Locating Suitable Site for Rescue Operation in Uttarkashi District, Uttarakhand Using Remote Sensing and GIS Technique

Sunmoon Kr, Jayvind Kr Yadav, Krishna Kumar[1], Saurav Yadav[2], Dr.Bratati Dey[3]

1.Student, Department of Civil Engineering, GNOIT
2.Assistant Professor, Department of Civil Engineering, GNOIT
3. Head Faculty, Swastik Edustart-Institute of Remote Sensing and GIS

Abstract

Disasters are a very unfortunate event faced by almost every country. Every year huge numbers of lives and properties are lost due to disasters. Disaster cannot be stopped but its effects can be lessened if proper measures are taken at the right time. A proper disaster planning and management is a crucial need. Basically, the Himalaya is considered a young fold of mountains as it is still rising, the unstable geology welcomes various kinds of disasters. Thus, in this research work an effort has been made to prepare a post disaster plan where suitable sites for rescue operations will be located using Remote Sensing and GIS techniques. Further housing plans in these places will also be created. The work will start by collecting secondary data from various open sources. Further each parameter will be given a weight based on importance. These data will be uploaded in a weighted overlay tool to get the required output.

Keywords: Disaster, GIS and Remote Sensing, Himalaya, Post Disaster, Rescue Operation.

Introduction

Hazard is the occurrence of natural event, phenomenon, situation, or activity within a certain period of time and area, which causes damage to the society and environment. Natural events are only termed as hazard when they harm people and environment. Hazard may pose a threat to the population in terms of injuries, deaths, damage to properties, direct financial costs, and economic disruption *(Nadim., 2013)*. Primary effects of hazards are the results of the hazardous process itself. For example, collapse of building during earthquake. Long term effects are caused by primary effects. For example, loss of habitat caused by flood. Multi-hazard zonation (MHZ) is an approach used in disaster risk reduction and management that involves the identification and mapping of areas that are at risk of multiple hazards, such as floods, landslides, earthquakes, and wildfires. MHZ aims to provide a comprehensive assessment of the potential risks and vulnerabilities of an area to different types of hazards, and to develop effective mitigation strategies and emergency response plans to minimize the impact of disasters.

Brief overview of Uttarkashi district and its vulnerability to natural disasters:

Uttarkashi district is a mountainous district located in the Indian state of Uttarakhand, situated in the northern part of the country. The district is known for its natural beauty, cultural heritage, and religious significance, as it is home to several important Hindu pilgrimage sites, including Gangotri, Yamunotri, and Kedarnath. Despite its natural beauty and cultural significance, Uttarkashi district is also highly vulnerable to natural disasters, primarily due to its mountainous terrain, which makes it prone to landslides, flash floods, and avalanches. The district is also located in a seismic zone, which makes it susceptible to earthquakes. In recent years, Uttarkashi district has experienced several major natural disasters, including the devastating flash floods of 2013, which caused widespread destruction and loss of life in the district and the surrounding areas. The district has also experienced several landslides, including the landslide that occurred in August 2021 in the village of Mando in the Purola block of the district, which resulted in several fatalities and significant damage to property. Due to its vulnerability to natural disasters, Uttarkashi district has been the focus of several disaster management initiatives by the state and central governments. These initiatives include the development of early warning systems, the construction of infrastructure to mitigate the impact of disasters, and the implementation of community-based disaster preparedness programs. In summary, while Uttarkashi district is known for its natural beauty and cultural significance, it is also highly vulnerable to natural disasters, primarily due to its mountainous terrain and location in a seismic zone. The district has experienced several major natural disasters in recent years, and significant efforts have been made to mitigate the impact of disasters and enhance the resilience of the local communities.

Importance

Rescue sites play a crucial role in disaster management, particularly in the immediate aftermath of a disaster when the focus is on saving lives and providing emergency relief to affected communities. Here are some key reasons why rescue sites are important in disaster management:

Provides a central location for rescue and relief efforts: Rescue sites serve as a central hub for rescue and relief operations, allowing responders to coordinate their efforts more effectively and efficiently. This helps to avoid duplication of efforts and ensure that resources are directed to where they are needed most.

Provides a safe and secure location for affected communities: During a disaster, many communities may be forced to evacuate their homes and seek shelter elsewhere. Rescue sites provide a safe and secure location for these communities to stay, ensuring that they have access to food, water, and other essential supplies.

Facilitates the distribution of aid and supplies: Rescue sites can serve as distribution centers for aid and supplies, ensuring that affected communities receive the support they need to recover from the disaster. This includes items such as food, water, medicine, and temporary shelter.

Enables rapid response to emergencies: By having pre-identified rescue sites in place, responders can quickly mobilize and respond to emergencies, reducing the time it takes to reach affected communities and provide assistance.

Supports effective communication and coordination: Rescue sites facilitate communication and coordination between different agencies and organizations involved in the disaster response. This helps to ensure that everyone is working together towards a common goal and that resources are being used effectively.

In summary, rescue sites are an essential component of disaster management, providing a central location for rescue and relief efforts, ensuring the safety and security of affected communities, facilitating the distribution of aid and supplies, enabling rapid response to emergencies, and supporting effective communication and coordination between responders.

Objectives

1. To find out the applicability of GIS and RS in disaster-based research.
2. To map out spatial- temporal disaster occurrence in Uttarkashi district (2010-2022).
3. To locate a rescue site using AHP technique.
4. To suggest construction in major Disaster-prone areas like Uttarkashi.

Literature Review

Pourghasemi *(et al., 2020)* used two well-accepted, machine-learning methods to develop multi-hazard risk maps of Fars Provience, Iran. These two machine-learning methods are The multivariate additive regression splines (MARS) and The support-vector machine (SVM). to identify the patterns of landslide, flood and forest fire, sixteen effective factors are used to develop the models. Finally, the resulting maps were overlapped to prepare the multi-hazard maps and these maps identified the areas which are most prone to natural hazard.

