

Study of Drastic Disaster Events between 2010-2020 in District Pithoragarh by Using Remote Sensing and GIS Applications

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ABSTRACT

The higher Himalayan region of Uttarakhand as well as district Pithoragarh is an environmentally sensitive area suffering from extreme weather and geodynamical events and hazards such as— rock fall, Land creeping, mud flowing, heavy rain fall, cloudbursts, flash floods, mass wasting, landslides and recurring earthquakes are selected for the present study. The Main Central Thrust passes through the district Pithoragarh which separates the Greater and Lesser Himalayas regions. Munsyari, Bangapani, Dharchula, Tejam, Didihat and Kanalicheena Tehsil of this district were severally affected due to the drastic disaster events from the disaster year 2010 to 2020. This study aims to identify and geo-tagging disaster sites yearly for preparing hazarded site maps to study disasters impact on the district Pithoragarh. A detailed field survey was conducted by using GPS in district Pithoragarh to find out the implications and distribution of different disaster events causing damage to life, livestock and property in the study area. Between 2010 to 2020, there were 174 people dead, 58 people missing, 153 people injured, and losses of 7016 livestock as well as 10 cowsheds damaged in district Pithoragarh. In the last decade 990 buildings were completely damaged, 1891 houses are dilapidated and 453 houses area partially damaged in the study area. Based on the present study suggests a detailed strategy and workout action plan to prevent disaster events using remote sensing and GIS application in the region which may be useful for the government in the management of disaster events in the future.

KEY WORD: Drastic, Disaster Events, Pithoragarh, Remote Sensing and GIS.

Date of Submission: 24-06-2022

Date of acceptance: 05-07-2022

I. INTRODUCTION

In the literature, some of the meteorological events such as the direction and amount of the rainfall, amount of sunshine, the morphologic structure of the area affect the disaster events and as well slope stability (Pourghasemi et al., 2012; Mohammadi, 2008). There are numerous definitions of flash floods; in the flash flood events unexpected increase in water close in streams and rivers and very high flow speed bring large amount of debris, boulders, uprooted trees, obliteration of infrastructures and constructed buildings stand in its path (Douvinet et al., 2013). A landslide are the downward and outward movement of a slope with a rock or artificial fill material under the influence of gravity, slope, water and other external forces and is one of the most drastic natural hazards in mountainous regions (IAEG, 1990). Cloud burst disaster event, also known as rain gust which is an extreme form of precipitation in which a high intensity of rain falls over a localized area (Das et al., 2006). These disasters have been known to cause major losses to ecosystem, resources, property, and life in the region and thereby affecting its process of economic development (Kazakis et al., 2015).

Disaster and Emergency Management Presidency of Turkey) indicate that in total 23,393 landslides have occurred in Turkey from 1950 to 2020 (AFAD, 2019; 2020). Therefore, considering the losses sourced by landslides, it is of major importance to produce landslide susceptibility maps (LSMs) to carry out human activities accordingly. Vulnerability assessment is a crucial input to comprehend the degree of loss that the built environment suffers because of the occurrence of a natural disaster (Bhatt et al., 2013).

In recent past, locally, regionally, nationally, and globally many researcher and workers have worked on the study of disaster and its managements. Remote sensing and GIS applications are being used to study different aspect of natural as well as anthropogenic disasters and its management by Ali et al., 2017; Rana and Parihar, 2018; Hussain et al., 2018; Parihar and Rawat, 2021; Singh et al., 2022; Parihar, 2022; Parihar et al., 2022 in their studies. Use of Remotes Sensing (RS) and GIS techniques are very effective for surveying,

integrating and assessing land use land cover (LULC) change within the disasters (flash flood, landslides, mud flowing, land creeping, rock fall, cloud bursting etc.) prone areas and assessment of change pattern at the watershed level is crucial to disaster risk reduction (Kienberger, 2009). RS and GIS can offer influential technology for risk assessment by using satellite images and GPS surveying method and disaster maps can be organized to outline susceptible areas prone to disaster events which maps are very useful for preparedness, decision making, response and recovery and appropriate measures can take for impact reduction (Youssef et al., 2011). A brief account some of the important local, regional, national and international works in study of disaster, its management, risk assessment, mitigation, strategy etc. is presented in the following paragraphs.

II. OBJECTIVE

The fundamental objectives of the present investigation for study of drastic disaster events between 2010-2020 in district Pithoragarh by using remote sensing and GIS applications are presented below:

1. To analyze the drastic disaster events and types this occurred between 2010- 2020 in district Pithoragarh.
2. To construct maps of the disaster event sites and affected damaged villages by using Remote Sensing and GIS, field survey and GPS coordinates.
3. Advantages of Remote Sensing and GIS application in the field of disaster and its management.
4. Suggesting strategies and workout action plan for prevent disaster events in the region.

