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Study of Drastic Disaster Events between 2010-2020 inDistrict Pithoragarh by Using Remote Sensing and GISApplications

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ABSTRACT

The higher Himalayan region of Uttarakhand as well as district Pithoragarh is an environmentally sensitivearea 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 areselected for the present study. The Main Central Thrust passes through the district Pithoragarh which separatestheGreaterandLesserHimalayasregions.Munsyari,Bangapani,Dharchula,Tejam,Didihata ndKanalicheena Tehsil of this district were severally affected due to the drastic disaster events from the disasteryear 2010 to 2020. This study aims to identify and geo-tagging disaster sites yearly for preparing hazarded sitemaps to study disasters impact on the district Pithoragarh. A detailed field survey was conducted by using GPSindistrictPithoragarhtofindouttheimplicationsanddistributionofdifferentdisastereventscausing damageto life, livestock and property in the study area. Between 2010 to 2020, there were 174 people dead, 58 peoplemissing,153peopleinjured,andlossesof7016livestockaswellas10cowshedsdamagedindistrict Pithoragarh. In the last decade 990 buildings were completely damaged, 1891 houses are dilapidated and 453houses area partially damaged in the study area. Based on the present study suggests a detailed strategy andworkout action plan to prevent disaster events using remote sensing and GIS application in the region whichmaybe usefulforthegovernmentin the managementofdisastereventsinthefuture.

KEYWORD: Drastic,DisasterEvents,Pithoragarh,RemoteSensingandGIS.

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 floodevents unexpected increase in water close in streams and rivers and very high flow speed bring large amount ofdebris,boulders,uprootedtrees,obliteration of infrastructuresandconstructedbuildingsstandin its path(Douvinet et al., 2013). A landslide are the downward and outward movement of a slope with a rock or artificialfill material under the influence of gravity, slope, water and other external forces and is one of the most drasticnatural hazards in mountainous regions (IAEG, 1990). Cloud burst disaster event, also known as rain gust whichis 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 regionand therebyaffectingitsprocessofeconomic development(Kazakisetetal.,2015).

Disaster and Emergency Management Presidency of Turkey) indicate that in total 23,393 landslideshave occurred in Turkey from 1950 to 2020 (AFAD, 2019; 2020). Therefore, considering the losses sourced bylandslides, it is of major importance to produce landslide susceptibility maps (LSMs) to carry out humanactivities accordingly. Vulnerability assessment is a crucial input to comprehend the degree of loss that the builtenvironmentsuffersbecauseofthe occurrenceofanatural disaster (Bhattet al., 2013).

Inrecentpast,locally,regionally,nationally,andgloballymanyresearcherandworkershaveworkedon the study of disaster and its managements. Remote sensing and GIS applications are being used to studydifferent aspect of natural as well as anthropogenic disasters and its managementby Ali et al., 2017; Rana andParihar, 2018; Hussain et al., 2018; Parihar and Rawat, 2021; Singh et al., 2022; Parihar, 2022; Parihar et al.,2022intheirstudies.UseofRemotesSensing(RS)andGIStechniquesareveryeffectiveforsurveying, integrating and assessing land use land cover (LULC) change within the disasters (flash flood, landsides, mudflowing, land creeping, rock fall, cloud bursting etc.) prone areas and assessment of change pattern at thewatershed level is crucial to disaster risk reduction (Kienberger, 2009). RS and GIS can offerinfluentialtechnology for risk assessment by using satellite images and GPS surveying method and disaster maps can beorganized 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 ofdisaster,itsmanagement,riskassessment,mitigation,strategyetc.ispresented inthefollowingparagraphs.

II. OBJECTIVE

Thefundamentalobjectivesofthepresentinvestigationforstudyofdrasticdisastereventsbetween2010-2020indistrict Pithoragarhbyusingremotesensingand GISapplicationsare presented below:

1. Toanalyzethedrasticdisastereventsandtypesthisoccurredbetween2010-2020indistrictPithoragarh.
2. Toconstructmapsofthedisastereventsitesandaffecteddamagedvillagesbyusing RemoteSensingand GIS, fieldsurveyandGPScoordinates.
3. AdvantagesofRemoteSensingandGISapplicationinthefieldofdisasterandits management.
4. Suggestingstrategiesand workoutactionplanfor preventdisastereventsintheregion.

