DETECTION OF HAZARD PRONE AREAS IN THE UPPER HIMALAYAN REGION IN GIS ENVIRONMENT

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Abstract

Himalayas are a great boon to India as they block the monsoon winds from the oceans, allowing the northern plain to receive plenty of rainfall. The rivers Ganga and Brahmaputra are fed by the snow of the higher peaks, and these also protect from the cold biting winds o North Asia. But it is this Himalayan range again, which is one of the biggest hotspots of natural disasters, because they are still growing and young mountains and the changing climate of the globe has added to the frequency and extent of such disasters. This paper involves the study of the Basin of Alakananda River, a tributary of the Ganges, so as to delineate the flood prone zones of the area. Almost every year this region is affected by cloudbursts and consequent floods. The parameters taken into consideration here are the slope, the river networks and the soil type of the area. River Tools has been used to extract the stream networks of the river. Consequent analysis has been carried out in ArcGIS. The results of the analysis show that the topology of the area is highly dangerous for any urbanization. Villages constructed on this region are very much vulnerable to heavy floods due to the loose soil type present on the surface and the steep slope. The study identifies such highly vulnerable regions in the Alakananda River Basin.

Keywords: *Cloudbursts, ArcGIS, ASTERDEM and RiverTools.*

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1. INTRODUCTION

According to United Nation's International Strategy for Disaster Reduction, Asia has the highest number of fatalities from natural disasters of any region, and within Asia, the countries of Himalayas have the greatest number of disasters and casualties. There are several reasons for this vulnerability, the mountains are young and dynamic and still tectonically very active; the intense monsoon rainfall leads to flooding and landslides, and the extreme relief contributes to the instability of both the land itself and the infrastructure built on it. The countries are particularly hard hit by recurring annual flash floods (ICIMOD, 2010). Flash Floods are generally the consequence of either cloudbursts, or may be due to landslides, dam breaks or glacial lake outbursts. Cloudburst is actually a situation when the intermolecular forces between the water molecules get very high due to the rapid decrease in temperature or excess of electrostatic induction in the clouds causing lightning to remain inside the cloud only, which causes hyperactive energy in the cloud. The water concentration gets higher and higher and the weight gets heavier, until water is no longer able to maintain the force within the clouds and they fall. As the water content is so high, the clouds seem to burst. Such cloudburst activity in every monsoon occur in the Himachal Pradesh (Kullu Valley) and the Western Uttaranchal (Chamoli, Uttarkashi, Tehri, Rudraprayag and Pauri Distrist). Sometimes it happens in Kumaun Mandal (Pithoragarh, Almora, Bageshwar, Chapawat and Nainital Districts) and Mussourie Hills of Dehradun district and Lesser Himalayas and Siwaliks also (Asthana, A.K.L, Asthana Harshita, 2014). Table 1 below lists the history of cloudburst events in Uttarakhand since the year 2001.

Table 1: History of Cloudbursts in Uttarakhand

	Place	*Date*
1	Phata, Rudraprayag	August 2001
2	Mussourie Hills, Dehradun	August 2001
3	Gouna Tehri	August 2001
4	Burhakedae-Agunda (Balganga valley), Tehri	August 2002
5	Shilagarh Village, Shimla	16 July 2003
6	Tevla Village Kullu Valley	August 2004
7	Dhanu Village Rudraprayag	July 2005
8	Village near Shimla	August 2007
9	Leh (Ladakh)	August 2010
10	Assiganga Uttarkashi	5 July 2012
11	Dyara Bugyal Uttarkashi	August 2012
12	Bageshwar, Kapkot near Almora	19 Sept 2012
13	Kedarnath	16-17 June 2013

A major challenge associated with flash floods is quantitative character of the forecast; the task is not just to forecast the occurrence of an event, which is difficult enough by itself, but to anticipate the magnitude of the event. With the impact of climate change, the effects on the intensity of the rainfall events, identifying the vulnerable areas and assessing the degree of impact for a higher magnitude flood risk event more clearly describes the potential risk at which the current developmental or infrastructural facilities are situated. Emphasizing the significance of flood risk assessment studies (Burby.R.J.,1998) states that the main components of such studies should focus on hazard identification and vulnerability assessment as the flood risk is considered as a product of spatial identification and vu lnerability (Great Britain Department of Communities and Local Government, 2006).

For producing flood hazard maps it is important to integrate geospatial and temporal data in a same computational environment that allows risk assessment, modeling and decision support. The advancement in computer-aided space-based technology such as Geographic Information System (GIS) and Remote Sensing (RS) has proved very useful in studying and mapping the flood-hazards and developing measures that can be useful to the local communities as well. The scope and scale of flood problems makes the GIS software a powerful tool for its integrated management process. GIS is ideally suited for various floodplain management activities, such as base mapping, topographic mapping, and post disaster verification of mapped floodplain extents and depths.