III. METHODOLOGY

For the present study Remote Sensing and Geographic Information System (GIS) of 2010 to 2020 disaster sites was prepared using GPS, Arc GIS and QGIS Software. Extract elevation, slope, aspect, and drainage system of the study area by using Cartosat-1 DEM (Figure-1). Disaster affected sites and villages recorded were obtained from District Disaster Management Office (DDMO) Pithoragarh and field survey. Affected villages details of damages caused by temporal disaster events from 2010 to 2020 are given in Table-3 and prepared the map using Q-GIS software. Rainfall recorded data (Table-2) was received from the DDMO Pithoragarh.

IV. STUDY AREA

District Pithoragarh is lies between 29.4° North to 30.3° North latitude and 80° East to 81° East longitude (Figure-1) and sharing boundaries with Almora, Champawat, Bageshwar and Chamoli districts and extends over an area of 7,210.85 km². The district Pithoragarh varies in between 498 m at Jauljibi to 6728 m (*based on DEM*) in the snow capped mountains in the Great and Lesser Himalayan ranges of the Kumaun Himalaya in the Uttarakhand state. Pithoragarh contains huge alpine and sub-alpine zones in the high altitude part which is locally called Bugyals by the local inhabitants. District Pithoragarh having its entire northern and eastern boundaries being international assumes a great strategic significance and obviously is a politically sensitive district along the northern frontier of India. Being the last district adjoining Tibet, it has tremendous strategic importance as the passes of Lipulekh, Kungribingri, Lampia Dhura, Lawe Dhura, Belcha and Keo, open out to Tibet. There are numerous scenic spots to which the prospective tourist may plan excursions like Chandak, Thal Kedar, Gangolihat (77 km) famous for its kali temple, Patal Bhuvneshwar (99 km), Berinag (Tea Garden of Chaukori– 11 km away from Berinag), Didihat, Munsyari (base camp for tracks to Milam, Ralam and Namik Glacier), Dharchula (base camp for Kailas Mansarover Yatra, Adi Kailash Yatra, Narayan Swami Ashram) and Jauljibi.

4.1 Demography: District Pithoragarh is the part of Kumaun Himalayan region, where West Dhaul Ganga, Saryu, Ramganga, Gori Ganga and its tributaries, East Dhaul Ganga and Kutyankti River flow from north to south direction and develop narrow valleys. Pithoragarh has total population 483439 where 239306 are male which accounts 49.50% and 244133 are female which accounts 50.50% of the total population (COI, 2011). The total population of below 06 years is 63293 where 34853 are male which accounts 55.07% and 28440 are female which accounts 44.93% of the total population of >6 years (COI, 2011). Female population in the study area is higher than the male population and the sex ratio of male to female stands at 1000:1020. The population density in the study area stands at 67.04 people per km² (COI, 2011). The total literate people are 345550 which accounts 71.48% in total population of the study area where 189623 (54.88%) are male and 155927 (45.12%) are female, and the illiterate are 137889 (45.12%) where 49683 (36.03%) are male and 88206 (63.97%) are female (COI, 2011).