III. METHODOLOGY

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

IV. STUDYAREA

District Pithoragarh is lies between 29.4° North to 30.3° North latitude and 80° East to 81° Eastlongitude (Figure-1) and sharing boundaries with Almora, Champawat, Bageshwar and Chamoli districts andextends over an area of7,210.85 km^2. 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 KumaunHimalaya in the Uttarakhand state. Pithoragarh contains huge alpine and sub-alpine zones in the high altitudepart which is locally called Bugyals by the local inhabitants. District Pithoragarh having its entire northern andeastern boundaries being international assumes a great strategic significance and obviously is a politicallysensitive district along the northern frontier of India. Being the last district adjoining Tibet, it has tremendousstrategicimportanceasthepassesofLipulekh,Kungribingri,LampiaDhura,LaweDhura,BelchaandKeo,open out to Tibet. There are numerous scenic spots to which the prospective tourist may plan excursions likeChandak, ThalKedar, Gangolihat (77 km) famous for its kali temple, PatalBhuvneshwar (99 km), Berinag (TeaGarden of Chaukori– 11 km away from Berinag), Didihat, Munsyari (base camp for tracks to Milam, Ralam andNamik Glacier), Dharchula (base campfor Kailas MansaroverYatra,AdiKailashYatra, Narayan SwamiAshram)andJauljibi.

4.1 Demography: District Pithoragarh is the part of Kumaun Himalayan region, where West Dhauli Ganga,Saryu, Ramganga, Gori Ganga and its tributaries, East Dhauli Ganga and Kutyankti River flow from north tosouth direction and develop narrow valleys. Pithoragarh has total population 483439 where 239306 are malewhich accounts 49.50% and 244133 are female which accounts 50.50% of the total population (COI, 2011). Thetotal population of below 06 years is 63293 where 34853 are male which accounts 55.07% and 28440 are femalewhich accounts 44.93% of the total population of >6 years (COI, 2011). Female population in the study area ishigher than the male population and the sex ratio of male to female stands at 1000:1020. The population densityin thestudy area stands at67.04 people per km^2 (COI, 2011). The total literate people are 345550whichaccounts 71.48% in total population of the study areawhere 189623 (54.88%) are maleand 155927 (45.12%)are female, and the illiterate are 137889 (45.12%) where 49683 (36.03%) are male and 88206 (63.97%) arefemale (COI, 2011).