Kaur *(et al., 2018)* prepared Hazard zonation map of Gangtok, India considering the hazards earthquake and landslide. Analytical hierarchy process (AHP) had been used in this study. Building, road and population vulnerability maps were prepared for earthquake and landslide hazard and they were overlapped to prepare the multi-hazard map. The outcome of the research provides useful document in the form of maps for future risk planning.

Gautam *(et al., 2021)* studied the weightage-based district and local level multi hazard zonation of Nepal. Sixteen natural hazards were considered to perform the analysis and data were taken from The National Disaster Risk Reduction Portal [DRR portal]. The consequences of multi-hazards in terms of building damage, fatalities, economic losses and affected population were also mapped at the district-level.

Pourghasemi *(et al., 2020)* used a machine learning technique for mapping multi-hazard risk susceptibility of Fars Province, Shiraz City as the machine learning technique is increasingly emphasized in the susceptibility modeling. In this study, the most important factors were recognized which contributed to the occurrence of landslides, foods and forest fires. Data were collected using Global Positioning System (GPS) in fieldwork and different province reports of the study area were also used. The susceptibility maps were prepared by random forest model.

Islam *(et al., 2013)* calculated disaster risk index based on hazard index and vulnerability index in a coastal area of Bangladesh called Assasuni Upazila, the sub-district of Satkhira district. A GIS based approach of multi-criteria analysis was applied to incorporate the spatial factors in the vulnerability index. Thematic maps of Disaster vulnerability and Disaster risk were prepared using the values derived from the calculation of indexes.

Kumar *(et al., 2013)* analyzed cloudburst in Uttarkashi, district of Uttrakhand, using River Tool and Geographic Information System. The influence of Land use land cover classification, slope angle and Drainage characteristics spatially integrated to analyze the Cloudburst. Landsat ETM, Google Earth Imagery and Aster DEM data were used in this study. The maps which were produced by this study using GIS technique, helps to identify the locations where implementation of development planning is needed.

Halder *(et al., 2021)* created landslide hazard zonation map of Yamunotri Valley, Uttarkashi, Uttrakhand, India. LISS IV data, geological Map and topo sheet were used for data collection. In total thirteen parameters were taken and thematic layer had been created and information values were calculated for each parameter. Lastly all information value maps were integrated for landslide zonation or susceptibility mapping. The study revealed that the Upper Yamunotri region a hazardous prone zone and hazard zonation maps can be used for development planning in this area.

Onagh and Rai, 2012, studied landslide in Uttarkashi district, Uttarkhand using Multiple Linear Regression method as this region suffers from frequent landslides every year. A Landslide Inventory map had been prepared using the database of landslide and this database was prepared by visual interpretation of Google Earth image, Landsat TM data and filed survey. Several variables were taken in the Multiple Linear Regression analysis and thematic maps were prepared for those variables. Finally, an overlay analysis was done for landslide susceptibility mapping. For the validation of the result, the landslide Inventory map and susceptibility map were compared. Three natural-hazards—seismic, flood and extreme waves—are combined and evaluated together to assess the multi-hazard risk, and the analysis is made on the level of homogenous zones.

Jeanne et.al (**1995**) in their work has indicated 'the impacts of landuse and landcover change are critical to many government programs like documenting the rates of driving forces and cost of change. Local landuse and landcover changes are primary agents of global climate change at all scale and are significant forces that impact biodiversity, water and radiation budgets, and trace gas emissions'.

Riebsame et.al (**1994**) has said Landuse and Landcover dynamics is a result of complex connections between quite a few bi0physical and socio-economic conditions. The effects of human behavior are instantaneous and often radical, while the natural effects take a relatively longer period of time. The difference in increase by households and landcover change indicate the pressure on forest land cover and related biodiversity. This implies that population pressure is believed to be one of the driving forces for the changes in the area of their study. In order to make relevant conclusions and recommendations of an area, one has to therefore properly consult situations of the past and present. i.e. socio-economic and biophysical aspects of that area'.

According to Watson and Zakri (**2005**) 'Human landuse particularly 0ver the past 50 years has changed ecosystems more frequently and vastly than in any comparable period of time in human history. This has occurred at a cost of rapidly growing demand on natural resource'.

Mark A. Drummond et. al (**2011**), have worked on 'land change unpredictability and human environment dynamics in the United States Great plain and they have found that a large part of the Great plain is in relatively stable land cover. However other land systems with significant bio physical and climatic limitations for agriculture have high rates of land change when pushed by economic, policy, technology or climate forcing factors'.

John Rogan et. al (**2004**) has given 'a details of the various types a details of the various types of sensors and satellites used for mapping and monitor landcover and landuse modification. They have also significantly pointed out the different technique used for image analysis in LULC study'.

There are sensors having various resolutions which are used by researchers for LULC studies like Abbas et. al(**2010**) have studied 'the changes in LULC of Katsina state of Nigeria over 13 years period using google earth images'.

Lee et. al (**1992**) indicated 'the consequence of understanding the implications of past,present and future patterns of human landuse for biodiversity and ecosystem function is ever more important in basic and applied ecology. To understand how landuse landcover(LULC) affects and interacts with global earth systems, information is needed on what changes occur, where and when they occur, the rates at which they occur, and the social and physical forces that drive those'.

According to Alex de Sherbinin (2002) 'Landuse is the term that is used to describe human uses of land; land cover refers to the natural vegetative cover types that differentiate a particular land area. Therefore, landuse change is the proximate cause of landcover change'.

FAO (1997) illustrates 'the landuse landcover dynamics by characterizing landuse as the arrangements, activities and inputs people undertake in certain land cover type to produce, change or maintain it, while landcover is the observed biophysical cover on the earth's surface. Therefore, landuse defined in this way establishes a direct link between land cover and the actions of people in their environment'.