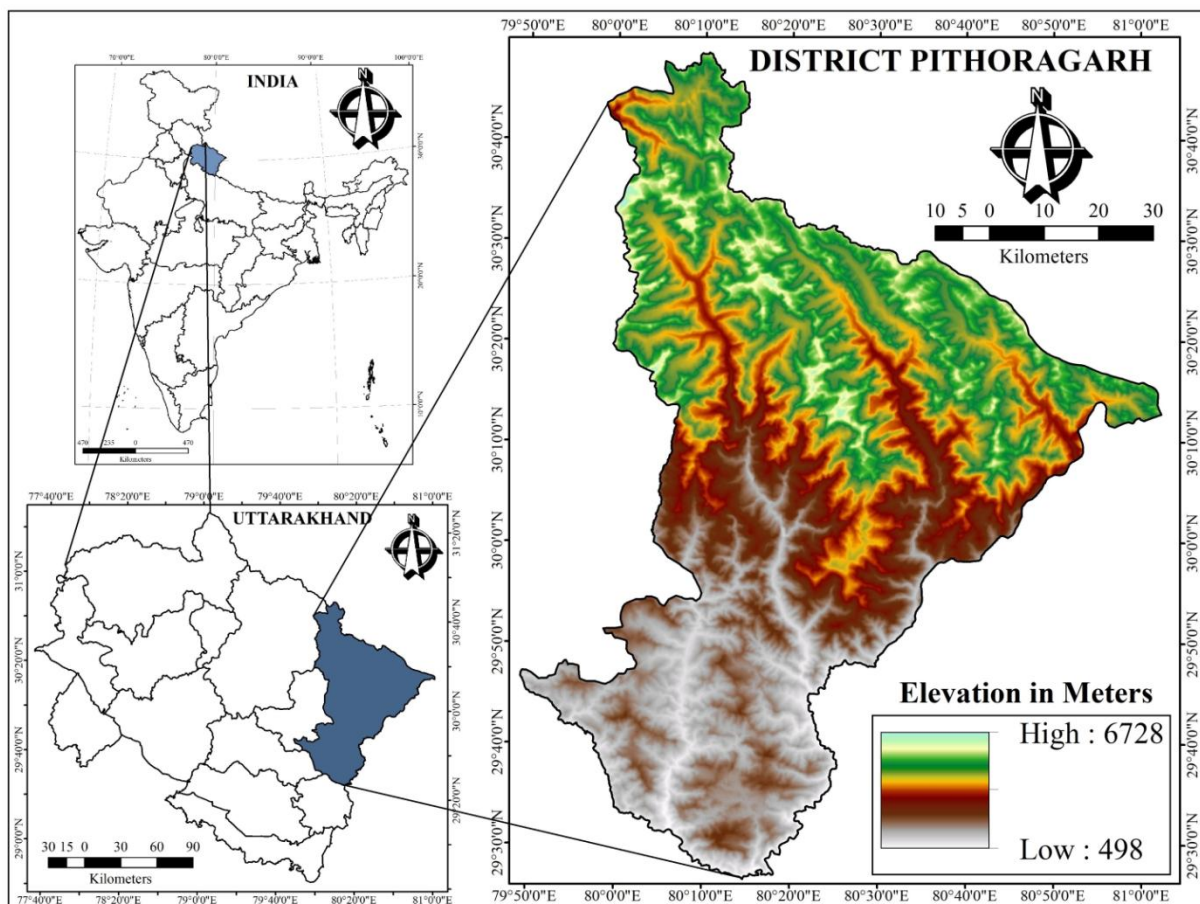


Figure-1: Location map and DEM of district Pithoragarh, Kumaun Himalaya, Uttarakhand (India) (based on Cartosat-1, Satellite data).

4.2 Drainage Network: Gori Ganga, East Dhauli Ganga, Ram Ganga, Saryu and Kutiyanti are the main tributary of the mighty Kali River which receives water from the Greater and Lesser Himalaya regions. Figure-2 depicts the spatial distribution of drainage network of district Pithoragarh which is based on DEM (Fig. 1) derived using Arc GIS software. The details of these rivers such as their origin type and length are presented in Table-1. The total length of river and streams in district Pithoragarh is about 1358.99 km having density of 0.19 km/km². Table-1 reveals that there are 16 major tributary and rivers of the main Kali River.

Table-1: Details of types, origin place and confluence of the major rivers of district Pithoragarh, Kumaun Himalaya (based on field survey and Cartosat-1 satellite data).

S.N.	Name of Rivers	Type of River	Length	S.N.	Name of Rivers	Type of River	Length
1	Dhauri Ganga West	Glacial	33.78 km	10	Bona Gad	Glacial	22.69 km
2	Kutiyanti	Glacial	78.48 km	11	Golpha Gad	Glacial	19.03 km
3	Dharam Ganga	Glacial	32.51 km	12	Gori Ganga	Glacial	401.17 km
4	Lesser Yankti	Glacial	40.64 km	13	Kali River	Glacial	190.94 km
5	Dhauri Ganga East	Glacial	87.73 km	14	Charma Gad	Non-Glacial	31.09 km
6	Lwan Gad	Glacial	12.25 km	15	Ramganga East	Glacial	224.35 km
7	Ralam Gad	Glacial	22.99 km	16	Saryu River	Non-Glacial	123.48 km
8	Poting Gad	Glacial	9.91 km	Total length			1358.99 km
9	Mandakini Gad	Glacial	27.95 km				

4.3 Physiographic Regions: Physiographically, district Pithoragarh is constituted of two physiographic regions. These are Great Himalayan region and Lesser Himalayan region separated by the Main Central Thrust (MCT). The MCT passing through the middle part of the district separates the Great Himalayan rock from the underlying younger rocks of the Lesser Himalayan region. The MCT passes through the villages Laspa, Khilanch, Rilkote, Ralam Zimiya, Quiri, Leelam, Paton, Bunie and Nagling, Sela, villages. Figure-3 depicts the distribution of Great and Lesser Himalayan region and villages in district Pithoragarh. A brief account of these physiographic regions of district Pithoragarh is given in the following paragraphs.