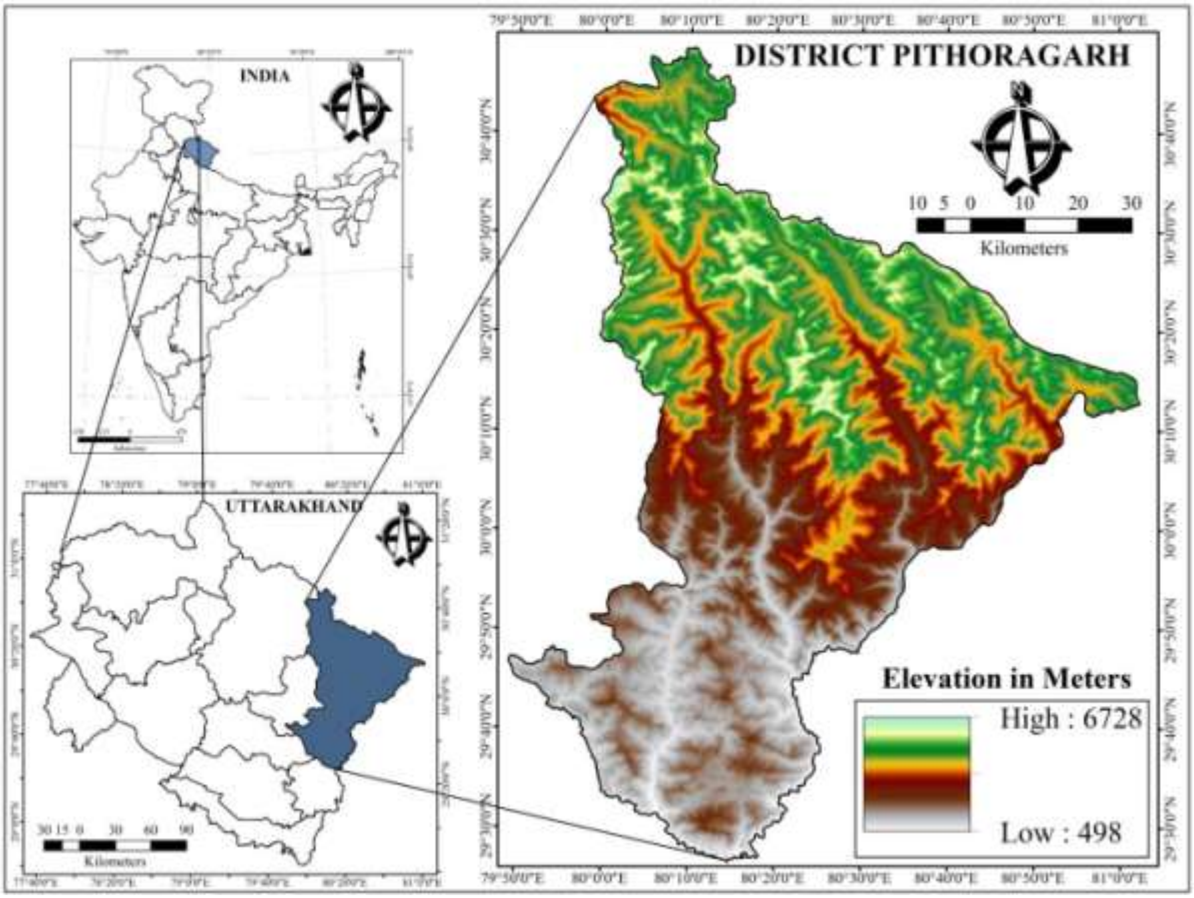


Figure-1: Location map and DEM of district Pithoragarh, Kumaun Himalaya, Uttarakhand (India) (based onCartosat-1, Satellitedata).

4.2 Drainage Network: Gori Ganga,EastDhauliGanga,Ram Ganga,Saryu andKutyanti are themaintributary of the mighty Kali River which receives water from the Greate and Lesser Himalaya regions. Figure-2depicts 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 inTable-1. The total length of river and streams in district Pithorgarh is about 1358.99 km having density of 0.19km/km^2.Table-1revealsthat thereare 16 major tributaryand riversofthemainKali River.

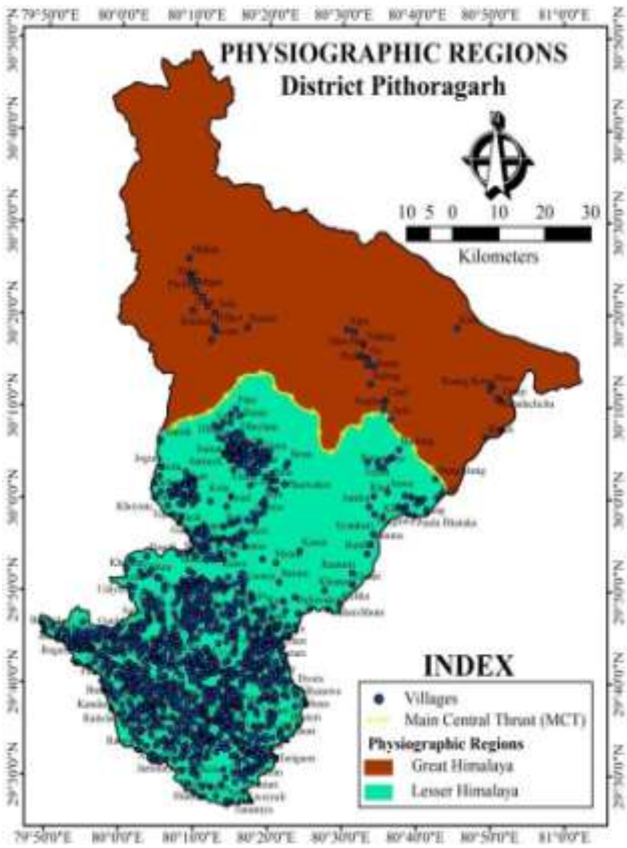
Table-1: Detailsoftypes,originplaceandconfluenceofthemajorriversofdistrictPithoragarh,KumaunHimalaya(basedonfield survey andCartosat-1 satellitedata).