Zubair, Ayodeji Opeyemi (2008) in his project work examined 'the use of GIS and RS in mapping land use/land cover in IIorin between 1972 and 2001 so as to detect the changes that has taken place in this status between these periods. Then an attempt was made at projecting the pragmatic land use land cover in the next 14 years. In achieving this Land consumption rate and land absorption coefficient were introduced to aid in the quantitative assessment of the change'.

Daniel Ayalew Mengistu, et. al (2014) worked to monitor 'the LULC status of IIorin city. He analyzed the changes in landuse/landcover in some parts of south western Nigeria over a 16 year period. Landsat imageries for the year 1986 and 2002 were used for this analysis. It was establish that all through these years forest cover has seen the maximum changes and population growth and growing economic activities were categorized as the main causes last this change'. Dafang Zhunang et. Al (2002) have tried to 'analyse the land use/cover change of China which is characterized by urbanization consequential in a decrease in arable land in the east along with a large area of grassland being cultivated in the west, it has been accelerated by rapid economic development in the last ten years'. All of the above changes will affect sustainable development in the next century. The Chinese Academy of sciences is conducting a study of land use/cover change over the last years based on the integration of remote sensing and GIS technology to establish a multi temporal database covering all of China'.

Daniel et al. (2002) have used '5 methods to compare the landuse landcover change. These methods are traditional post classification cross tabulation, cross correlation analysis, neural networks, knowledge based expert systems and image segmentation and object oriented classification. After undergoing the study they have found that each of this method has its own advantage but remote sensing and GIS alone cannot solve the local level problems'.

In the present Study 'the Snow cover of Uttarkashi was also Analysed using the Technique Normalized Difference Snow Index as in the recent time the NDSI is widely used for Snow cover Mapping at large scale (Dozier J. 1989). There have been plenty of studies on snow cover mapping and monitoring using NDSI like Sibandze Phila et. al (2014) used 'normalized difference principle snow index(NDPSI) for distinguishing snow from connected land cover types and they have found an accuracy of 84.9% in snow cover mapping using this technique'. NDSI is preferred over 0ther snow identification method such as the Relative spectral mixture analyses. (***Shreve et. al***) ,Xiao et. ***al***(2000) Used Normalized difference snow/Ice index(NDSII) by adopting reflectance values of red and mid infra red spectral bands of landsat TM'. The three visible bands (TM1,2,3) of landsat TM is useful spectral band for sorting out snow and ice cover. For instance in using landsat TM data and ground radiometer measurements to classify ice and snow type in the eastern Antartic. Bresjo Bronge and Bronge (1999) found that 'the TM3/TM4 ratio is a simple tool for distinguishing between blue ice and snow of various characters and the TM3/TM5 ratio is useful tool for quantifying snow grain size variations'. Basnet Smriti et. al has also used 'the NSDI technique to scrutinize the seasonal snow cover in Sikkim Himalayas between 2004-2008. Besides the NSDI technique image classification and ultimately overlapping technique also helps in identifying the locational change of any landcover'. Though very less studies has been done to monitor snow cover change using this technique. Thus in this study an effort has been made to use both these techniques to find out the snow cover change of Uttarkashi district between 2000 and 2015. In the present study surface temperature of the area was also estimated. At the present time many satellites are providing thermal bands which are used for estimating surface temperature using image processing algorithm in GIS platform, many work has been done in this like Sobrino et. al(2004) have provided three methods to abstract the land surface temperature(LST) from thermal infrared data supplied by band 6 of the thematic mapper(TM) sensor onboard the landsat 5 satellite are compared. According to Sameen et.al(2016), 'RS has helped in monitoring environmental conditions and natural resources. The new instrument called thermal infrared sensor(TIRS) approved on board of the new generation of landsat satellite captures the temperature of the earth's surface in two bands. These bands can be calculated using image processing algorithm and ArcGIS processing tools'

Materials and methods

Study area

Location: - Uttarkashi is a district of Uttarakhand state and lies in the northwestern part of the state. The present study area covers 8016 km2. The area is geographically bounded by 30040' and 30050' N latitude to 78020' and 78030' W longitude and it falls in the survey of India toposheet Nos. 53 J/5 and 53 J/6. It is bounded by Himanchal Pradesh from the northwest, it also shares boundary with China from northeast, below it lays Dehradun District from the southwest side, Tehri Garhwal in the south, Rudraprayag and Chamoli District in Southeast.

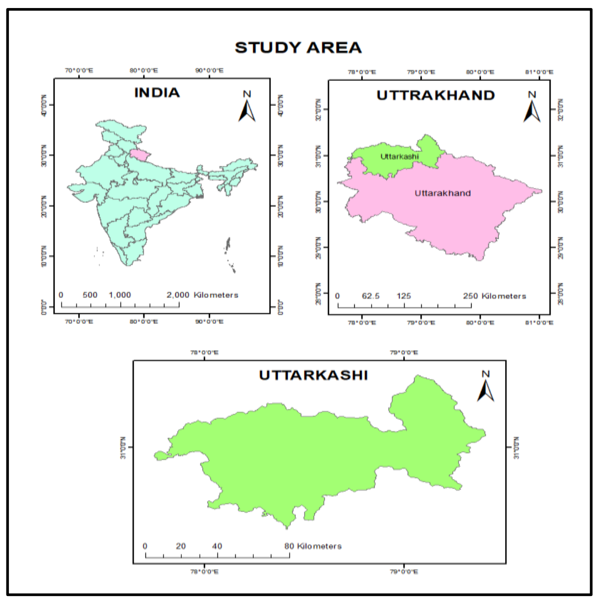


Fig 1-Study Area Map

Uttarkashi is located in the Upper Himalayan region and geographic environment of this area ranges from snowless valley to high peak covered with vast glaciers. The land is not good for cultivation because most of the land is covered by boulders and gravels.

A range of variety in natural vegetation is present in this region. Between 1,000 – 2,000 meters, the forest is covered with pine tree. Deodar, oak and rhododendron are found between 2,000 m – 3,000 meters. Beyond 3,000 meters, forests of spruce, birch and fir are seen.