(A) **Great Himalayan Region:** In the northern region of district Pithoragarh about 3529.58 km² which accounts for 48.95% of total district is constituted of the Great Himalaya physiographic region. About 2.31% villages (total 31 villages) of the study area are situated in the Great Himalayan region (Figure-3). The villages which are located in this region are: Milam, Pachhu, Ganghar, Bilju, Mapa, Burphu, Mapa (paar), Martoli, Tola, Rilkote, Ralam, Khilach, Laspa, Sipu, Marchha, Tidang, Philam, Go, Dugtu, Baun, Dantu, Baling, Chal, Nagling, Sela, Bundi, Naplachchu, Gunji, Navi, Raung Kong and Kuti.

(B) **Lesser Himalayan Region:** In the southern part of district Pithoragarh about 3681.27 km² which accounts for about 51.05% area of total district is constituted of the Lesser Himalaya physiographic region. About 97.69% villages (total 1311 villages) are situated in the Lesser Himalayan region of district Pithoragarh (Figure-3).

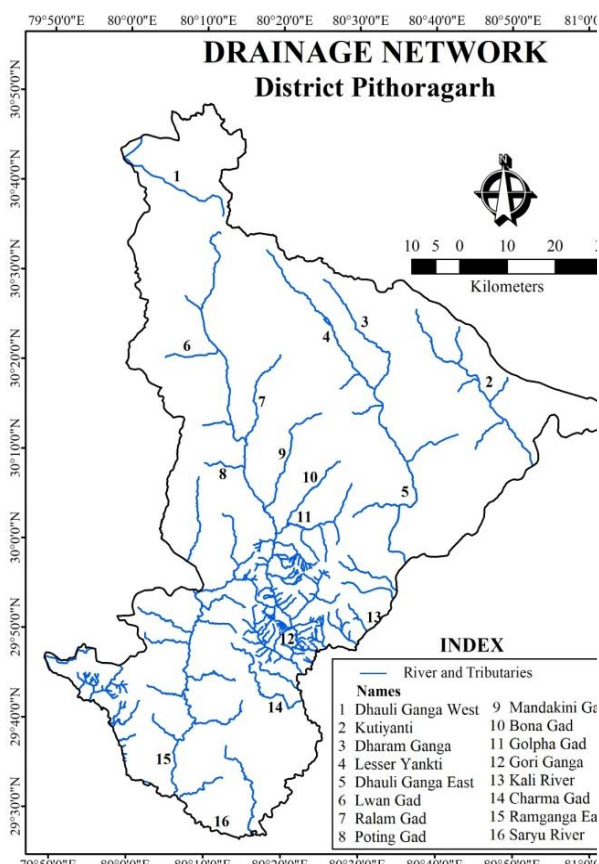


Figure-2: Drainage network of district Pithoragarh, Kumaun Himalaya (based on Cartosat-1 satellite data).

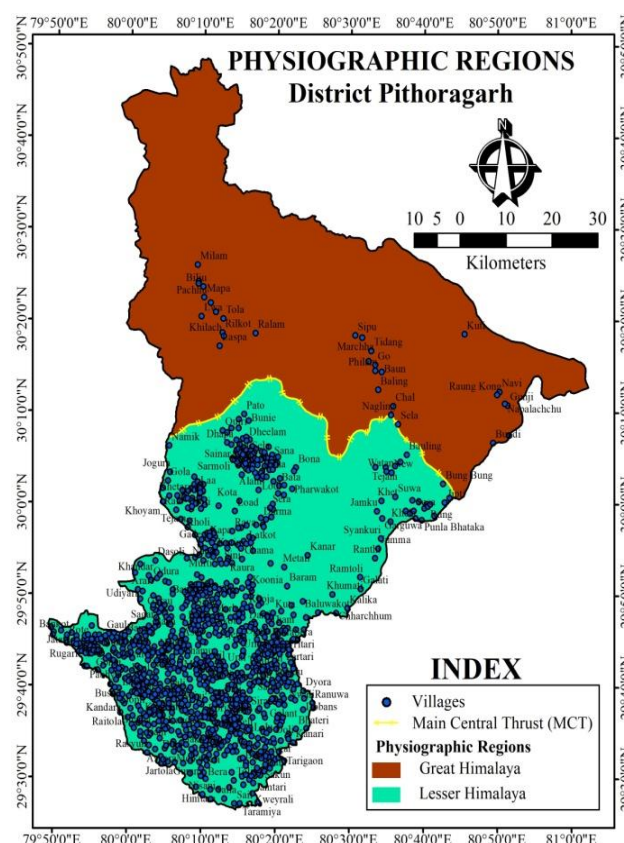


Figure-3: Physiographic regions of district Pithoragarh, Kumaun Himalaya (after Pathak et al. 2015 and Censuses of India- 2011).

4.4 Rainfall: Table-2 contains monthly average rainfall data from 2011 to 2019 obtained from different Tehsil Headquarter Offices of district Pithoragarh (meteorological station) which differentially lies in the study area. The summary of these data is registered in Table-2 which reveals that the maximum average rainfall occurs in the month of July (2861.72 mm) in each meteorological station while the minimum average rainfall occurs in the month of November (24.81 mm).