S.N.	NameofRivers	TypeofRiver	Length	S.N.	NameofRivers	TypeofRiver	Length
1	DhauliGangaWest	Glacial	33.78km	10	BonaGad	Glacial	22.69km
2	Kutiyanti	Glacial	78.48km	11	GolphaGad	Glacial	19.03km
3	DharamGanga	Glacial	32.51km	12	GoriGanga	Glacial	401.17km
4	LesserYankti	Glacial	40.64km	13	KaliRiver	Glacial	190.94km
5	DhauliGangaEast	Glacial	87.73km	14	CharmaGad	Non-Glacial	31.09km
6	Lwan Gad	Glacial	12.25km	15	RamgangaEast	Glacial	224.35km
7	RalamGad	Glacial	22.99km	16	SaryuRiver	Non-Glacial	123.48km
8	PotingGad	Glacial	9.91km	Totallength			1358.99km
9	MandakiniGad	Glacial	27.95km				

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).TheMCTpassingthroughthemiddlepartofthedistrictseparatestheGreatHimalayanrockfromtheunderlyingyoungerrocksoftheLesserHimalayanregion.TheMCTpassesthroughthevillagesLaspa,Khilanch, Rilkote, RalamZimiya, Quiri, Leelam, Paton, Bunie and Nagling, Sela, villages. Figure-3 depicts thedistribution of Great and Lesser Himalayan region and villages in district Pithoragarh.A brief account of thesephysiographicregionsofdistrict Pithoragarhis giveninthe followingparagraphs.

(A) **Great Himalayan Region:** In the northern region of district Pithoragarh about 3529.58 km^2 which accountsfor 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 arelocated 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, RaungKongand Kuti.

(B) **Lesser Himalayan Region:** In the southern part of district Pithoragarh about 3681.27 km^2 which accountsfor about 51.05% area of total district is constituted of theLesser Himalayaphysiographic region.About97.69% villages (total 1311 villages) are situated in the Lesser Himalayan region of district Pithoragarh (Figure-3).



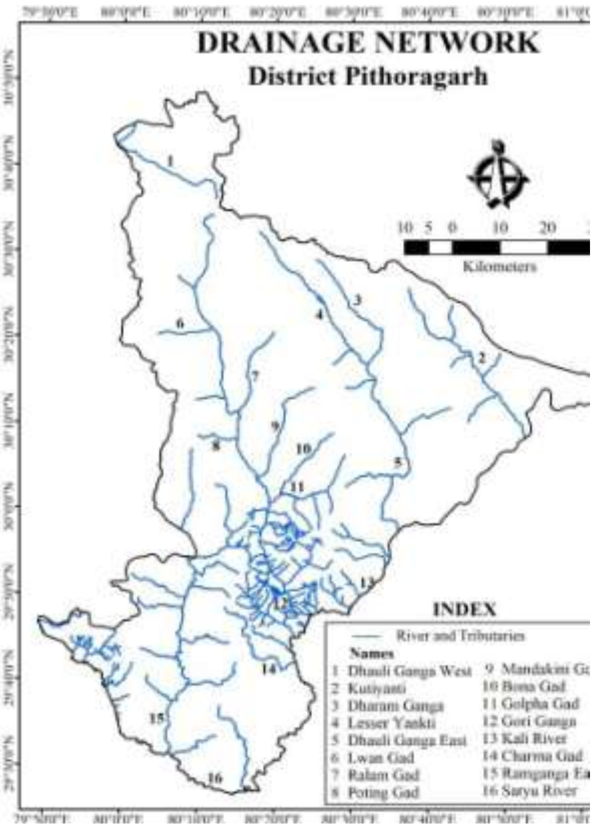


Figure-2:DrainagenetworkofdistrictPithoragarh,KumaunHimalaya(basedonCartosat-1satellitedata).
Figure-3:PhysiographicregionsofdistrictPithoragarh, Kumaun Himalaya (after Pathak et al.2015andCensesofIndia-2011).

