

Study the 2013 Flood Damages and Risk Assessment in Kedarnath, Himalaya Area Using Geoinformatic Techniques

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Abstract

Recent climate variability has had significant impact on atmosphere and its produces uneven rainfall in high-mountain and glacial regions. On 16th and 17th June 2013, heavy rains together with moraine dammed lake (Chorabari Lake) burst caused flooding of Saraswati and Mandakini rivers in Rudraprayag district of Uttarakhand. A multi-day cloudburst centered in the Uttarakhand caused devastating floods and landslides becoming the country's worst natural disaster since the 2004 tsunami, which was about 375% more than the benchmark rainfall during a normal monsoon. The resultant consequence is the damage of infrastructures, crops and forest areas etc. Apart from the social, political and economical losses these natural calamities modify the pre-existing landscape of Kedarnath area. To study the damaged area of Kedarnath, remote sensing and GIS techniques is used and damaged area classified as highly, moderate and low based on the intensity of the damages.

Keywords: Kedarnath; Flash flood; Risk assessment; Damages; Remote sensing and GIS

Introduction

Recent climatic changes have a significant impact on high mountainous glacial environment. Flash floods are one of the most dangerous weather-related natural disasters in the world. Such floods develop less than six hours after a rainfall event that led to hazardous situations for people and extensive damage to property. Hence, it is very difficult to forecast and be warned in a timely manner to prevent and prepared from impacts [1]. The mountainous regions like Uttarakhand and Himachal Pradesh received heavy rainfall during Northwest monsoon (July-September), which generally causes natural disasters like cloud burst that led to flash floods almost every year [2]. One of such flash flood occurred because of heavy rainfall (366.3 mm) from June 13 and 19th, 2013, in the Rudraprayag district of Uttarakhand. It is the 580% more than the normal rainfall (i.e) 53.9 mm previously South Asia Network on Dams, Rivers and People, 2013 [3]. The Shri Kedarnath town is situated on the outwash plane of the Chorabari Glacier. The flash flood occurred in the Saraswati and Mandakini Rivers after breaking of moraine-dammed. Chorabari Lake, which is situated above the Kedarnath region. In this century, it was the largest catastrophic event in the magnitude, which accompanied by huge landslides and mudflow. This flash flood created huge devastation to the Kedarnath area in the form of loss to the human, livestock, natural resources, and damage to the property. Apart from the social and economic losses, the event modified the pre-existing landscape of Kedarnath area Wadia Institute of Himalayan Geology, 2013 [4].

The exact reason for the flash floods was the breaking of the Kedar dome that led to the rupture of Chorabari lake, less than 6 km from the Kedarnath shrine [5]. The Chorabari lake (3960 m msl) also known as Gandhi Sarover lake which is approximately 400 m long, 200 m wide having a depth of 15-20 m, is a snow melt and rain fed lake, located about 2 km upstream of Kedarnath town. These flash floods created huge devastation to the Kedarnath area. It damages the building and bridge accompanied by landslide and mudflow. The population of Kedarnath Township is increasing day by day with proportionate increase towards the needs of the residents as well as the seasonal pilgrims whose influx is increasing every year. To fulfill the requirement of the tourist/pilgrims several unplanned and unauthorized houses, hotels, restaurants, shops and dharamsalas have been constructed on the river bed of Mandakini

around the temple, which was the old channel of Mandakini River. Kedarnath temple in the district of Rudraprayag in Uttarakhand, one of the four holy Dhams, has been one of the worst hit in the flash floods [6].

Because of such cloud burst in this region flash floods takes place like, Tevala, district Kullu of Himachal Pradesh was highlighted due to cloud burst that caused sudden flash flood and 2 kilometers area was filled with mud and debris. The front of 1200 meters tunnel disappeared due to mud and debris. The fast flowing water of Jograi Nala (stream) has changed the direction of Parvati River and creates a lake there. After break into the lake, the flow of water was so high by which the road has been washed away [7].