In this Study, the watershed basin of one of the tributaries of Ganga, namely Alakananda River has been taken for studying the flood risk of the villages constructed along this river. It lies in the Uttarakhand state, India, The main objective of this paper is to study the river stream networks of the Alakananda River and its reaches, and slope and soil type, which determine whether a place has a tendency to get damaged due to heavy floods. The results can be used for further studies to identify vulnerable zones in Alakananda River basin.

2. MATERIALS AND METHODS

Study Area: Uttarakhand is one amongst the Himalayan states of India, often referred to as “Devbhumi” (Land of Gods) due to many of the many Hindu temples and pilgrimage centres found in this region (Kumar Govind V. V, Jain Kamal, Gairola Ajay, 2013). The study area consists of Badrinath, which is one of the famous “Char Dhams” and since time immemorial has been the destination of countless pilgrims. The Alakananda River Basin lies in the Chamoli District of Uttarakhand, which extends upto an area of 7613 sq km. the watershed basin lies between 31° 00' 43"N to 30° 00' 24"N and 79° 12' 12"E to 80° 10' 27"E. This area heavily affected due to flashfloods in the year 2012. The Elevation of the area varies from 604-7791 meters (ASTERDEM analysis). In the year 2012, 7 cloudbursts hit Uttarakhand state. The regions Badrinath, Hanuman Chatti, Pandukeshwar, Joshimath, Gopeshwar, Karanprayag and Rudraprayag were the worst affected villages, and have been used in this study as the sub-watershed outlet point. Figure 1 shows the Alakananda River basin extracted from the ASTERDEM, above mentioned places marked in green, and the River in red.

Datasets: Digital Elevation Models are elevation data that collect by remote sensing methods or by transforming the contour maps to raster format by digitizing and surface analyzing (Seyed Reza Hosseinzadeh, 2011). The analysis of the watershed was done completely using the Digital Elevation Model (DEM) downloaded from the ASTER (Advanced Space-borne Thermal Emission and Reflection Radiometer) GDEM (Global Digital Elevation Model). It was used for delineation of the catchment area and also to obtain the slope and drainage pattern. The ASTERGDEM covers land surfaces between 83°N and 83°S and is composed of 1° by 1° tiles. The ASTERGDEM has a resolution of 30m and is in Geographic Latitude/ Longitude system. With the help of Uttaranchal Administrative Atlas, prepared by the Census of India, 2001 and Google Earth, locations were observed and later mapped into ArcGIS.

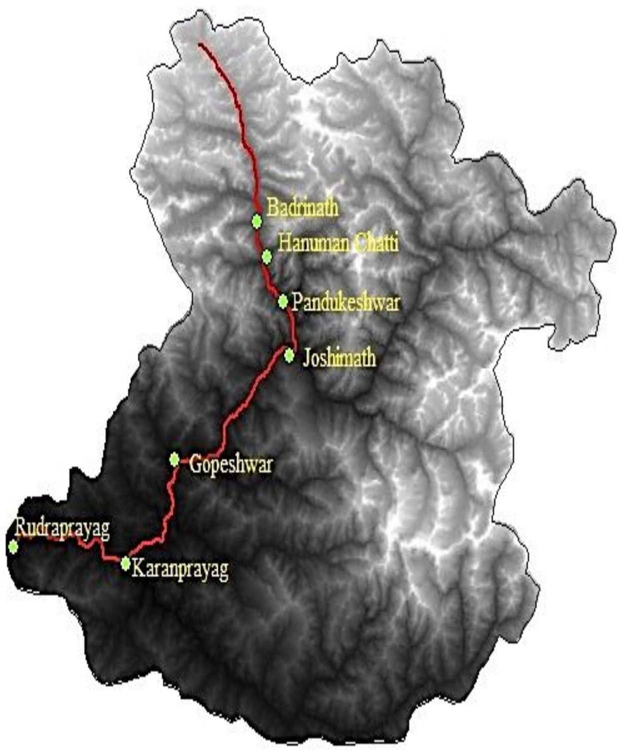

Fig 1: Alakananda River Basin and the worst affected places

Google earth is a virtual globe, map and geographical information program. It maps the Earth by the superposition of images obtained satellite imagery, aerial photographs and GIS.

The RiverTools software is a digital terrain analysis program designed specifically for studying the drainage network morphology and basin morphometry using DEMs. It also can visualize the digital topography very well. The drainage pattern was extracted for each of the sub-outlet points namely Badrinath, Hanuman Chatti, Pandukeshwar, Joshimath, Gopeshwar, Karanprayag, Rudraprayag.

Stream networks denote all the small tributaries of the main river which contribute to the water in the river. The purpose of extracting then for a particular basin outlet is to understand the direction of water flow, and also to visualize those villages which lie in the path of the free flow of the streams, which has been done here.