4.4 Rainfall: Table-2 contains monthly average rainfall data from 2011 to 2019 obtained from different TehsilHeadquarter 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 inthemonthofJuly(2861.72mm)ineachmeteorologicalstationwhiletheminimumaveragerainfalloccursinthemonthof November(24.81mm).

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

Month	AverageRainfall(mm)2011-2019(atDistrictPithoragarh)						Total monthly averagerainfall
	Pithoragarh	Didihat	Dharchula	Munsyari	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. RESULTANDDISSCUSSION

The large amount of precipitation increases discharge through streams and artificial channels and also thesubsurfaceseepage, leading to bed/sheet erosion, groundsaturation andnearby landfailures in the affectedareas. Maincausesofthedisasterproblems inthe district Pithoragarhare asfollows.

- Heavy rainfall, inadequate surface water management and unregulated seepage in the area causingsaturationofinternalfrictionoftheweathered rockandsoilmaterials.
- Steep slope cuttings for developmental work in weak materials and construction without planning closeto natural water courses and frequent presence of very weak natural materials and unlined natural water coursesinthedistrictarea.
- Loadingofweakslopesbyheavyconstruction,includingunplannedroadconstruction,withoutnecessary slope treatment. Mass wasting and landmasses undercut due to flash floods, dumping zones, and weaknaturalmaterialsnearbyfromnatural and artificialsources.

5.1 DrasticDisasterEventssince2010-2020

During field survey, I have heard and seen much in the study area about recent devastating effects ofcloud bursting, mud flowing, land creeping, flash flood, mass wasting, and landslides in Pithoragarh, especiallyin Munsyari, Bangapani and Dharchula Tehsil. Due to heavy rainfall and cloud bursting events, the study areaexperienced many types of disaster events with heavy losses of human life, livestock, agriculture land, land andproperties, etc. by Gori Ganga, Dhauli Ganga, Kutiyankti, Kali, Ramganga and Saryu River. Table-3 presentaverage rainfall data between 2011- 2019 recorded by different Tehsil headquarter offices based on DDMOPithoragarh,which affectsdeeply thestudy area.Figure-4depicts thegeographicaldistribution ofdisasterevents in the study area andwhichdetailed states are registered in Table-3 based on DDMO Pithoragarh. In2010 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, in2016 cloud burst, mud flowing occurred in 2 villages, landslide, in 2017 landslide, flash flood, water loggingoccurred 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, masswastingandLandcreepingoccurredin22 villagesofdistrictPithoragarh.

Table-3: Details of major drastic disaster types and affected sites (126) during 2010-2020 in districtPithoragarh,KumaunHimalaya(source:DDMO,Pithoragarh,field surveyandGPS).

Year	Date	Impact of HeavyRainfall	NameofDisasterSites	Tehsil
2010	JulyandAugust	Flash floods,landslides and rockfalls	Bhadeli, Radgari, DaniBagar, Umargada, Ropar, Motighat,Bangapani, Seraghat, Sera, Mavani, Farvekote, Bali Bagar,Ghigrani,KhinnuGauna,ChhoriBagar,TallaMori,Ghatta Bagar,Garjiya	MunsyariDharchula

2013	13/06/2013	Flash flood, masswasting, waterlogging	JimyGhat, TallaDhapa, Basantkote, Bhadeli, Sana, Gaila,Ropar, Radgari, Motighat, DaniBagar, Bali Bagar, Madkote,DeviBagar,BhoraBagar,FaguaBagar,Sera, Umargada, Bangapani, Seraghat, Mavani, Davani, Ghigrani and KhinnuGauna	Munsyari
	16/06/2013 17/06/2013	Landslide, flashflood, waterlogging	Chhoribagar, Mori, Pangla, DootiBagar (Jauljibi), Jamku,Ranthi (Dobat), Garbyang, Sela, Baluwakote, Gargua, Sirkha,Bangapani,Jipti,Sobla,Baram,Jumma(Eilagad),Suwa,Chhalamchhailason,Kalika(Gothi),Teejam, Chharchhum, Kanar, Toli (Ghattabagar), NayaBasti, Khela (Tawaghat),Bouling,Khet,Nagling	Dharchula
	18/06/2013	Flashflood	DekunaTok,Lachhuli	Tejam
	27/07/2014	Landslide	Kanar,Garguva	Dharchula

