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Disastrous events of 2021 in Uttarakhand Province of India: Causes, Consequences and Suggestions for Disaster Risk Reduction (DRR)

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INFORMATION

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ABSTRACT

The Central Himalayan state of Uttarakhand in Indian subcontinent has a long disastrous history before its creation because of various natural hazards like earthquake, landslide, flood, flash flood, cloudburst, glacial lake outburst flood (GLOF), and landslide lake outburst flood (LLOF). These events caused massive loss of lives, property and infrastructure in the same region. Adverse impact on local inhabitants as also pilgrims and tourists across the country and abroad due to the same. Recently, throughout the pre-monsoon, during monsoon and post-monsoon periods heavy downpour, cloudburst, rock fall, debris flow, avalanche, flood/flash flood occurred in many places of the state. Causing 308 people were killed, 61 people went missing and 105 people were injured while 1048 farm animals lost in these incidences. Except for, about 5729 houses were fully damaged and 18.5 ha of agriculture fields were also washed away in these incidences. These are mainly attributed to changes in weather regime and abnormal rainfall patterns together with indiscriminate manner human initiatives in high-risk areas. The main purpose of this research is to highlight the recent disastrous issues. As also find out the possible causes of recent disastrous incidences and suggestions for reduction of disaster risk within the region.

1. Introduction

The state of Uttarakhand province of India is a geo-dynamically active and most fragile landscape in the world. Geo-tectonically, four major Thrusts/Faults encountered across the region from South to North are Main Frontal Thrust (MFT), Main Boundary Thrust (MBT), Main Central Thrust (MCT) and Trans Himadri Fault (T-HF) (Heim and Gansser, 1939; Auden, 1949; Valdiya, 1980; Valdiya and Goel, 1983; Valdiya, 1989; Hubbard et al., 2021).

Geo-morphologically, the region exhibits distinctive characteristic features like U-shaped valley, V-shaped gorges, highly, moderately and low dissected denudation hills, rapid tectonic uplift, intense fluvial and glacial incision produce long steep slopes, meandering and river borne materials terraces across the region (Shroder and Bishop, 1998). Meteorologically, it is observed that heavy concentrated precipitations occur in many places of hilly regions every year not only during monsoon season, as pre-monsoon also. This is mainly attributed to global warming and climate change due to which changing of rainfall pattern (Goswami et al., 2006; Kumar et al., 2010; Guhathakurta et al., 2011; Trenberth, 2011; Loo et al., 2015; Nandargi et al., 2016). These caused landslides and LLOF incidences happened in the region (Villanueva et al., 2017; Dikshit et al., 2020).

Located in the Central Himalayan sector the same region is an integral part of Himalaya where higher reaches of Uttarkashi, Rudraprayag, Chamoli, Bageshwar and Pithoragarh districts having glaciers are the source of major streams of the state as well as the country (Fig. 1). Bordered with Tibet in the North and Nepal in the East internationally whereas Uttar Pradesh in the South and Himachal Pradesh in the West nationally. Topographically, this region has a total of 53483 km^2 geographical area of which 93 percent is mountainous where it ranges from 250 m to 8000 m altitude with Nanda Devi (7817 m) is the highest massif which is the second-highest mountain of the country (Sain et al., 2021).

Uttarakhand has a long disastrous history before its creation as even in the independence of the country and Some of the major disastrous events occurred over the past in this region are Sher-Ka-Danga landslide of 1880 claiming 151 lives, Uttarkashi earthquake of 1991 claiming 768 lives, Okhimath landslide of 1998 claiming 101 lives, Malpa landslide of 1998 claiming 221 lives, Chamoli earthquake of 1999 claiming 100 lives (Atkinson,1886; Bist and Sah,1999; Jain et al., 1999; Kumar and Mahajan, 1994; Paul et al., 2000). Seismically, the region is being marked in both Zone-IV and V according to the Seismic Zonation Map of India (IS 1893, 2002) and has witnessed two earthquakes as 1991 Uttarakashi and 1999 Chamoli (Kumar and Mahajan, 1994; Jain et al., 1999) wherein killing 768 and 106 persons respectively, after the great earthquakes of 1803 Garhwal, 1905 Kangra and 1934 Bihar-Nepal (Middlemis, 1910; Ambraseys and Bilham, 2000; Dasgupta and Mukhopadhyay, 2004; Sapkota et al., 2016).