Soil is another important factor in determining the vulnerability of an area towards flooding. This is because the structure of soil and soil type determines how much water can infiltrate through such soil, or how much it can hold back water, or else is water can easily carry away such soils. Looking into these information, we can predict the vulnerability of a region.

This study is focused on all the above mentioned factors, using the mentioned tools to define the vulnerability of the area.

3. RESULTS AND DISCUSSION

The district of Chamoli has been affected by a number of cloudburst events in the last decade. Huge amount of casualty along with loss of infrastructure and cattle has taken place. As such there has been no effective flood management practices undertaken for disaster prevention, before it has already occurred.

The following figures show the result of the stream networks overlayed on the DEM of the study region, showing how the water from one outlet point collects more from the surrounding streams to contribute to the next outlet point.

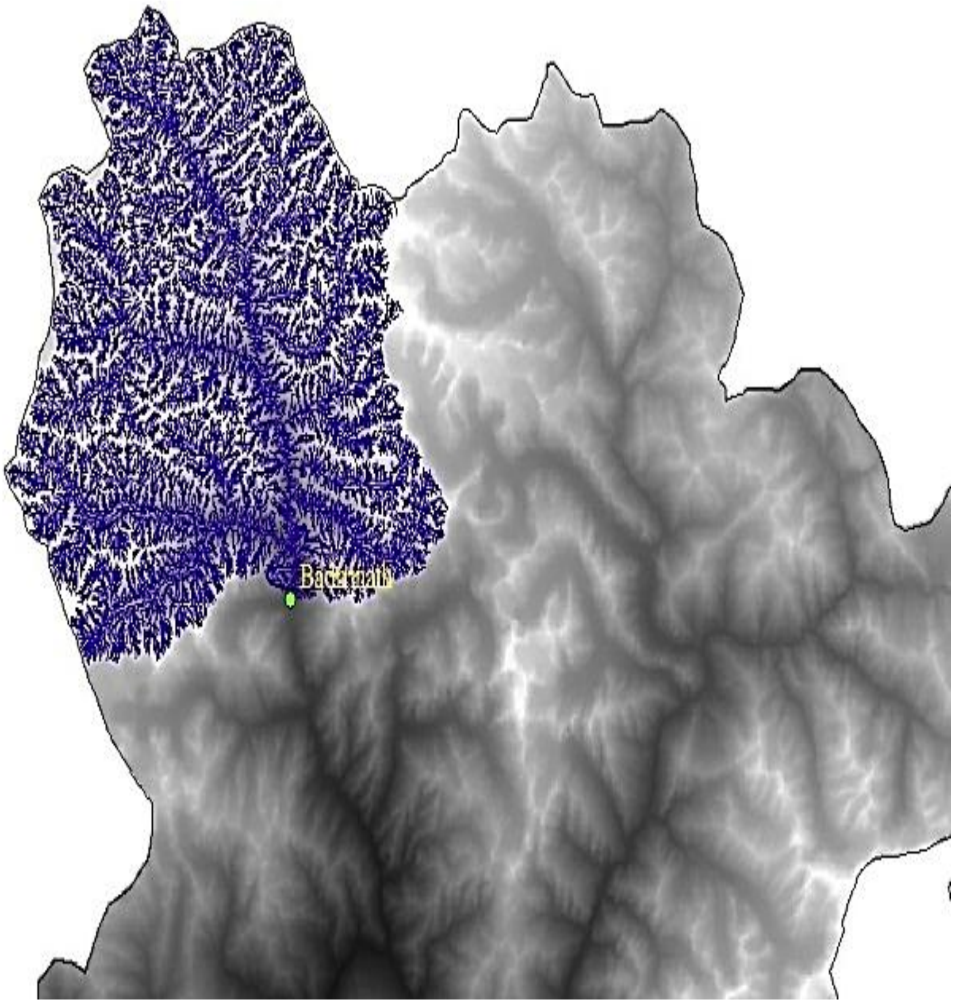

Fig 2: Stream networks upto Badrinath

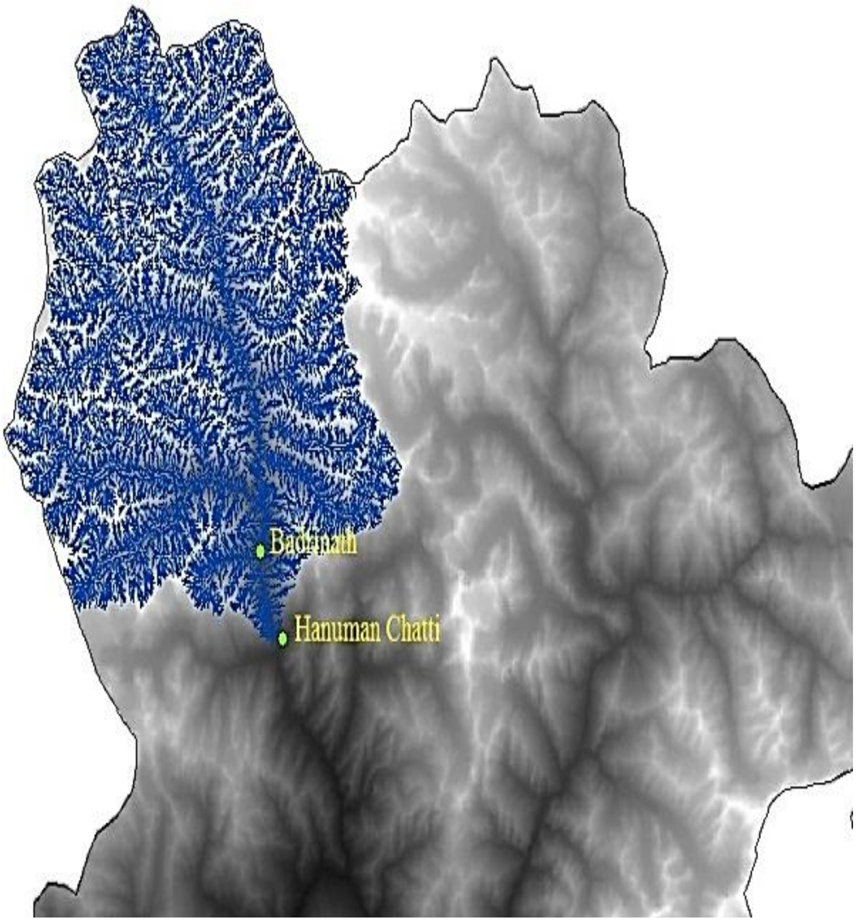

Fig 3: Stream Networks upto Hanuman Chatti

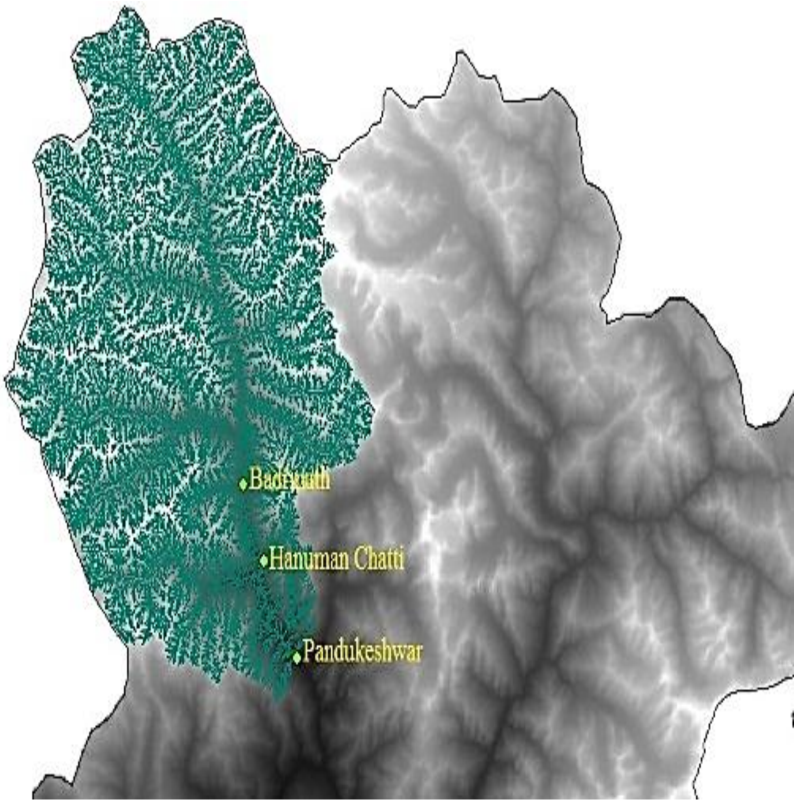

Fig 4: Stream networks upto Pandukeshwar

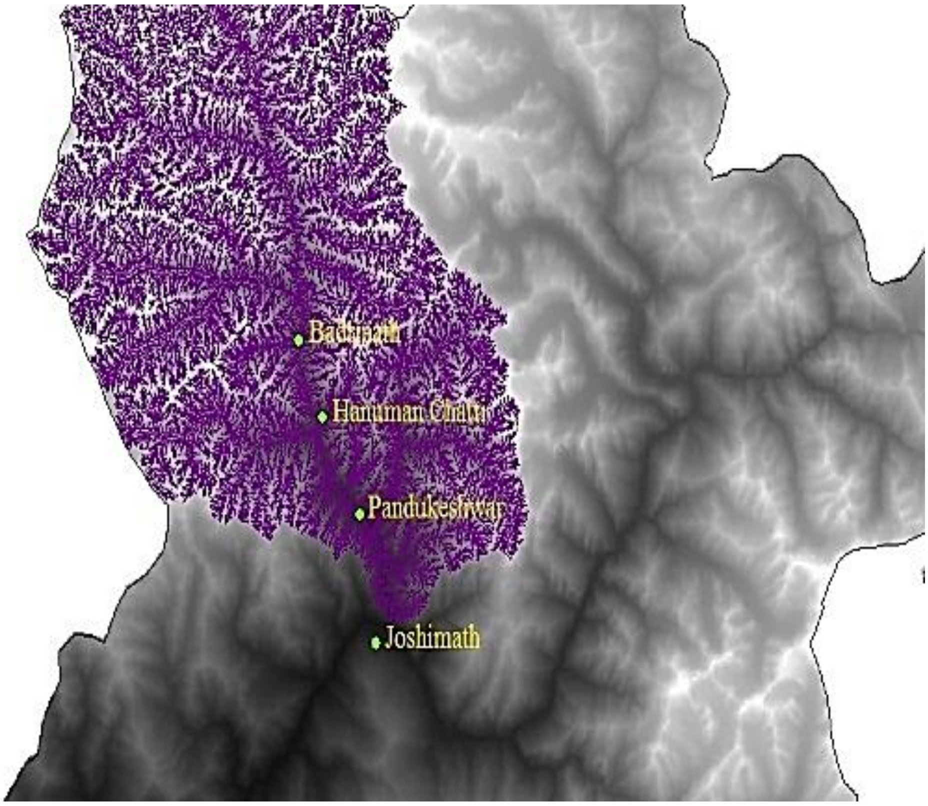

Fig 5: Stream networks upto Joshimath

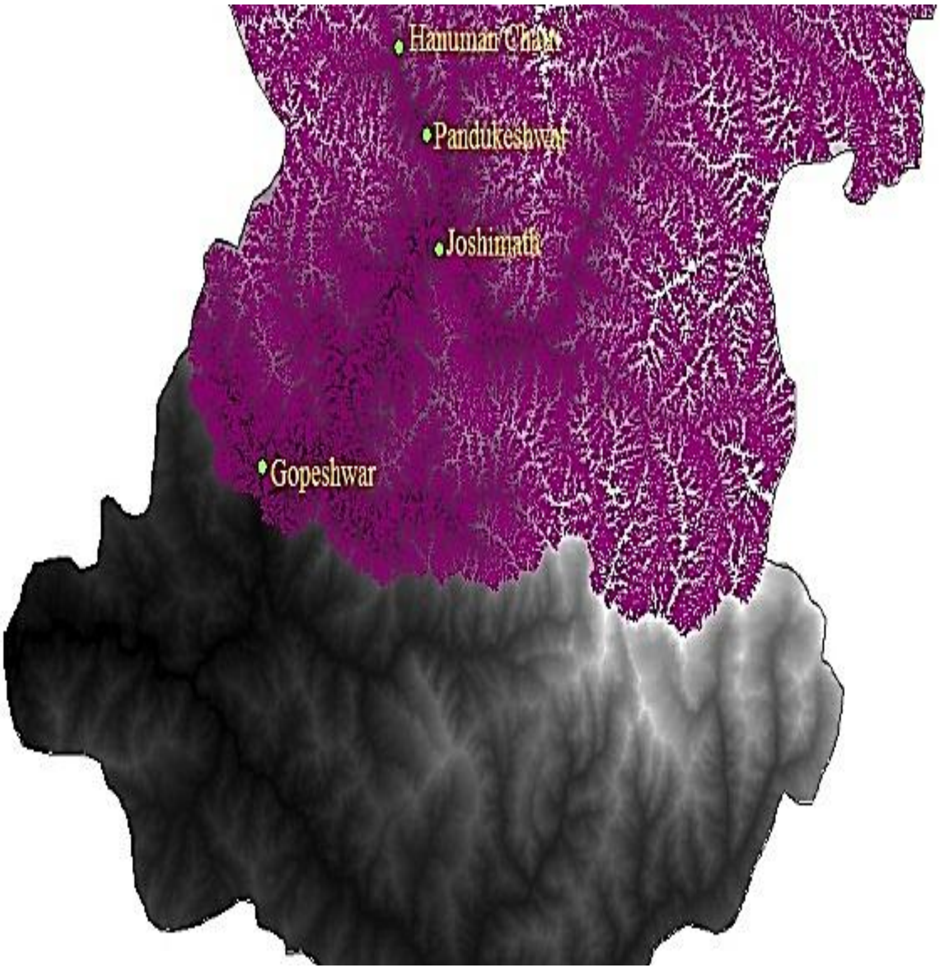