Study area

The Shri Kedarnath town is located in the western extremity of the Central Himalaya, where the famous Kedarnath temple is situated. The location of this town is (30°44'6.7" N; 79°04'1" E) in the Mandakini River valley which has a total catchment area of ~96 km² (up to Sonprayag), out of which ~17% area is covered by glaciers. The catchment area is situated in the glacier modified U shaped valley; the altitude ranges from 1700 m above mean sea level (MSL) to 6578 m above MSL. Mandakini River is originated from the Chorabari Glacier (3895 m above MSL) and joins Saraswati River (which originates from Companion glacier) near Shri Kedarnath temple passing through Rambara, Gaurikund and Sonprayag where Vashuki Ganga merges with it, finally becoming the part of Alaknanda River at Rudraprayag (640 m above MSL). The Shri Kedarnath town is situated in the outwash plain of the Chorabari and Companion glaciers [8]. The general climate of the study area is humid-temperate in summer and dry humid cold in

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winter. The area receives heavy rainfall during summer monsoon [9], and it also receives equal amount of precipitation during summer and winter monsoon seasons.

The Mandakini is the main river originating from the Chorabari Glacier just 2 km upstream from Shri Kedarnath shrine. The Saraswati, Madhu Ganga and Dudh Ganga are few tributaries which join Mandakini within the campus of Shri Kedarnath shrine itself. The network of the streams of Kedarnath area is evidence that there is a typical dendritic pattern of drainage. But at some places it also shows some anomalies mostly controlled by the structures of the bed rocks and moraines. Some tributaries of Mandakini River near Gaurikund and Rambara are following NW-SE direction and show typical rectangular pattern. The Mandakini River follows N-S trending lineaments, where most of the drainage in the area follows the regional strike of underlying litho units i.e. NW-SE direction. The drainage pattern of the region is influenced by tectonic features and thus is structurally controlled (Figure 1).

Geological Set-up

It is a well-established fact that geological set-up of an area plays a vital role, which controls the entire lithological surface of the particular area [10]. The area between Sonprayag and Kedarnath lies in Vaikrita Group [4] of Central Crystalline [11], which comprises the Munsiri, Joshimath, Pandukeshwar and Pindari Formation. In Kumaon, these crystallines were included as integral part of the “Central Crystalline Zone” by Kazunori [11]. Kedarnath temple and the township are located over the rocks of Kyanite Sillimanite zone of Higher Central Himalaya. The geological deposition of the area evidences that the higher central crystalline mass overlying the lower Meta sediments of Garhwal window series along Thrust contact i.e. Main Central Thrust (MCT) [12].

Geomorphological set-up

Geomorphology of any mountainous region includes mainly four characteristics that are very important for describing the process acting upon them. These are: (1) elevation, often in absolute terms; (2) steep, even precipitous gradients; (3) rocky terrain; and (4) the presence of snow and ice [13]. The study area is highly dissected into numerous small ridges and spurs, wide U-shaped to narrow V-shaped valleys, deep gorges to wide outwash plains with variety of slopes. The entire valley from Rambara up to the snout of the Mandakini river (Chorabari Glacier) is covered with glacial deposits in the form of lateral and medial moraine. The area is covered by erosional as well as depositional features including cirques, horns, ridges, alluvial fans, morainic deposits, talus cone, terraces, etc. The lowest point in the Kedarnath area is Sonprayag i.e. the confluence point of Mandakini and Songanga Rivers, whereas the highest elevated summit is known as Kedarnath peak (6940 m) Wadia institute of Himalayan Geology, 2013 [4].

Materials and Methodology

Data source

To fulfill the purpose of this research paper digital elevation model (DEM), Survey of India (SOI) toposheets, pre and post disaster satellite image of the study area, CARTOSAT-1 and CARTOSAT-2 data were utilized.

Methodology

The land use and land cover (LULC) map of the study area were classified using supervised classification technique. To study the damaged area of Kedarnath, remote sensing and GIS techniques were used and damaged area classified as highly, moderate and low based on