Table-2: Distribution of average rainfall (mm) from 2011 to 2019 at District Pithoragarh (source: District Disaster Management Office, Pithoragarh).

Month	Average Rainfall (mm) 2011-2019 (at District Pithoragarh)						Total monthly average rainfall
	Pithoragarh	Didihat	Dharchula	Munsiyari	Berinag	Gangolihat	
January	27.36	31.24	37.73	32.96	41.21	32.98	203.48
February	37.16	38.38	51.94	76.13	60.06	44.64	308.31
March	30.21	31.94	51.37	48.01	54.72	44.61	260.86
April	44.08	37.39	67.81	69.24	79.18	37.53	335.23

May	73.9	52.09	85.11	99.59	67.87	61.9	440.46
June	107.17	241.43	320.99	215.67	215.08	184.23	1284.57
July	256.13	434.11	614.06	551.81	522.33	483.28	2861.72
August	183.48	392.89	528.57	464.97	492.66	367.39	2429.96
September	97.2	172.07	300.88	205.78	191.16	207.5	1174.59
October	10.08	10.11	26.28	27.08	20.33	22.51	116.39
November	2.91	3.44	2.22	5.44	7.49	3.31	24.81
December	13.64	13.98	6.82	10.33	14.03	12.94	71.74
Total	883.32	1459.07	2093.78	1807.01	1766.12	1502.82	9512.12

V. RESULT AND DISSCUSSION

The large amount of precipitation increases discharge through streams and artificial channels and also the subsurface seepage, leading to bed/sheet erosion, ground saturation and nearby land failures in the affected areas. Main causes of the disaster problems in the district Pithoragarh are as follows.

- Heavy rainfall, inadequate surface water management and unregulated seepage in the area causing saturation of internal friction of the weathered rock and soil materials.
- Steep slope cuttings for developmental work in weak materials and construction without planning close to natural water courses and frequent presence of very weak natural materials and unlined natural water courses in the district area.
- Loading of weak slopes by heavy construction, including unplanned road construction, without necessary slope treatment. Mass wasting and landmasses undercut due to flash floods, dumping zones, and weak natural materials nearby from natural and artificial sources.

5.1 Drastic Disaster Events since 2010-2020

During field survey, I have heard and seen much in the study area about recent devastating effects of cloud bursting, mud flowing, land creeping, flash flood, mass wasting, and landslides in Pithoragarh, especially in Munsyari, Bangapani and Dharchula Tehsil. Due to heavy rainfall and cloud bursting events, the study area experienced many types of disaster events with heavy losses of human life, livestock, agriculture land, land and properties, etc. by Gori Ganga, Dhauri Ganga, Kutiyankti, Kali, Ramganga and Saryu River. Table-3 present average rainfall data between 2011- 2019 recorded by different Tehsil headquarter offices based on DDMO Pithoragarh, which affects deeply the study area. Figure-4 depicts the geographical distribution of disaster events in the study area and which detailed states are registered in Table-3 based on DDMO Pithoragarh. In 2010 main disaster events are flash floods occurred in 18 villages, landslides and rock falls, in 2013 flash flood, landslide, mass wasting, and water logging occurred in 50 villages, in 2014 landslide occurred in 3 villages, in 2016 cloud burst, mud flowing occurred in 2 villages, landslide, in 2017 landslide, flash flood, water logging occurred in 9 villages, in 2018 landslide, flash flood, water logging occurred in 12 villages, in 2019 cloud burst, mud flowing, landslide, flash flood occurred in 5 villages and in 2020 cloud burst, mud flowing Landslide, mass wasting and Land creeping occurred in 22 villages of district Pithoragarh.

Table-3: Details of major drastic disaster types and affected sites (126) during 2010-2020 in district Pithoragarh, Kumaun Himalaya (source: DDMO, Pithoragarh, field survey and GPS).