Fig 6: Stream networks upto Gopeshwar

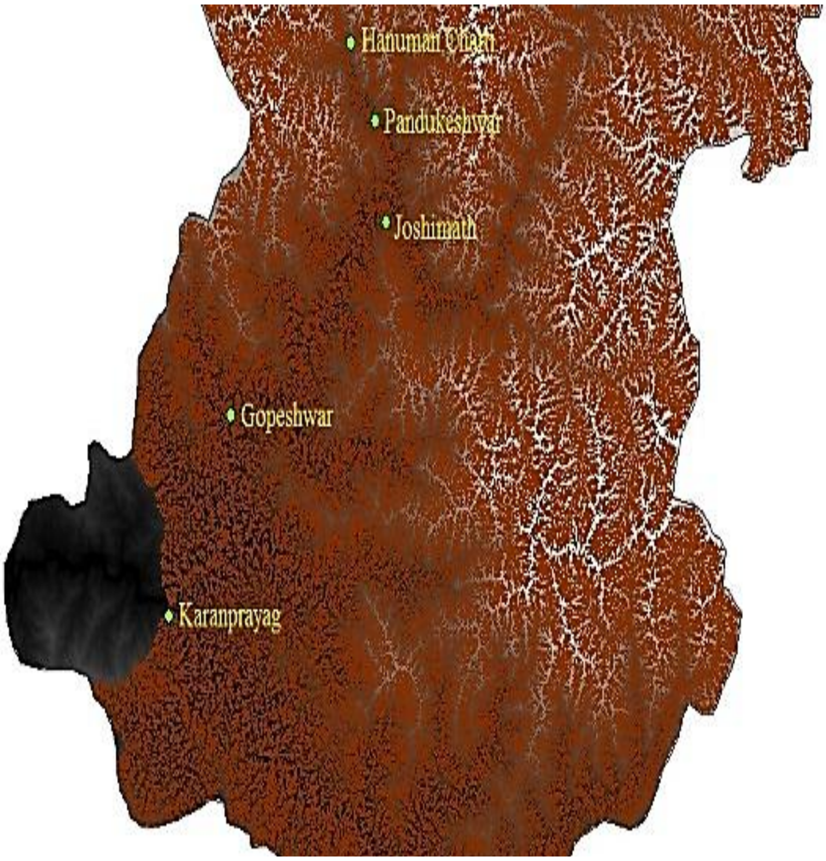

Fig 7: Stream network upto Karanprayag

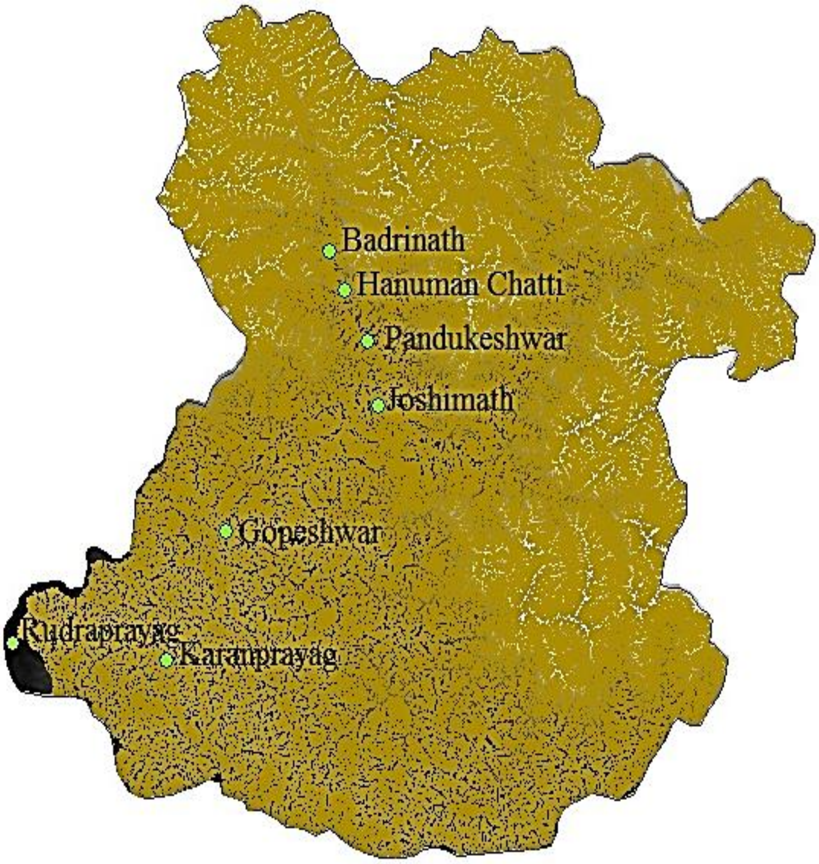

Fig 8: Stream Network upto Rudraprayag with the affected places

The Figure 9 below shows result of the village map overlayed on the stream networks map, on Arc GIS, which clearly shows how the villages stand in the way of the stream flow, and hence face high risk of being affected by coudbursts.