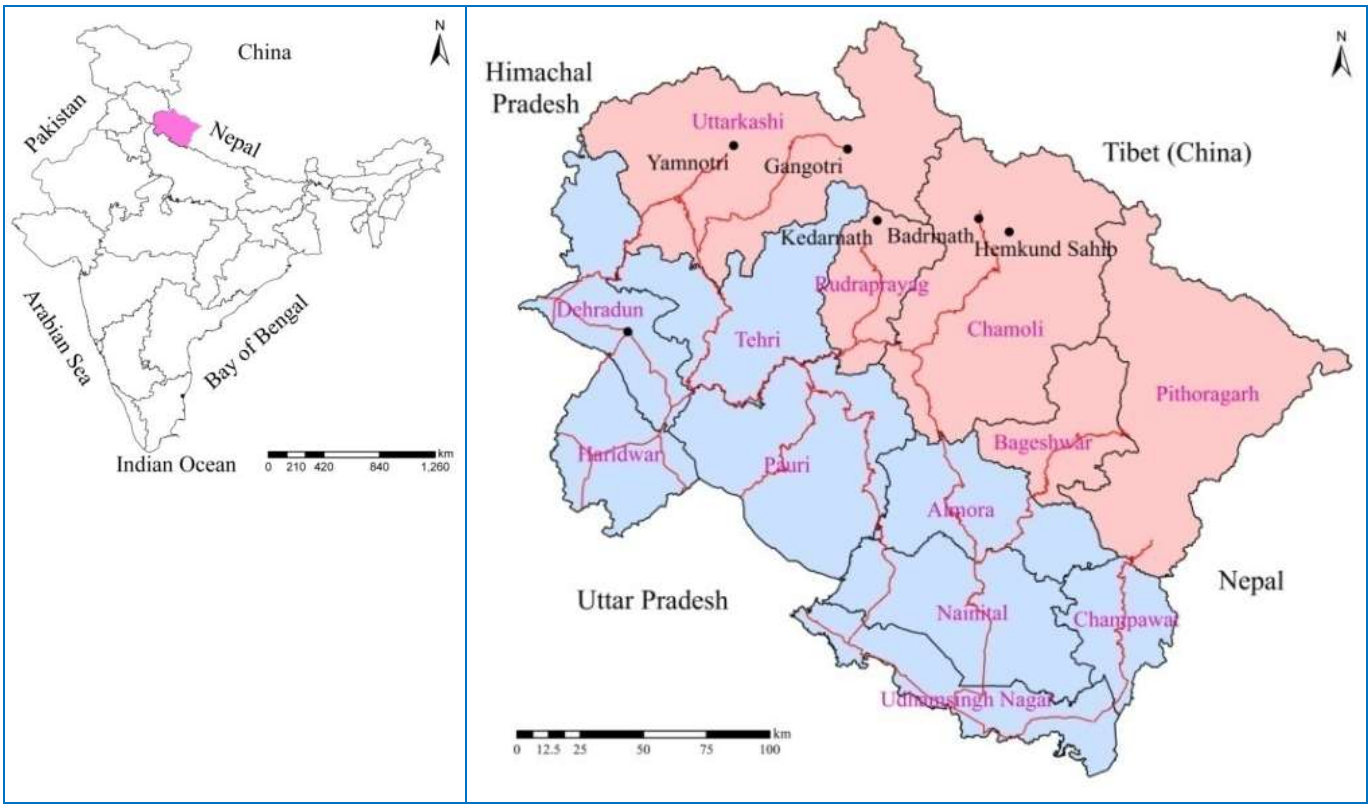

Fig. 1. Map depicting Uttarakhand Himalaya (the districts having glaciers where from glacier-fed rivers are originate shown in red color)

According to State Emergency Operations Center (SEOC), Uttarakhand data, human losses of at least 433 people were caused both by landslides and flash floods in the state during the periods of 2000 to 2009. Major disastrous events which happened in the region during the same periods are the Phata-Byung landslide of 2001 claiming 27 lives, Budakedar landslide of 2002 claiming 28 lives, Govindghat debris flow of 2005 claiming 11 lives, and Jhakhla and Lah landslide of 2009 claiming 43 lives (Naithani et al., 2002; Sah et al., 2003; Sarkar and Kanungo, 2010).

