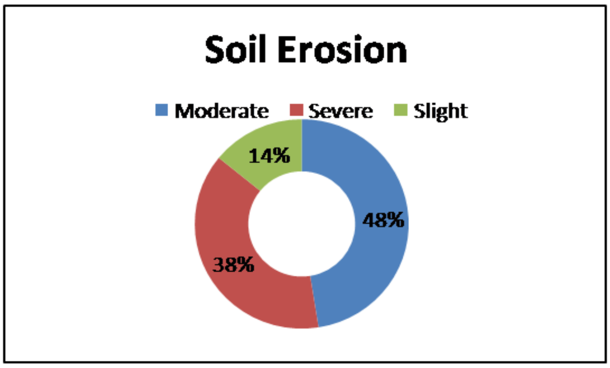

Figure 8. Showing soil erosion type in the study region

5.6Soil Depth

Soil depth is a factor which is also responsible for land-slides as major landslides are found in moderate and deep areas of soil depth. After analysis 35.16% landslides of total are found in moderate and deep areas.

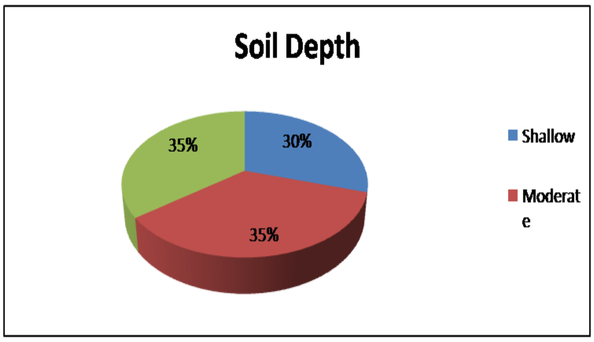

Figure 9. Showing soil depth type in the study region

5.7Drainage Density

Since the study area is characterized by moderate drainage density along with mostly high slope, it indicates a high degree of landslide.

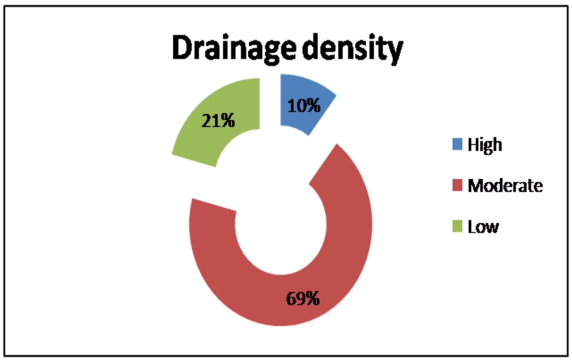

Figure10. Showing drainage density type in the study region

5.8Vulnerability

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This was observed that total 84 watersheds are highly vulnerable for landslide. Some regions are partial area of Tal nadi, Sukhrao, Paschmi Nayar and Purvi Nayar.

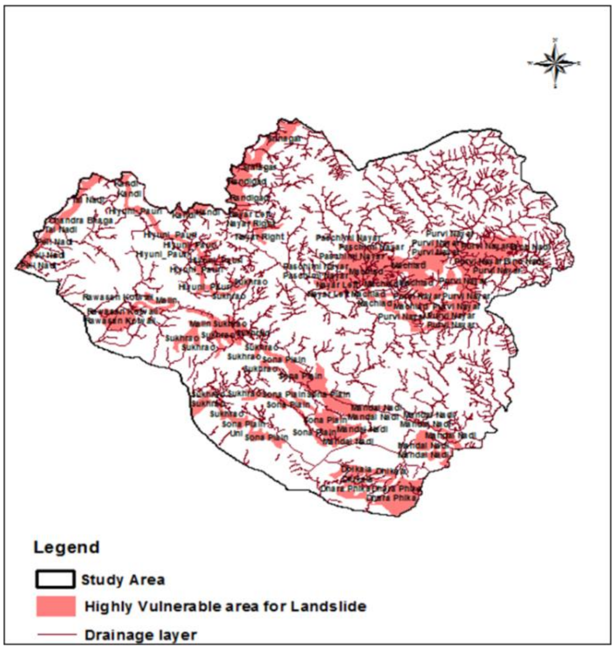

Figure 11. Showing highly vulnerable area of landslide in the study region

We identified eight important soil characteristics to deduce eight soil parameters and listed their types from past references. Based on the analysis of high resolution satellite data total 1257 landslides was observed. 47.49 percent landslides are found in moderate category which is maximum.

It was observed that the Slope and Land use are the important landslide causing factor.

The drainage density exerts a great influence on landslide susceptibility as erosion ablation of the streams is the main cause for slope instability and areas with high draining density are found to be valuable.

Further landslide can be prevented in hilly areas by adopting the cutting methods for mountains instead of blasting the mountain.

The vulnerable area should not be employed for settlement or any industrial purpose, and preferably should be left for forests and trees should be planted in whole area. If employed then proper early warning systems should be developed and used to save the lives.

VI. ACKNOWLEDGMENTS

The authors are especially thankful to **Dr. Durgesh Pant**, Director USAC, Dehradun for providing the permission to use USAC lab facilities and satellite datasets for the research work.

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BIOGRAPHIES

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Dr. Asha Thapliyal, currently serving in the capacity of Scientist at Uttarakhand Space Application, Dehradun. She has more than 8 years' experience in the field of remote sensing and GIS.