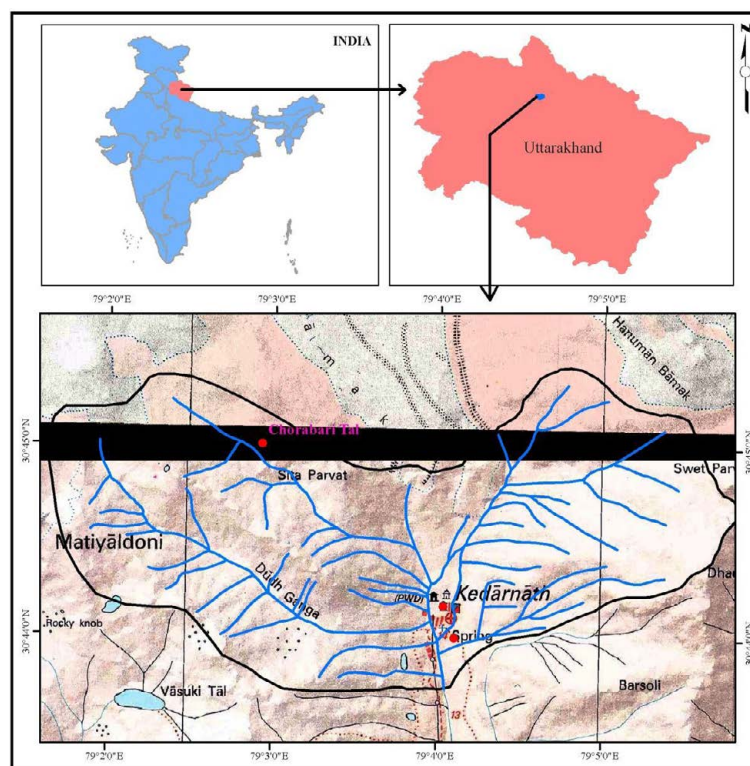


Figure 1: Location map of the study area, Kedarnath, India.

the intensity of the damages. The Built-up land, glacial/snow, gullied slope, late moraine land, spring/tank, transport/infrastructure, valley, and water body are the LULC features classified in this study.

Results

Breach of moraine - dammed Chorabari Lake resulted into excessive flows across all the channels due to cloudburst. This also results the destructive flash flood occurred in the Mandikini river and Saraswati river, which flows through the Kedarnath town that devastated the region worst. It is observed that the eastern and northern portions of Shri Kedarnath temple are badly damaged. The Laxmi-Naryan Temple (near the main temple) and settlements (shops, restaurant and building) have been completely damaged. This excessive flow triggered active erosion in all the gulleys/streams causing excessive water and sediment accumulation in the rivers. It activated the abandoned channels, initiated new channels and increased the discharge of the main channel. This high- energy flow of water laden with debris, increased the bank erosion, caused deepening of the valley and washed out almost everything that came its way.

According to 2011 data there are 8259949 Sq.m. land deteriorated in the form of gullied slope. Most of the infrastructure in and around the risk of natural disasters has increased in the area as a result of increasing anthropogenic activities. This trend is likely to increase in future as the activities like pilgrimage, tourism, etc. will increase. The natural flow paths of the channels get obstructed due to the construction of man-made structures that results in deviation of the

flow from its natural course. The debris has filled the whole area with more than 5 m thickness.

As we know, this area is tectonically active and not stable due to terrain and texture of this area is not very hard some of the areas are more vulnerable. The present study divides the damaged area into high, moderate, and low damaged area (Figure 2). Then the damage assessment map was integrated with land use and land cover map to analyze the feature wise damage assessment (Table 1).

There are highly damaged area of built-up land is 114233 Sq. m. Because the Chorabari lake is located on the above north of Kedarnath town, after the breaching of the Chorabari Lake the channel took a very irregular path resultant the water began to passing through the middle of Kedarnath town. This area is more vulnerable whereas the low damaged area of built-up land is 5322 Sq. m. Another degraded land use and land cover is glacial snow because of torrential rainfall glaciers of the adjacent area melted rapidly and it is also divided in three categories such as low moderate and highly damaged area. Highly damaged area of glacial snow area is 300290 Sq. m. moderately damaged area is 399 Sq. m. and low damaged area is 4388760 Sq. m.

Moraines are the deposition of eroded debris and transported by the glaciers in the foothills and the lateral sides of the valley. Late moraine land area is also damaged and it is also divided into three parts i.e. highly damaged, moderately damaged and low damaged area. The highly damaged area of the late moraine land is 194072 Sq. m.