Year	Date	Impact of Heavy Rainfall	Name of Disaster Sites	Tehsil
2010	July and August	Flash floods, landslides and rock falls	Bhadeli, Radgari, Dani Bagar, Umargada, Ropar, Motighat, Bangapani, Seraghat, Sera, Mavani, Farvekote, Bali Bagar, Ghigrani, Khinnu Gauna, Chhori Bagar, Talla Mori, Ghatta Bagar, Garjiya	Munsyari Dharchula
2013	13/06/2013	Flash flood, mass wasting, water logging	Jimy Ghat, Talla Dhapa, Basantkote, Bhadeli, Sana, Gaila, Ropar, Radgari, Motighat, Dani Bagar, Bali Bagar, Madkote, Devi Bagar, Bhora Bagar, Fagua Bagar, Sera, Umargada, Bangapani, Seraghat, Mavani, Davani, Ghigrani and Khinnu Gauna	Munsyari
	16/06/2013 17/06/2013	Landslide, flash flood, water logging	Chhoribagar, Mori, Pangla, Dooti Bagar (Jauljibi), Jamku, Ranthi (Dobat), Garbyang, Sela, Baluwakote, Gargua, Sirkha, Bangapani, Jipti, Sobla, Baram, Jumma (Eilagad), Suwa, Chhalamchhailason, Kalika (Gothi), Teejam, Chharchhum, Kanar, Toli (Ghatta bagar), Naya Basti, Khela (Tawaghat), Bouling, Khet, Nagling	Dharchula
	18/06/2013	Flash flood	Dekuna Tok, Lachhuli	Tejam
	27/07/2014	Landslide	Kanar, Garguva	Dharchula

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2014	18/07/2014	Landslide	Gaisaleenadu (Chharandev)	Kanalicheena
2016	01/07/2016	Cloud burst, mud flowing, landslide	Bastari (Singali)	Didihat
	30/06/2016	Landslide	Nwali (Peepali)	Kanalicheena
2017	13/08/2017	Landslide, flash flood, water logging	Tankul, Garbyang, Bung-Bung, Suva	Dharchula
	14/08/2017			
	16/06/2017	Landslide,	Metali, Chami, Tanga	Bangapani
2018	08/07/2017	Landslide	Sanikhet, Binari Nala	Berinag
	04/07/2018	Landslide, flash flood, water logging	Glanti, Jamku, Bansh Bagar, Tankul, Mangti, Dharpangu, Himkhola, Khela, Chhalamchhailason,	Dharchula
	11/07/2018			
	10/07/2018	Landslides	Kanar, Jimtari, Tanga	Bangapani
2019	18/06/2019	Landslides	Bundi	Dharchula
	07/09/2019	Cloud burst, mud flowing	Timtiya	Tejam
	09/09/2019	Landslide	Talla Banshkote, Bamangaun, Khalsa	
2020	19/07/2020	Flash flood	Bangapani, Chhoribagar	Munsyari Bangapani Dharchula
	20/07/2020	Cloud burst, mud flowing Landslide, mass wasting	Tanga, Patharkote (Gaila), Lodi, Bali Bagar	
	27/07/2020	Landslide	Dhami Gaun	
	28/07/2020	Landslide	Metali, Talla Devlekh, Bangapani, Mori, Kaulikanyal	Didihat
	27/07/2020	Cloud burst, mud flowing landslide	Silauni, Aankote	
	19/08/2020	Landslide	Khetarkanyal	
	27/07/2020	Landslide	Goonthi, Kotyura	
19/07/2020	Landslide	Dhapa, Suring (Balauta)	Munsyari	
	Land creeping	Joshua, Malupati, Serasurayidhar		