Geology: -The geology of Uttarkashi is complex as this region have undergone repeated tectonic activities. It lies over Alpine Himalayan belt which is one of the most earthquake prone belts. Indian plate lies below this area which is moving towards the Eurasian plate at a rate of 7 cm per year and this is the reason of the continuous movement of this region.

There are many high mountain peaks in Uttarkashi i.e. Banderpooch, Gangotri, Kedarparvat and Shivling. Very sharp undulations are found in high mountains, narrow valleys. Several landforms are also present here i.e. end moraines, lateral moraines, V shaped fluvial valley, U- shaped glacial valley, river terraces and denudational structural mountain etc. and these are created by Fluvial, Glacial and Fluvio-Glacial processes

The lesser Himalayas consists of Pateozoic and Merozoic crystattines, heranorphic and sedimentary rocks. The main central thrust is a major tectonic feature of the Himalayas and has brought the crystalline rocks of Hi8her Himalayas over the younger Sediments.

Climate: - Summer season in the Uttarkashi is moderate and the most extreme temperature does not exceed thirty degrees (30℃). This season start from the month of April and ends by June and the temperature does not fall below fifteen degrees (15℃). The rainy season in Uttarkashi begins from the month of July and it continues till September. The extreme rainfall found in July and August and the average rainfall is found to be 1693 mm. Winter is dry compared to summer and the temperature begins to decrease from October. Winter season stays longer than the other seasons and the temperature remains low up to the month of February. The average temperature of this season is six degrees (6℃).

Methodology

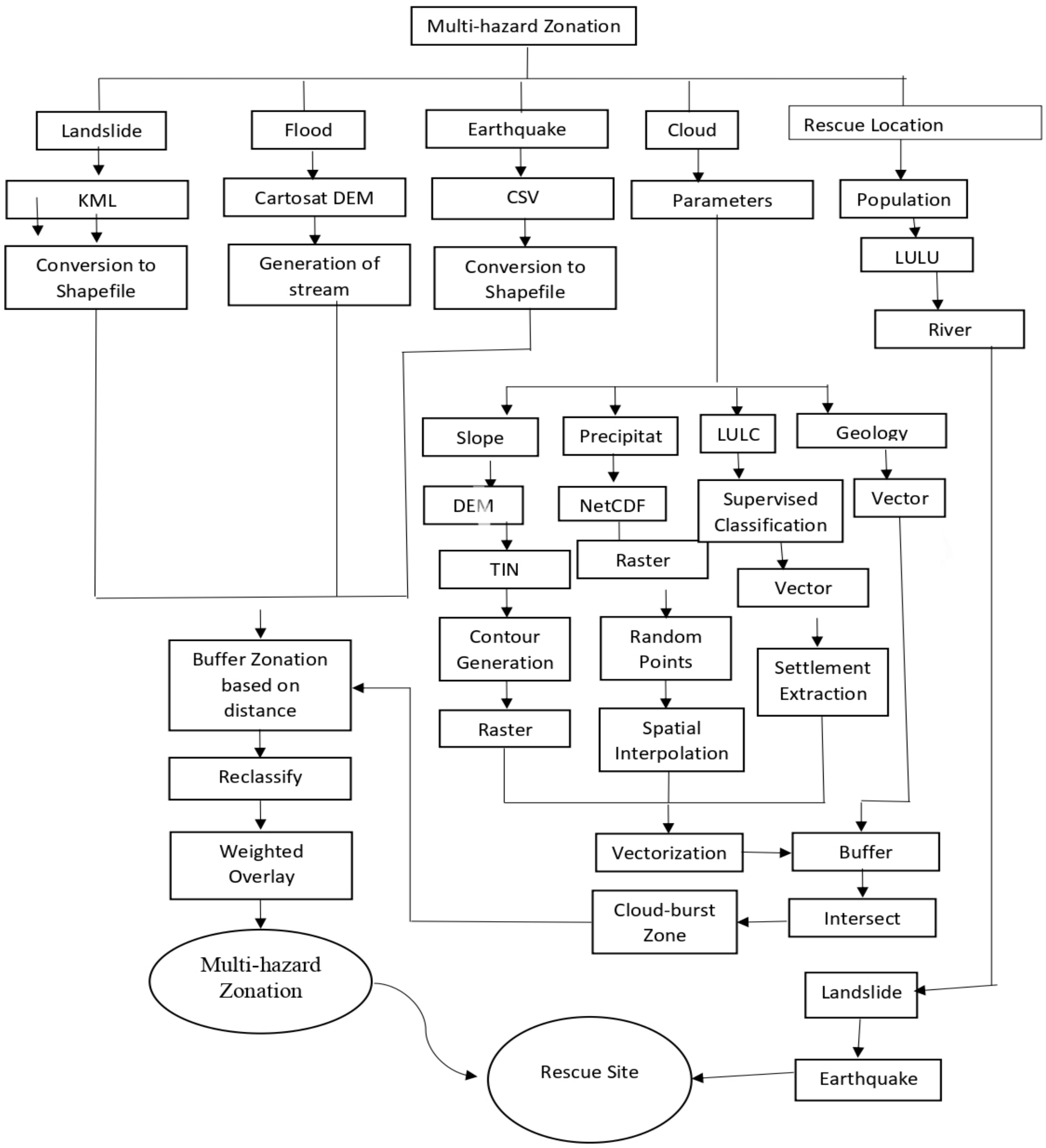


Fig 4 Methodology Chart

Data source

Dataset	*Source*	*Resolution*
DEM (CARTOSAT 1)	Bhavan	2.5m
Landsat 8	Earth Explorer	30m
Flood	DIVAGIS	----
Landslide	Google earth pro	----
Precipitation	Chc. UCSB. Edu	0.05 Deg
Geology	Bhukosh	----
Population	Census of India	----

Table 1 -Data Source

RESULTS & DISCUSSION

Hazards and disasters are regular phenomenon in Uttarkashi. The fragile geological structure, tectonic activities, lithological settings make the disasters worse. Every year various kinds of disasters occur here though magnitude and impact vary from year to year.