In the recent decade, the region is witnessed to have a number of disastrous events wherein killing 1312 persons while 4076 persons went missing and 1013 persons injured (Fig. 2). Heavy rains received between September 16 and 20, 2010 resulted in a number of landslides, cloudbursts, and flash flood incidences across the state causing 214 persons killed and 1771 animals lost (Sati et al., 2011). On the other hand, heavy rains triggered the Sumgarh landslide on September 18, 2010 claiming 18 lives in Kapkot Tehsil of Bageshwar District (Prakesh, 2015). Similarly, excessive heavy rains or cloudbursts induced debris flow and flash flood incidences took place in the area around Okhimath in Rudraprayag District and the Asiganga Valley in Uttarkashi District killing 79 and 35 persons, respectively (Khanduri, 2020).

Likewise, abnormally high rains or cloudburst caused disaster on June16/17, 2013 that resulted in flash floods and a number of landslides in the region (Asthana and Asthana, 2014). 225 persons dead while 4.021 persons went missing in June 2013 disaster alone and it was one of the biggest tragedy since the creation of Uttarakhand (Khanduri et al, 2018a; Rautela, 2018). Subsequently, Bastari-Naulra landslides of 2016 killed 22 persons, Mangti-Malpa flash flood and debris flow of 2017 killed 24 persons and Mori flash flood of 2019 killed 21 persons (Khanduri, 2017; Khanduri et al., 2018b; Khanduri and Sajwan, 2019).

About 1309 ha and 1285.5 ha agriculture fields were damaged respectively in years 2013 and 2014 while about 1087.1 ha agricultural fields in the year 2020 were damaged in the region. Besides, slope instability occurred in 233, 341

and 395 villages respectively during the periods of 2000-2012, 2013-2017 and 2018-2021 which are being marked unsafe for habitations by district Authority (Source: Uttarakhand State Disaster Management Authority, Government of Uttarakhand). During the periods 2013-2017, total of 108 villages have been affected because of heavy rains and cloudbursts induced landslide and flash flood incidences across the state.

Table 1. Losses incurred in disasters of 2021 in Uttarakhand (Source: State Emergency Operations Centre (SEOC), Uttarakhand)