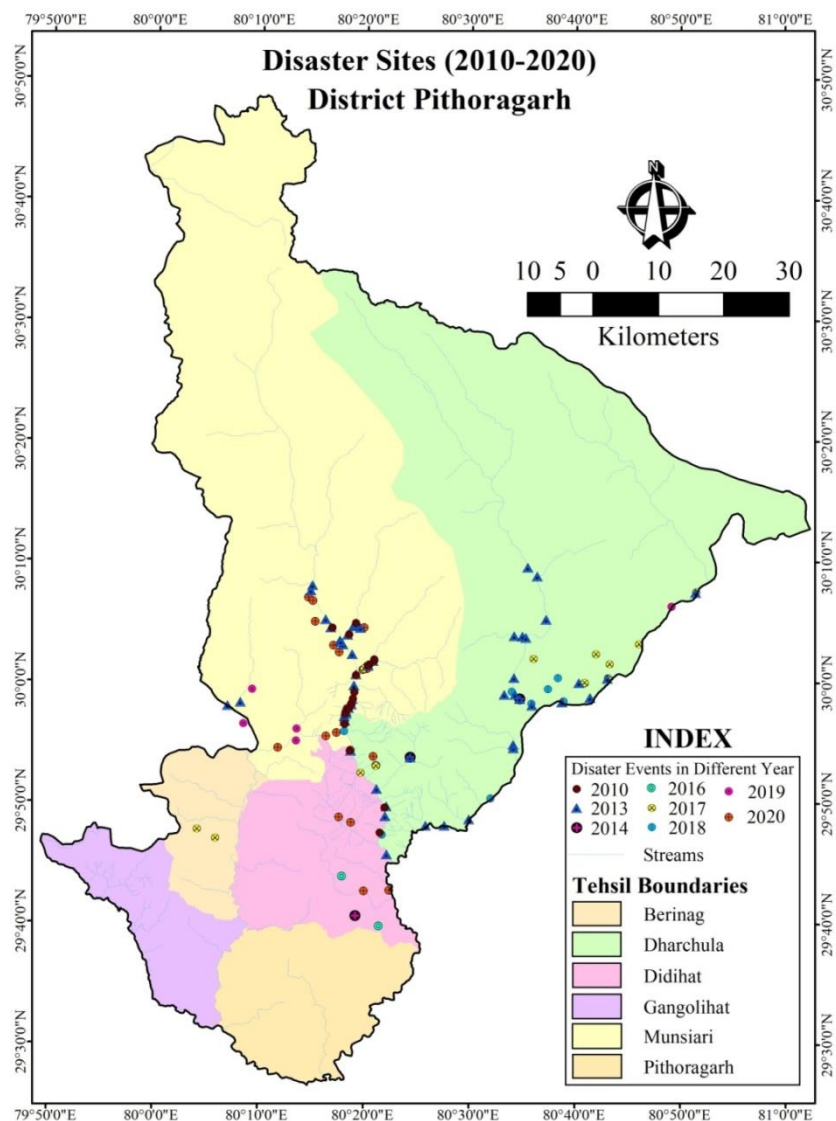


Figure-4: distribution of disaster events occurred during 2010-2020 in district Pithoragarh, Kumaun Himalaya (source: DDMO, Pithoragarh, field survey and GPS).

5.2 IMPACT OF DISASTER EVENTS IN DISTRICT PITHORAGARH

Frequencies of disaster events in district Pithoragarh are more pronounced during monsoon season yearly. Among these are most responsible for the heavy rainfall and cloudbursts leading to flash floods, mass wasting, mudflows, land creeping, rock falls and landslides which cause loss of animal and human lives and disruption of settlements, and agricultural lands together with motor road networks etc. Disaster affects all the physical, economic and social aspects of the district Pithoragarh area because disaster does affect the whole community, i.e., humans, culture, livestock, wild animals, etc. of disaster sites. In district Pithoragarh, about 121 villages from 6 Tehsils have been affected due to the increasing heavy rainfall, cloudburst, flash flood, mass wasting, mud flowing, and landslides phenomenon in the last 10 years. Between 2010 to 2020, there were 174 people dead, 58 people missing, 153 people injured, and losses of 7016 livestock as well as 10 cowsheds damaged in district Pithoragarh. In the last decade 990 buildings were completely damaged, 1891 houses are dilapidated and 453 houses area partially damaged in the study area which is registered in Table-4 based on DDMO Pithoragarh . Plate-1 and Plate-2 presents the physical impact of landslides, land creeping, flash flood and mass wasting including the damage to the artificial and natural environment and can be classified as affecting the residential, commercial, industrial, infrastructure, and community service sectors. Plate-3 presenting the collapsing structure impact of cloudburst triggered landslides, mudflow and flash flood in different parts of Pithoragarh district has been analyzed in the study. Plate-4 presents the social and cultural impact of all disaster events that can take the form of cultural, demographic, psychological and economic in nature resulting directly from the physical impact. Table-4 presents the economic impact of these disaster events

was tremendous effect in the forms of loss of human and animal lives, building loss, loss of arable land, forest loss, existing crop loss, loss of bridges, road networks and any other infrastructure.

VI. SUGGESTING STRATEGIES TO PREVENT DISASTER EVENTS

The landslide is deduced to be highly susceptible to slope failure in mountainous regions of district Pithoragarh, particularly in the event of heavy rainfall. Based on field surveying, it is perceived that necessary precautions are required to be taken, especially in view of the fact that the slide is in close proximity of densely populated area, nearby stream network and remaining part of road network of Pithoragarh. Besides major landslides so many several landslide scars are also observed on the uphill sides in mountainous regions. Activation of these landslides has the potential of posing danger to the nearby villages in the study area and following some suggestive measures are given, which are:

Table-4: Details of losses during and after major drastic disaster events from 2010 to 2020 in district Pithoragarh, Kumaun Himalaya (*source: DDMO, Pithoragarh from 2019*).