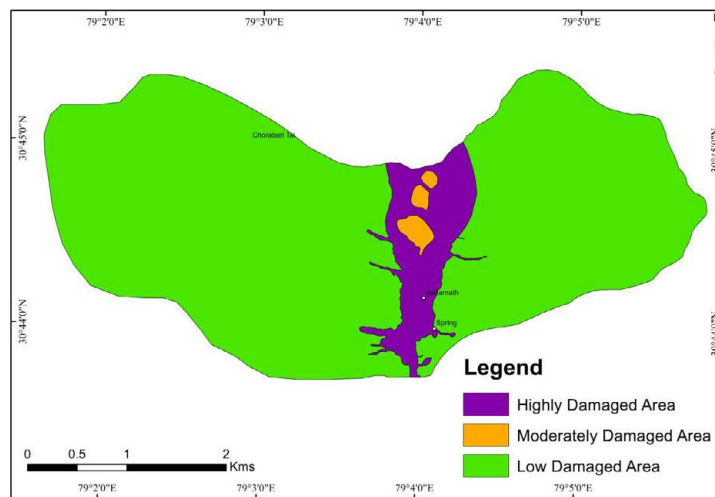


Figure 2: Damage assessment map of the Kedarnath Region.

Due to flash flood Land use and Land cover Features	Highly Damaged (in Sq.m)	% Area	Moderately Damaged (in Sq.m)	% Area	Low Damaged (in Sq.m)	% Area
Built-up Land	114223	10.45	-	-	5322	0.04
Glacial/Snow	300290	27.47	399	0.29	4388760	35.53
Gullied Slope	332621	30.43	-	-	7927329	64.18
Late Moraine Land	194072	17.75	136129	99.71	6	-
Spring/Tank	3232	0.3	-	-	7051	0.06
Transport/Infrastructure	5936	0.54	-	-	14480	0.12
Valley	142801	13.06	-	-	2959	0.02
Water body	0	0	-	-	5967	0.05

Table 1: Land use and land cover features with their area of damage.

moderately damaged area of late moraine land is 36129 Sq. m. and low damaged area of late moraine is 6.0 Sq. m.

Research has demonstrated that gully erosion is a threshold phenomenon determined by critical values for slope and drainage area [14]. During the flash flood in the Kedarnath region gullied erosion also took place on a large scale approximately 332621 Sq. m area was highly damaged and the low damaged area was 7927329 Sq. m.

A spring is a natural situation where water flows from an aquifer to the earth's surface. It is a component of the hydrosphere. In the form of land use and land cover the spring is also a part this area. It is also badly affected. The highly damaged area of spring/tank is 3232 Sq. m. and the low damaged area is 7051 Sq. m. Because of catastrophic flash floods in the Kedarnath region the transportation facility is badly affected. The transport infrastructural mediums like roads are the washed away during the natural calamities i.e. flash floods. The exact highly damaged area of transport infrastructure is 5936 Sq. m. and the low damaged area of transport infrastructure is 14480 Sq. m. During the calamities there are some portions of valley that are also damaged the highly damaged area of the valley is 14280 Sq. m. and the low damaged area of the valley is 2959 Sq. m. Water bodies also affected during the flash floods.

Conclusion

Flash floods, is a natural phenomenon due to heavy rainfall in the mountaneous area like like Kedarnath, that is controlled by the distinguished geographic, orographic and geomorphic parameters of the Himalayan mountain ranges. In these parameters, height of the particular area, cirques, saddles, hanging valleys like topography, cumulus rain clouds with humidity, formation of cold and warm convection current etc. plays an important role. These circumstances and parameters are controlled by the nature. Thus the events of cloud burst cannot be restricted but loss of life and properties can be minimized by taking certain precautionary measures. In such areas construction should be carried out after thorough and detailed geologic, geomorphic, tectonic, land use and hazard zonation studies for the development of the region by beforehand planning [15].

Recommendations

- Geological Geomorphologic and environmental study should be done by the expert agencies for any construction work in such areas.
- Meteorological parameters like the wind velocity, volume of rainfall, percentage of relative humidity, flood levels etc. should be monitored regularly.
- Drainage and sewer line facilities should be developed in villages.
- If rainfall is occurring in any particular place continuously, the water levels in the rivers are to be continuously monitored, so the warning can be given for floods to save the life and property of the people living in that area.

- A scientific view point should be evolved among the local people by training and vigilant programmes on the topic of landslides, soil creeps, erosion processes, preparation of terraces and land use planning etc. New technological acquaintance (know how) should be given to local people so that they can use in construction of house, environmental safeguard and also in agricultural work to enhance their economic conditions.
- Through the bank of river or drainage channels plantation should be there that can be helpful to prevent the shore erosion.

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