Some areas which are facing the worst kind of landslides in different parts of Uttarkashi in different time frames. In the June 2013 disaster 1930 houses were slightly damaged, 186 houses were totally damaged and 467 houses were severely damaged. There was a loss of 339 hectares of agricultural land, 12 people were killed and 20 were severely injured (DMMC, Dehradun)2. Many roads and bridges were cut down. Its losses are yet to be recovered; there are many villages where the repair work is still under process. Such incidents makes it clear the Himalayan region is very sensitive, a small change in temperature, rainfall or snowfall can have a severe consequence for itself as well as for the low lying places.

LAND USE LAND COVER MAPPING

The term Land use land cover are two different terminologies which are often used interchangeably, one is land use an the other one is land cover. Land use maps are created to show the different potential use of land and how is has been changed over time. Land cover maps shows coverage of different physical materials like forest, wet lands, agricultural land, water bodies etc on the earth surface. Land use land cover maps provide information of the current landscape of any region. The land use land cover pattern of any region is an outcome of various physio-cultural factors and their utilization by man in time and space *(*Tripathi *&* Kumar., 2012*)*. So, this is an important component in understanding the interaction between human activities and the environment and thus it is necessary to be able to simulate changes *(Tiwari & Khanduri 2011)*.

Land cover has changed over the past millennium, after the invention of fire. Once man started settling down in different pales, they have been continuously modifying their surroundings and its land cove. Over the centuries man learned to use land for agriculture and stared to burn or destroy the natural vegetation for agricultural purpose and development activities like construction of buildings. In the past two centuries, 'the impact of human activities on Land has grown enormously because of population increase, technological Development and the other requirements (Dey.,).

Particularly in the developing world which has accelerated research on LULC (Dey.,), this study is very are indispensable for future planning and development. With the increasing use of lands, it is important to monitor the ongoing process on land. It requires the involvement of the past studies on the same to compare the pattern of land use in present. We can use land use land cover maps to plan the future use of the land otherwise within the next few decades, the future generation may face difficulties to find out proper land for any king of use.

GIS and Remote Sensing techniques are the major tool for classifying Land use land cover. Using Remote sensing, we can extract information of remote areas where we cannot reach physically and remote sensing images provides images with different temporal, spatial, spectral and radiometric resolutions. Mainly two methods are used for the Land use land cover classification. One pixel based and the other one is object-based classification. Pixel based classification is done on per pixel level and it uses the spectral reflectance value of each pixel, whereas object-based classification is done by localizing a group of pixels where the spatial properties of those pixels are related to each other and in this method both the shape and the spectral reflectance vale are considered. The pixel-based classification is further divided in supervised and unsupervised classification. In this study we have used Supervised classification of maximum likelihood classifier.

We can see that the western and south-western region of Uttarkashi is covered by dense vegetation and the eastern and north-eastern land is mostly barren land with snow cover. The western region of Uttarkashi has the settlements and the agricultural land is very less in the study area.

PRECIPITATION MAP

In this study we have analyzed the precipitation for pre-monsoon, during monsoon and post monsoon in Uttarkashi. For pre monsoon we have taken the precipitation data for the months of February, March and April. For pre-monsoon we have taken the precipitation data from June to September and post-monsoon period is from October and November. We can see that during the pre-monsoon period the average precipitation is high in the central part of Uttarkashi. The maximum amount of average precipitation is 1730 millimeter during monsoon. During the monsoon, the amount of precipitation is highest. The amount of precipitation is the lowest in post-monsoon period.

LANDSLIDE MAPPING

Uttarkashi lies between Main boundary thrust (MBT) and Main central thrust (MCT) and rock here belongs to Damta group of rocks, which is very new in nature. Therefore, this region of Himalaya is very prone to hazard like landslide. Landslides basically means a slow and rapid downward movement of instable rocks and debris masses under the action of gravity which can be categorized into various types on the basis of failure characteristics *(Carden., 1991)*. Landslides impact the nature and environment in a various way like loss of human life, damage to natural resources and private properties, blockage of road for days which disrupts the connectivity among different regions. It also effects the agriculture when the excavated rock layer falls on agricultural field. According to a report of Geological Survey of India (GSI) 0.49 million sq. land of the country is vulnerable to landslide and out of that 0.098 million sq. km area located in north eastern region. Though landslide is a natural activity but in recent time unplanned human activities are also increasing the probability of landslide occurrence. Development activities like blasting of mountain for road, cutting of trees are giving rise to landslides in Uttarkashi. Below are some images showing worst kind of landslides in different parts of Uttarkashi in different time frame.

EARTHQUAKE MAPPING

As Uttarkashi is situated in in the main Alpine Himalayan belt, the region has witnessed many major earthquakes. In the 1990s, the first major earthquake struck the Indian subcontinent and it devastated Garhwal Himalayan region, especially Uttarkashi, Tehri and Chamoli districts. In Uttarkashi, earthquake of 19th October 1991, occurred in the greater Himalayan region north of the main central thrust, at the depth of 12 km and magnitude of 6.8. At least 768 people died, 5,066 people were injured, 42,400 houses destroyed due to the high intensity of this earthquake. Till date this earthquake had the highest magnitude. The roads between Uttarkashi and Gangotri were disrupted. The Uttarkashi earthquake of October 20, 1991 (magnitude 6.6) in the Garhwal Himalayas in northern India caused strong ground shaking in the districts of Uttarkashi, Tehri, and Chamoli in the state of Uttar Pradesh. The intensity on Modified Mercalli Intensity (MMI) scale was IX in a region of about 20 sq. km. The area was instrumented with 28 numbers of 3—component strong moan analog accelerographs (SMA-I Bf Kinematrics); of these, 13 accelerographs recorded the event (Chandrasekaran and Das, 1992). Pig. 2 shows the location of these 13 accelerographs as well as the location of epicenter. All the instruments were located in free—field (or close to a free-field condition) and the sites could generally be considered as rocky dates. The epicentral distance of these records is in the range of 25 km to 150 km. Table 1 provides the epicentral distance of recording stations.