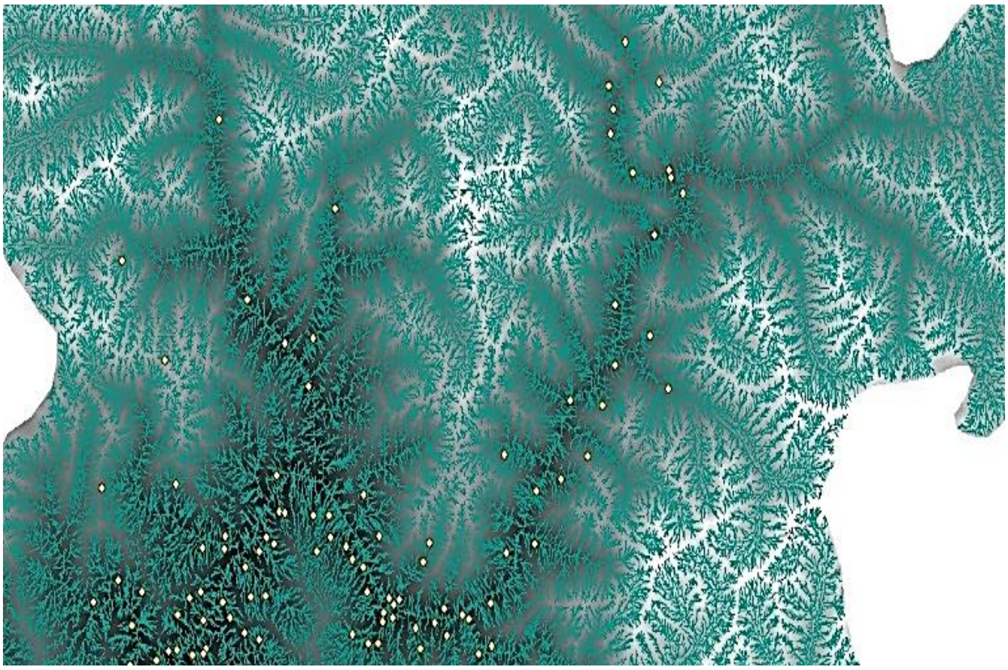

Fig 9: Stream networks and villages

Figure 9 shows the village map overlayed on the stream networks along with the DEM. The villages are represented by the yellow dots. When analysed very closely, it can be seen that most of these villages lie on the stream networks obtained. This clearly shows that such villages always are in grave danger from flooding, when any kind of a high intensity rainfall occurs.
The slope map of the study area has been given in Figure 10.

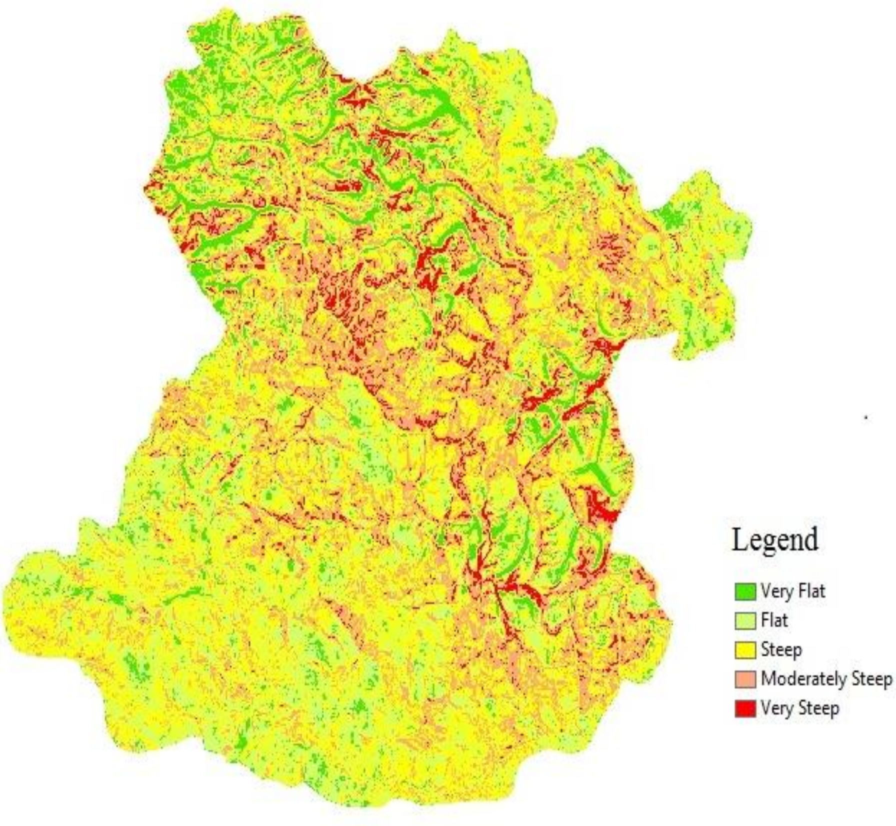

Fig 10: Slope Map of Study area

The study area has been classified by colours into Very Flat Land, Flat Land, Steep Land, Moderately Steep Land and Very Steep Land. As can be seen, nearly 50% of the region show a trend of moderate and steep slope. Also more than 90% of the region has a steep to very steep slope. It indicates that such a high gradient region is very much unsuitable for construction of any kind, be it settlement or infrastructure. As it is such high slopes tend to be very unstable themselves, and with an infrastructure built on it, would surely collapse.