S. N.	Disaster date /Year	Types of losses of people, livestock and property		
		Dead/missing	Injured	Property
1	2010	10 dead	-	<ul style="list-style-type: none"> • Completely damaged building- 100
2	2013	53 dead, 21 missing	57	<ul style="list-style-type: none"> • Completely damaged building- 692 • Dilapidated- 800 • Animal loss- 6000 • And many micro hydro projects, river bridges, footpath, motor road
3	2014	18 dead, 2 missing	21	<ul style="list-style-type: none"> • Completely damaged building- 30
4	2016	21 dead, 9 missing	09	<ul style="list-style-type: none"> • Completely damaged building- 14 • Dilapidated- 36 • Partial- 109 • Cowshed- 10 • Animal loss- 86 • 169 sheep and goats collapse due to landslide • Losses of live stock and agriculture land due to mud flowing and landslide
5	2017	25 dead, 23 missing	17	<ul style="list-style-type: none"> • Completely damaged building- 14 • Dilapidated- 219 • Partial- 90 • Animal loss- 241
6	2018	19 dead	19	<ul style="list-style-type: none"> • Completely damaged building- 40 • Dilapidated- 589 • Partial- 173 • Animal loss- 142
7	2019	6 dead	13	<ul style="list-style-type: none"> • Completely damaged building- 38 • Dilapidated- 95 • Partial- 36 • Animal loss- 27
8	2020	22 dead, 3 missing	17	<ul style="list-style-type: none"> • Completely damaged building- 62 • Partial- 45 • Dilapidated- 152 • Animal loss- 351



Plate-1: Impact of landslides and land creeping in district Pithoragarh: (A) Madkote to Munsyari motor road affected by land creeping (2013), (B) Tawaghat to Garbyang motor road affected by land slide (2014), (C) Ghigrani is a all-weather landslide zone (2018) and (D) Josha village affected by land creeping (2020) (based on field survey).



Plate-2: Impact of flash flood and mass wasting disasters in district Pithoragarh: (A) at Ghatta Bagar (2013), (B) at Mori village (2013), (C) at Dani Bagar (2016) and (D) Himalaya Hydro Power Project Dam damaged at Bali Bagar (2018) (based on field survey).



Plate-3: Impact of cloudburst and mud flowing events in district Pithoragarh: (A) at Bastari (2016), (B) at Naulara, Near Nachani (2016), (C) at Malpa (2017) and (D) at Tanga (2020) (based on field survey and DDMO Pithoragarh).



Plate-3: Impact on society by disaster events in district Pithoragarh: (A) Homeless people at Umargada village affected by flash flood (2013), (B) Seraghat to Madkote motor road affected by mass wasting (2013), (C) Tawaghat to Shobla motor road affected by landslide (2017) and (D) Tanga village affected by cloudburst (2020) (based on field survey and DDMO Pithoragarh).

- To all the community are advised to keep a safe distance from the vulnerable slope, seasonal streams, landslide sites, and vacate the area, especially during monsoon season as well as heavy or prolonged rainfall.
- The landslide, rock fall, land creeping and debris flow event have sent a strong signal for the urgent need for disaster risk analysis on the ground basis. District Pithoragarh has numerous major active disaster sites that may cause disaster in the event of major rainfall or earthquake. Further, there are many potential landslide slopes which have large volume of debris and rock boulders threatening to come down as massive debris flow or rock fall. Such a type of drastic disaster hazard cannot be prevented, but the consequences can be minimized if there is proper training, disaster awareness, risk estimation and planning prior to such a major event.
- Prepare all disasters and their management study relative maps with excellence by ground surveying with GPS, remote sensing and GIS techniques.
- Participatory GIS-based slope map, aspect map, relief map, landslide, flood risk, and road-induced disaster risk assessment have higher accuracy than sophisticated risk delineation based on numerical and physical models. These maps can be effectively used at various levels in the disaster management process in the study area.

VII. SUMMARY

Study of Disaster and its Management in District Pithoragarh, Kumaun Himalaya by Using Remote Sensing and GIS Technology contributes an important approach for predicting the disaster-prone areas, which can help in effective mitigation and rural development. The same study can be carried out in other geographical areas with different topographical characteristics.

From the study, Heavy Monsoon Rainfall, cloudburst in the landscape increases the intensity of flash flood along riverbanks, which makes rainfall one of the main contributing factors for flash flood in the landscape. It is also concluded that slope is highest contributing factor because the driving force of mass increases with increasing slope. The slope with multiple joint sets fails particularly during monsoon, when this region receives heavy rainfall. The slopes become saturated with water, destabilizing the slope beyond the stability limit. Rock fall, debris flow and complex landslides are various types of slope failure that occur.

Unscientific construction of roads causes rock falls, landslides, land creeping, soil erosion, uprooting of large trees and destruction of lower plants. It adds to siltation in the path of the river and stream as well as increases water and air contamination. Blasting, excavation and cutting of slopes result in geological disturbances and subsequent landslides and land cracks. Dumping landslide rubbles and road construction material at insecure places risks the lives of downhill population.

Climate change brings related disaster risks of landslides, droughts, cloud bursts, flash floods, receding glaciers, glacial runoffs, uneven precipitation, extreme events and loss of wildlife habitats and biodiversity of the region. Mountain roads are the only lifeline during climatic disasters and lack of other alternate escape routes makes mountain regions very vulnerable to extreme events.

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