In this study we have taken a total of 47 earthquake locations from the year 2008 to 2020. In 9th June, 2008, the earthquake occurred in 36km north-west of Uttarkashi, where the depth was 10 km at the magnitude of 2.8. In 2009 and 2010, total 4 earthquakes occurred in each year. Among them, the earthquake with the highest magnitude of 5, occurred in 2009, 21st September and the depth was 36 km. Till date, the highest number of earthquakes occurred in the year 2011. In total 10 earthquakes occurred and the magnitude and depth of earthquakes in this year ranged between 2.7-2.5 and 8-20 km respectively. In 2012, the earthquakes were more devastating from 2011 and 2013 and 2 earthquakes took place with the magnitude of 5 and 4.4. In total 5 earthquakes happened in 2013 and magnitude and depth of earthquakes varied from 208 to 3.8 and 10-25 respectively. Though earthquake occurs every year in Uttarkashi, but in 2014 and 2015 there was no earthquake at all. In 2016 and 2017, 3 earthquakes occurred in each year and the magnitude ranged between 3.2 to 3.6 in both of these years. In 2018, 2019 and 2020, the number of earthquakes were 4, 5 and 6 respectively and the magnitude varied from 2.9 to 3.8, 2.9 to 3.7 and 2.7 to 3.5 respectively.

FLOOD MAPPING

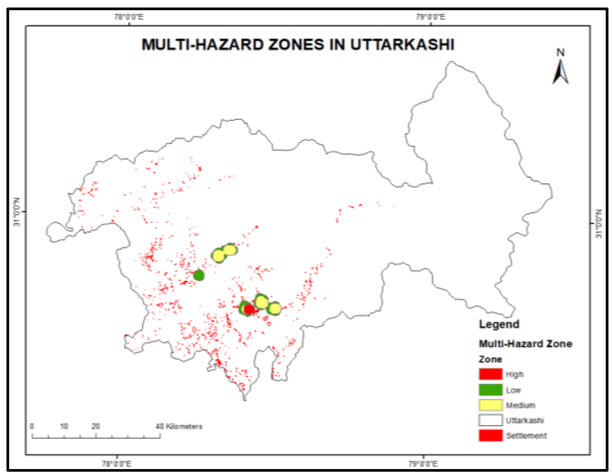
Flood in Uttarkashi occurs along the two major rivers namely Bhagirathi which is known as Ganga in plain and Yamuna. Bhagirathi, originated from Gangotri glacier, traverses 128 kilometers in Uttarkashi district. Yamuna river is originated from Banderpooch glacier which is located in the west of Bandarpunch peak. Tons is the third important river of Uttarkashi. The slope of the rivers is from north to south. Every year during monsoon floods occur and cause the loss of human property and infrastructure. Because of continuous tectonic activities and fragile geological condition Bhagirathi River basin, in the Himalayan region, considered as highly flood prone area and it affects the villages of Uttarkashi. The hydrologic process of this region enhances the probability of flood during monsoon. Floods in this region are of two categories, rapid flood and flash flood. Rapid floods occur due to the continuous rainfall and flash floods occur out of extreme rainfall in a short period of time. Flood mapping of this region is important to prevent the risk. Hence, flood prone areas of this region need to be identified to obstruct the threat on lives and socio-economic losses.

Uttarkashi receives maximum amount of precipitation in the months of July, August and September. For flood mapping in the study area, we have taken the precipitation for the month of August. From the analysis we can observe that the areas which are lying near the river channel, are highly vulnerable to flood and as we move forward away from the river channel the risk of flood decreases gradually.

CLOUD BURST HAZARD-ZONATION

Cloud burst is such a natural phenomenon which can give rise to another disasters like flash flood or landslide. There are several factors which can cause cloud burst, but in the present work four parameters are taken namely slope, precipitation, settlement and geology. The areas where all the parameters have overlayed, can be considered as cloud burst zones. We can see that our study area has been divided into four hazard zones. Very small area is falling under low cloud burst hazard zone. North-eastern and north-western region are falling in medium cloud burst hazard zone. Most of the study area can be considered as high cloud burst hazard zone. The areas which are very highly prone to cloud bust, are scattered in the central and south-eastern Uttarkashi.

Fig 4. Multi Hazard Zone



MULTI-HAZARD ZONATION

Multi-hazard zonation mapping is important for risk planning through which precautions can be taken for a particular area where hazards take place frequently. One of the difficult issues in studying hazard or risk assessment is the analysis of various hazards in a same place. Multi-hazard can be studied in different ways like overlaying single hazards, identification of all hazards in a same place and identification of all hazards in a same place and the interaction among them. One hazard can influence another hazard which can affect largely the environment and the living beings of that environment. Certain conditions can make a particular area more vulnerable to hazards and those conditions may change constantly. For instance, earthquake may cause tsunami, change in land use land cover effects the hydro-meteorological hazards, cloud burst gives a rise to flash flood etc. Many of the hazards are related to each other in such way that disrupts the rhythm of daily lives of human beings and animals. Some examples can be taken to understand it - volcanic eruptions cause the deposition of volcanic ash and it may lead to landslides and flood. Earthquakes may trigger landslides, and the landslides increase the erosion and debris flow.

The study of multi-hazard is difficult but if we consider the right parameters, we can make multi-hazard maps using GIS system and some specific powerful tools.

For creating multi-hazard maps, we can take different hazards depending on the area of interest. We can refer the past studies which have been done on our area of interest and choose the hazards which occur frequently or with a high intensity. In our present study, we have taken landslide, earthquake, flood and cloud burst for generating the multi-hazard map of Uttarkashi.