2014	18/07/2014	Landslide	Gaisaleenadu(Chharandev)	Kanalicheena
2016	01/07/2016	Cloudburst,mud flowing,landslide	Bastari(Singali)	Didihat
	30/06/2016	Landslide	Nwali(Peepali)	Kanalicheena
2017	13/08/2017 14/08/2017	Landslide, flashflood,water logging	Tankul,Garbyang,Bung-Bung,Suva	Dharchula
	16/06/2017	Landslide,	Metali,Chami,Tanga	Bangapani
	08/07/2017	Landslide	Sanikhet,BinariNala	Berinag
2018	04/07/2018 11/07/2018	Landslide, flashflood, waterlogging	Glanti,Jamku,BanshBagar,Tankul,Mangti,Dharpangu,Himkhola, Khela, Chhalamchhailason,	Dharchula
	10/07/2018	Landslides	Kanar,Jimtari,Tanga	Bangapani
2019	18/06/2019	Landslides	Bundi	Dharchula
	07/09/2019	Cloudburst,mud flowing	Timtiya	Tejam
	09/09/2019	Landslide	TallaBanshkote,Bamangaun,Khalsa	
2020	19/07/2020	Flashflood	Bangapani,Chhoribagar	MunsyariBangapaniDharchula
	20/07/2020	Cloudburst,mud flowing Landslide,masswasting	Tanga,Patharkote(Gaila), Lodi, BaliBagar	
	27/07/2020	Landslide	DhamiGaun	
	28/07/2020	Landslide	Metali,TallaDevlekh,Bangapani,Mori,Kaulikanyal	
	27/07/2020	Cloud burst, mudflowinglandslide	Silauni,Aankote	Didihat
	19/08/2020	Landslide	Khetarkanyal	
	27/07/2020	Landslide	Goonthi,Kotyura	Tejam
	19/07/2020	Landslide	Dhapa,Suring(Balauta)	Munsyari
		Landcreeping	Josha,Malupati,Serasurayidhar	