The soil map of the area was also studied (Figure 11).

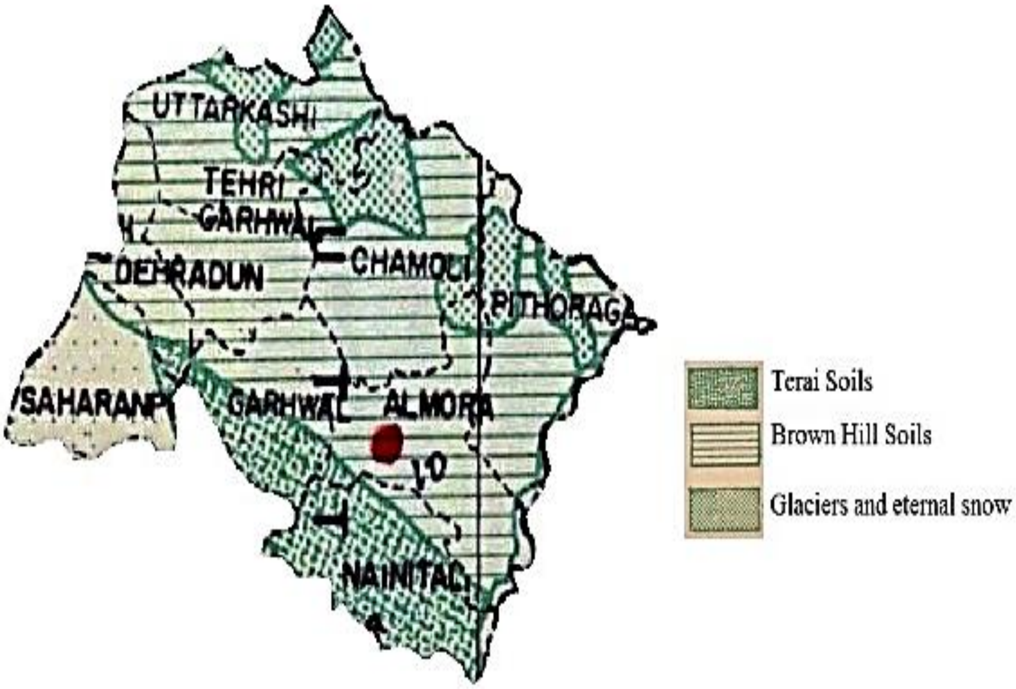

Fig 11: Soil map of Uttarakhand

Soil map of the state shows that there are broadly three types of soil in the region: first, the Glaciers with eternal snow, second the Brown Hill Soils, and third, the Terai Soil. The Glaciers and snow soil occur in the high altitudes of the Himalaya. Here negligible rainfall occurs and main form of precipitation is snow. The soil found here is very thin and fragile. Since the texture of the soil is very course with high gravel content, they are very much prone to displacements. The Brown Hill soils are mixed with pebbles and gravels in many regions. The texture varies from sandy to sandy loam, therefore, coarse and are easily carried away by water. Most of the region in the study area, namely Chamoli district is covered by these two types of soils. The Terai Soil found in other regions of the state is the soil found in the foothills of the mountains, where it has been transported by hilly rivers and streams and is made up of sandy material and raw humus.

Thus when gathering all the information studies, we can say that the villages located in such steeply sloping region and with such coarse soil type, which is unable of withstanding water flow, are always in a huge danger of flooding. Application of GIS and RiverTools have helped to visualize the proximity of the villages to the stream networks, and hence point out the highly vulnerable villages.

4. CONCLUSION

From the river network study and the other parameters studied, that is soil, slope and topographic position of villages, the low-lying areas can be easily identified. Thus the villages which are vulnerable to heavy floods along the Alakananda River basin can be delineated. Further study of the above work include the study of land use/cover pattern of the area, which also highly affects the run-off from a watershed. Also, hydraulic parameters of the river can be evaluated using HEC-RAS and GIS. The study undertaken here can help the government of Uttarakhand to locate the regions which are highly unsuitable for construction of infrastructure or residential areas, restrict the construction permission at those places and thus minimize the risk of a calamity happening from a disaster.

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