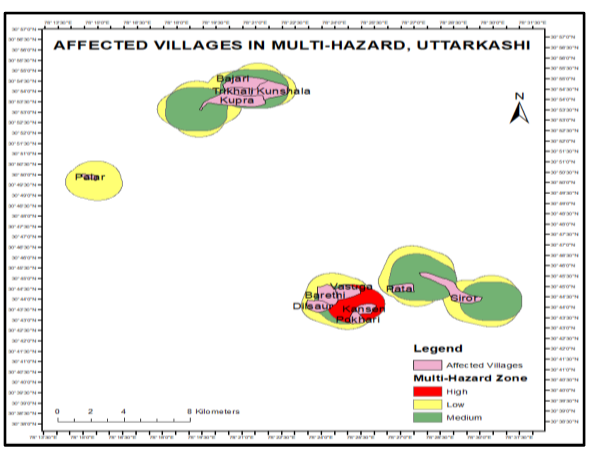


Fig 5. Affected Villages

We can see that, there are several multi hazard zones in the district Uttarkashi. We have divided the map into three zones namely high, medium and low. All the multi-hazard zones have been detected in south-western region where the settlements are also located. So from this study we can understand that, human activities are also influencing the natural hazards which is causing the occurrence of more than one natural hazard in the same area. The after effects of several hazards in a same location, not only take the human lives but also damage the property and cause economic loss.

VILLAGES OF UTTARKASHI AFFECTED BY MULTIPLE HAZARDS

The villages of Uttarkashi which gets affected by multiple natural hazards. There are 12 villages which are located in the south-western part of the study area. From Table 1 we can see the number of households and total population of those villages. Village Kansen, Pokhrai, Vasunga and some part of Barethi are falling in the high multi-hazard zone. The population and number of households are highest in Kansen among the other villages affected by multiple hazards. The villages like Bajari, Trikhali, Kupra, Kunshala, Pata and Siror are in medium multi-hazard zone. Only two villages namely Palar and Dilsaur are falling in low multi-hazard zone.

Table 1: Number of households and total population of the villages affected by multiple hazards in Uttarkashi

Name of Villages	Number of Households	Number of Total Population
Kunshala	56	253
Trikhali	28	145
Kupra	116	551
Palar	99	603
Siror	128	720
Barethi	248	1203
Pata	97	531
Bajari	46	264
Vasuga	49	230
Dilsaur	83	420
Pokhari	38	230
Kansen	490	2070

Suitable site for Rescue

From the study, it was found that Uttarkashi is one the most disaster-prone district of Uttarakhand, it faces all types of disaster like earthquake, flood, cloud burst, landslide. The main reason is its sensitive geology and remoteness from mainland. In this study an effort was made to find out multi hazard zone of the district using GIS techniques. The multi hazard zone was defined by getting the common area affected by all these disasters. But just locating the hazard zone is not enough unless a proper solution is provided.

A suitable site for rescue operation was generated to provide a solution to this problem. The rescue sites were found using various parameters like distance away from earthquake, landslide, flood, cloud burst, nearness from the road and habitation. These data were extracted from various sources and converted into shake file format. Further, buffers were created, finally the area fulfilling all the required parameters was generated using the intersect tool. The village boundary was overlapped and final location was traced out.

Locating rescue sites for disasters is a critical task to ensure that affected individuals receive timely assistance and support. Here are some key considerations for selecting a suitable location for a rescue site in the event of a disaster:

Accessibility: The location should be easily accessible to rescue personnel, emergency vehicles, and affected individuals. This is particularly important if the disaster has caused damage to roads, bridges, or other infrastructure.

Proximity to affected areas: The location of the rescue site should be close to the affected area to minimize response time. The site should also be strategically placed to ensure that it is easily visible to individuals who may be in distress.

Infrastructure: The location should have adequate infrastructure to support the rescue operation. This includes access to electricity, water, and sanitation facilities, as well as communication infrastructure.

Safety: The rescue site should be safe for both rescue personnel and affected individuals. The site should be located in an area that is not at risk of further disasters, such as landslides, floods, or earthquakes.

Capacity: The location should have enough space to accommodate the rescue operation, including space for rescue personnel, equipment, and supplies. The site should also have the capacity to accommodate a large number of affected individuals.

These are just some of the key considerations when selecting a location for a rescue site in the event of a disaster. Other factors may include the availability of transportation, security, and the availability of medical facilities. It is important to carefully evaluate all of these factors when selecting a location for a rescue site to ensure that the operation is successful and effective.

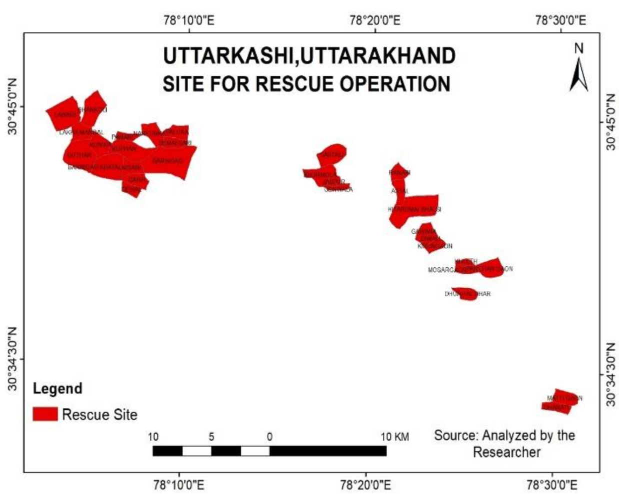


Fig 6. Site for Rescue operation

MITIGATION PLANING

Mitigation planning can be defined as the planning process of identification and implementation of processes and plans to reduce the threats of hazards. It can be used to reduce the long-term effects of hazards and disasters. Mitigation planning is very essential in a place like Uttarkashi where natural hazards are becoming a very common phenomenon.