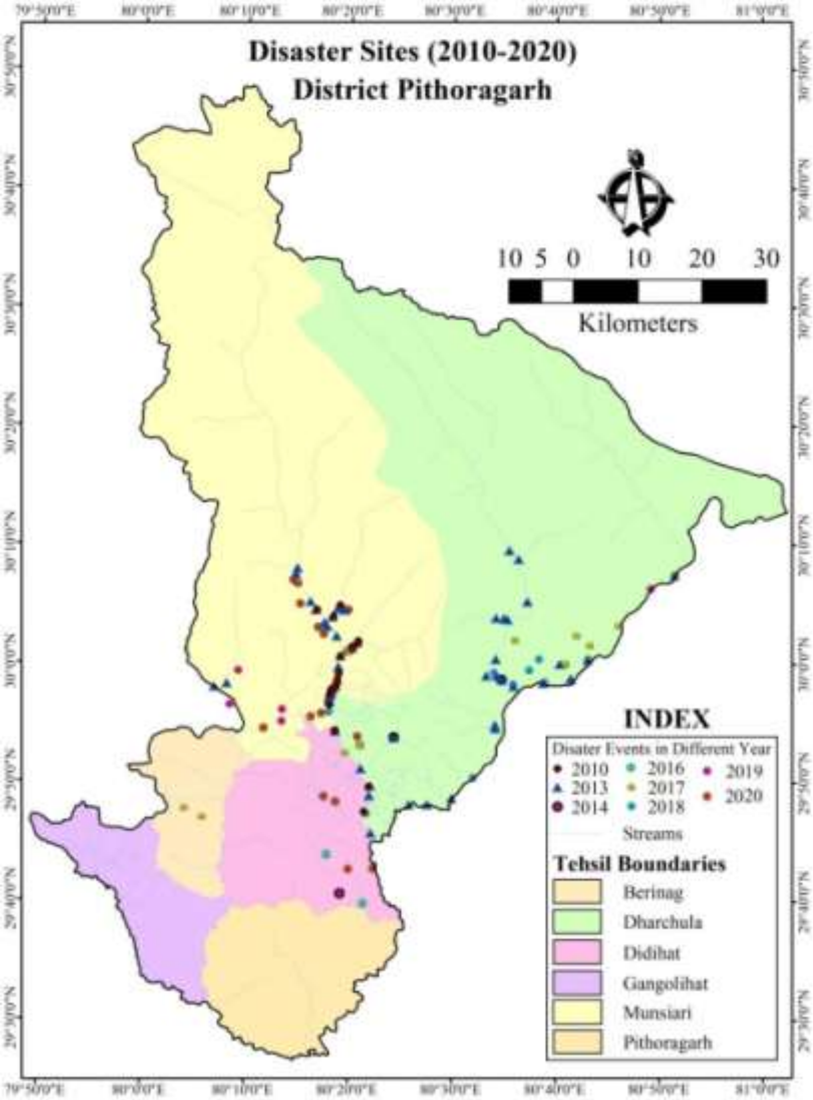


Figure-4:distributionofdisastereventsoccurredduring2010-2020indistrictPithoragarh, KumaunHimalaya (source:DDMO, Pithoragarh,fieldsurveyandGPS).

5.2 IMPACTOFDISASTEREVENTSINDISTRICTPITHORAGARH

Frequencies of disaster events in district Pithoragarh are more pronounced during monsoon seasonyearly. Among these are most responsible for the heavy rainfall and cloudbursts leading to flash floods, masswasting, mudflows, land creeping, rock falls and landslides which cause loss of animal and human lives anddisruption of settlements, and agricultural lands together with motor road networks etc. Disaster affects all thephysical, economic and social aspects of the district Pithoragarh area because disaster does affect the wholecommunity, i.e., humans, culture, livestock, wild animals, etc. of disaster sites. In district Pithoragarh, about 121villages from 6 Tehsils have been affected due to the increasing heavy rainfall, cloudburst, flash flood, masswasting, mud flowing, and landslides phenomenon in the last 10 years. Between 2010 to 2020, there were 174people dead, 58 people missing, 153 people injured, and losses of 7016 livestock as well as 10 cowshedsdamaged in district Pithoragarh. In the last decade 990 buildings were completely damaged, 1891 houses aredilapidated and 453 houses area partially damaged in the study area which is registered in Table-4 based onDDMO Pithoragarh . Plate-1 and Plate-2 presents the physical impact of landslides, land creeping, flash floodand mass wasting including the damage to the artificial and natural environment and can be classified asaffectingtheresidential,commercial,industrial,infrastructure,andcommunityservicesectors.Plate-3presentingthecollapsingstructureimpactofcloudbursttriggeredlandslides,mudflowandflashfloodindifferent parts of Pithoragarh district has been analyzed in the study. Plate-4 presents the social and culturalimpact of all disaster events that can take the form of cultural, demographic, psychological and economic innature resultingdirectlyfromthephysicalimpact.Table-4presentstheeconomic impact ofthesedisasterevents wastremendouseffectintheformsoflossofhumanandanimallives,buildingloss,lossofarableland,forestloss,existingcrop loss, lossof bridges,roadnetworksandanyotherinfrastructure.

VI. SUGGESTINGSTRATEGIESTOPREVENTDISASTEREVENTS

The landslide is deduced to be highly susceptible to slope failure in mountainous regions of districtPithoragarh, particularly in the event of heavy rainfall. Based on field surveying, it is perceived that necessaryprecautions are required to be taken, especially in view of the fact that the slide is in close proximity of denselypopulated area, nearby stream network and remaining part of road network of Pithoragarh. Besides majorlandslidessomany severallandslidescars arealsoobservedon theuphillsides inmountainous regions.Activation of these landslides has the potential of posing danger to the nearby villages in the study area andfollowingsome suggestivemeasuresare given,whichare:

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

S. N.	Disasterdate/Year	Typesoflossesofpeople,livestockandproperty		
		Dead/missing	Injured	Property
1	2010	10dead	-	• Completelydamagedbuilding-100
2	2013	53dead,21 missing	57	• Completelydamagedbuilding-692 • Dilapidated-800 • Animalloss-6000 • Andmanymicrohydroprojects,riverbridges,footpath,motorroad
3	2014	18dead,2missing	21	• Completelydamagedbuilding-30
4	2016	21dead,9missing	09	• Completelydamagedbuilding-14 • Dilapidated-36 • Partial-109 • Cowshed-10 • Animalloss- 86 • 169sheepandgoatscollapseduetolandslide • Lossesoflivestockandagriculturelandduetomudflowingandlandslide
5	2017	25dead,23 missing	17	• Completelydamagedbuilding-14 • Dilapidated-219 • Partial-90 • Animalloss-241
6	2018	19dead	19	• Completelydamagedbuilding-40 • Dilapidated-589 • Partial-173 • Animalloss-142
7	2019	6dead	13	• Completelydamagedbuilding-38 • Dilapidated-95 • Partial-36 • Animalloss- 27
8	2020	22dead,3missing	17	• Completelydamagedbuilding-62 • Partial-45 • Dilapidated-152 • Animalloss-351

Plate-1: Impact of landslides and land creeping in district Pithoragarh: (A) Madkote to Munsyari motor roadaffected 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 onfield survey).

Plate-2:Impactofflashfloodandmass wastingdisastersindistrictPithoragarh:(A)atGhattaBagar(2013), (B)atMorivillage(2013),(C)atDaniBagar(2016)and (D)HimalayaHydroPowerProjectDamdamagedatBaliBagar(2018)(basedonfieldsurvey).

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

Plate-3: Impact on society by disaster events in district Pithoragarh: (A) Homeless people at Umargada villageaffected 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)(basedonfieldsurveyand DDMO Pithoragarh).

- To all the community are advised to keep a safe distance from the vulnerable slope, seasonal streams,landslidesites,andvacatethearea,especiallyduringmonsoonseasonas wellasheavyorprolongedrainfall.
- The landslide, rock fall, land creeping and debris flow event have sent a strong signal for the urgentneed for disaster risk analysis on the ground basis. District Pithoragarh has numerous major active disaster sitesthat may cause disaster in the event of major rainfall or earthquake. Further, there are many potential landslideslopes which have large volume of debris and rock boulders threatening to come down as massive debris flow orrock fall. Such a type of drastic disaster hazard cannot be prevented, but the consequences can be minimized ifthereisproper training,disaster awareness,riskestimationandplanningpriorto suchamajorevent.
- Prepare all disasters and their management study relative maps with excellence by ground surveyingwithGPS, remote sensingandGIStechniques.
- Participatory GIS-based slope map, aspect map, relief map, landslide, flood risk, and road-induceddisasterriskassessmenthavehigheraccuracythansophisticatedriskdelineationbasedonnumericalandphysical models. These maps can be effectively used at various levels in the disaster management process in thestudyarea.

VII. SUMMARY

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

From the study, Heavy Monsoon Rainfall, cloudburst in the landscape increases the intensity of flashfloodalongriverbanks,whichmakesrainfalloneofthemaincontributingfactorsforflashfloodinthelandscape. It is also concluded that slope is highest contributing factor because the driving force of massincreases with increasing slope. The slope with multiple joint sets fails particularly during monsoon, when thisregion receives heavy rainfall. The slopes become saturated with water, destabilizing the slope beyond thestabilitylimit.Rock fall,debrisflowandcomplexlandslidesarevarioustypesofslopefailurethatoccur.

Unscientific construction of roads causes rock falls, landslides, land creeping, soil erosion, uprooting oflarge trees and destruction of lower plants. It adds to siltation in the path of the river and stream as well asincreaseswaterandaircontamination.Blasting,excavationandcuttingofslopesresultingeologicaldisturbances and subsequent landslides and land cracks.Dumping landslide rubbles and road constructionmaterialat insecure placesrisksthe livesofdownhillpopulation.

Climate change brings related disaster risks of landslides, droughts, cloud bursts, flash floods, recedingglaciers,glacial runoffs,uneven precipitation, extremeevents and loss ofwildlife habitats and biodiversity ofthe region.Mountain roads are the only lifeline during climatic disasters and lack of other alternate escaperoutesmakesmountainregionsveryvulnerable toextreme events.

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