There are several elements of mitigation planning. First, we have to identify the factors or natural hazards which cause the risk. After the identification, proper planning and strategies can be developed by the expertise who can plan it according to the budget, available resources etc. The probability of occurrence of hazard must be measured so the planning can be done in a proper way. The risk out of hazards should be defined properly so that the people can be concerned about it respond to it. The consequences or the after effects of hazards must be conveyed to the people to spread the awareness. Most of the times, we do not get any hint before the occurrence of hazards. In this case we need to study the occurrence of hazards in past so that we can understand the pattern and frequency of occurrence.

Proper land use planning is needed to prevent the damages of landslide. Sometimes the construction of new road is done in such areas where the geological structure is fragile and it leads to landslide. Through proper planning these areas need to be identified so that no future project is planned here. Some other methods are also there which can be adopted and they are Vegetation placement and management, removal of debris, grading to lessen slope, constructing rock buttresses and retaining walls etc.

An early warning system can be developed to reduce the risk of earthquake which is currently under processing. The damage restoration activities after earthquake should be taken properly as the aftereffect cause destruction of buildings.

For flood mitigation, several plans can be adopted. Water resource development planning is needed to prevent flood. As the flood maps identifies the food prone areas, the amount of water flow can be controlled in those specific locations. Dams can be made to store water during heavy rainfall and the water can be used in agriculture during drought. Deforestation also increases the flood as the water holding capacity decreases. The people must be aware about this, so that they stop cutting trees. Cloud burst also cause flash floods so the same mitigation plans can be adopted here.

Conclusion

The aim of the present analysis was to do a detailed study of the hazards in Uttarkahsi. Then to find out the areas which are prone to multiple hazards.

In this study we have prepared the land use land cover map which showed that the barren land and the snow cover is more than the vegetation land and the agriculture is very less here. Then we have prepared precipitation map of pre-monsoon, monsoon and post-monsoon period. The landslide map of Uttarkashi showed 23 landslide locations along the roads of Uttarkashi where most of those landslides took place in the south-western part. From 2008 to 2020, 47 earthquakes happen in the study region and most of them occurred in the populated places. The highest magnitude of earthquake was 5 over the mentioned study period. Then the flood map showed that the Bhagirathi River basin is highly prone to flood. For cloud burst zonation we have taken four parameters namely slope, precipitation, settlement and geology and the cloud burst map showed that a large area of Uttarkashi is prone to high cloud burst zone. Lastly, the multi-hazard map of Uttarkashi has been prepared which showed that 12 villages of Uttarkashi fall under different multi hazards zones like low, medium and high.

Therefore, mitigation planning is needed in Uttarkashi as various parts the district is highly prone to different hazards. There is a possibility of reducing the risks by increasing awareness in people.

References

- K. Ray and R. J. Pandey. “Landslide hazard zonation mapping: a case study of Uttarkashi district, Uttarakhand, india”. *ENVIS Bulletin Himalayan Ecology*, 2016, Vol 24
- Bratati Dey. Lnduse/Landcover dynamics and it’s impact on environment and livelihood structure in district Uttarkashi – uaing geoinformatics techniques. (Unpublished doctoral thesis). HNB Grhwal Central University, Srinagar, Uttrakhand
- Dipendra Gautam , Saraswati Thapa , Sudeep Pokhrel & Suraj Lamichhane. “Local level multi-hazard zonation of Nepal”. *Geomatics, natural hazards and risk*, 2021, 12, NO. 1, 405–423
- Eshrati, Leila & Mahmoudzadeh, Amir & Taghvaei, Masoud. “Multi hazards risk assessment, a new methodology”. *International Journal of Health Syatem and Disaster Management*, 2019, 5: 79-88
- Hamid Reza Pourghasemi , Amiya Gayen, Mohsen Edalat, Mehrdad Zarafshar, John P. Tiefenbacher. “Is multi-hazard mapping effective in assessing natural hazards and integrated watershed management?”. Geoscience Frontiers, 2020, Volume 11, Issue 4:1203-1217
- Harjeet Kaur, Srimanta Gupta, Surya Parkash & Raju Thapa. “Application of geospatial technologies for multi-hazard mapping and characterization of associated

risk at local scale". *Annals of GIS,* 2018, 24:1, 33-46

- Hamid Reza Pourghasemi, Narges Kariminejad, Mahdis Amiri, Mohsen Edalat, Mehrdad Zarafshar, Thomas Blaschke & Artemio Cerda. "Assessing and mapping multihazard risk susceptibility using a machine learning technique". *Scientific Reports*, 2020, 10:3203
- Mohammad Onagh, V.K. Kumra and Praveen Kumar Rai. "Landslide susceptibility mapping in a part of Uttarkashi district (India) by multiple linear regression method". *International Journal of Geology, Earth and Environmental Sciences*, 2012, ISSN: 2277-2081, Vol. 2
- Saheb Halder, Dr. Shovan Lal Chattoraj, Dr. P. K. Champati Ray, Saroj Mahapatra, Dr. Shambhu Nath Mishra, Dr. Amit Dhorde, Dr. Kishore Dandapat. "Landslide hazard zonation mapping using statistical information value method of upper Yamunotri valley in Uttarkashi district, Uttrakhand, India". *International Journal of Remote Sensing & Geoscience (IJRSG)*, 2021, Volume 10, Issue 1
- Tiwari Kuldip, Khanduri Kamelsh. "Land use/Land cover change detection in Doon valley, (Dehradun Tehsil), Uttrakhand: using GIS and Remote Sensing Technique". *International Journal of Geomatics and Geosciences*, 2011, Volume 10; Issue 1; 34-41
- V.V.Govind Kumar, Kamal Jain, Ajay Gairola. "A Study and Simulation of Cloudburst event Over Uttarkashi Region using River Tool and Geomatic Techniques". *International Journal of Soft Computing and Engineering (IJSCE)*, 2013, Volume-3 Issue-1: 2231-2307