No	Date & Year of occurrence	Place of incidence	Losses and damages
February 2021			
1	February 7, 2021	Rini and Tapoban, Rauthi Gadhera-Rishiganga, a tributary of Dhauliganga river, Chamoli District	204 people killed, of these bodies of 83 persons could be recovered and 380 animals lost. 5 pedestrian bridges over the Dhauliganga River and 1 RCC Bridge over Rishiganga washed off whereas 2 hydropower projects as operational Rishiganga HEP (13.2 Mw) washed off and under constructional Tapovan-Vishnugad HEP (550 Mw) severely damaged
April 2021			
1	April 23, 2021	On Joshimath-Malari-Girthi-Dobla-Sumna-Rimkhim road. Near Sumna of Niti Valley, Chamoli District	Killing at least 13 labours because of avalanche
May 2021			
1	May 3, 2021	Narkota, Rudraprayag	1 vehicle and 1 motorcycle packed with debris
2	May 4, 2021	Kumrara Village. Chinyalisaur tehsil, Uttarkashi	10 water supply lines damaged, 110 ha. Agricultural lands damaged
3	May 4, 2021	Ghat market, Chamoli	Shops filled with debris, debris spread over road
4	May 11, 2021	Bauntgaon, Devprayag, Tehri Garhwal	A number of agricultural lands damaged
5	May 11, 2021	Dasharath Danda Parvat, Devprayag, Tehri Garhwal	8 houses destroyed, 01 pedestrian bridge in Devprayag market due to excessive discharge in the Shanta Gadhera
6	May 11, 2021	Katal Kyara village, Narendra Nagar, Tehri Garhwal	1 house and 1 cowshed damaged
7	May 20, 2021	Bijnor Chhani of Kwansi Village, Chakrata, Dehradun	3 persons dead, 4 persons injured, 20 animals lost and 1 Chhani (temporary shelter) destroyed
8	May 21, 2021	Revenue Village Goonakot (Ratair), Bageshwar	Killing 2 persons, 7 persons injured and 1 house damaged due to falling tree
July 2021			
1	July18, 2021	Mando, Nirakot, Kankarari, Mastari, Kuroli, Mangalpur and Siror villages, Bhatwari tehsil, Uttarkashi	4 persons were killed while 1 person was injured and 2 animals lost. 4 houses fully, 22 houses severely and 2 houses partially damaged while2 bridges washed off and 6 ha agricultural lands damaged
August 2021			
1	August 27, 2021	Jumma Village (Jamuni, Jeoldhunga, Seriudayar, Khatpoli, Rejani, Nalapani, Tusrani toks etc), Dharchula Tehsil, Pithoragarh	7 persons killed and 3 houses destroyed
October 2021			
1	October 17, 2021	Banbasa, Champawat	1 person killed
2	October 18, 2021	Lansdowne Chamkhal, PauriGarhwal	3 persons killed and 2 persons injured
3	October 18, 2021	Selkhola, Champawat	Killing 2 persons and 1 house destroyed
4	October 18, 2021	Chal Bugiyal in Dharchula and Gangolihat, Pithoragarh District	2 persons killed and 2 persons injured
5	October 19, 2021	Sakuna, Thaledi, Totapani, Jhutiya, Kaichi Dham, Bohrakot, Kwarab, Sirodi, Takula, Bhimtaal, Ramnagar, Dhari, Betalghat in Nainital District	Killing of 35 persons and 5 persons injured, 19 houses fully and 55 houses partially damaged
6	October 19, 2021	Rapad in Bhikiyasain, Heeradungi, Siran, Syaldey, Bhanoli, Someshwar in Almora District	6 persons were killed and 2 persons injured, 20 houses fully and 20 houses partially damaged
7	October 19, 2021	Tilwarda in Champawat, Pati in Thuwamuni and Siulla in Lohaghat, Champwat District	8 persons died, 4 persons injured and 1 house was fully damaged
8	October 19, 2021	Bajpur, Rudrapur and Kichha in Udham Singh Nagar	Killing 2 persons while 3 persons injured and 93 houses damaged
9	October 19, 2021	Mankhandi in Joshimath and Narayanbagar, Chamoli District	1 person was killed while 4 persons injured and 15 houses partially damaged
10	October 19, 2021	Neelapani and Lamkhaga Pass, Uttarkashi District	10 persons were killed and 2 persons injured while 2 persons went missing
11	October 19, 2021	Kapkot, Bageshwar	1 person killed

In the year 2021, a flash flood disaster occurred on February 7, 2021 in the Rishiganga-Dhauliganga River while on April 23, 2021 an avalanche took place near Sumna in the Dhauliganga Valley of Chamoli District. Later, heavy concentrated rains between May 3 and 21, 2021 occurred in many places of the region. During monsoon, particularly in the months of July and August 2021 respectively at Mando in Uttarkashi District and at Jumma in the Pithoragarh district were hit hard by heavy localized precipitation or cloudburst like incidences. Subsequently, between October

18 and 21, 2021 heavy rains ensuing landslide and flood incidences occurred all across the state. These inflicted massive loss of lives, property and infrastructure. The main objective of this research is to find out the possible causes of the disastrous events of 2021 and suggestions for disaster risk reduction which would definitively be minimizing the disastrous impacts as also reducing human and other losses in the same region.

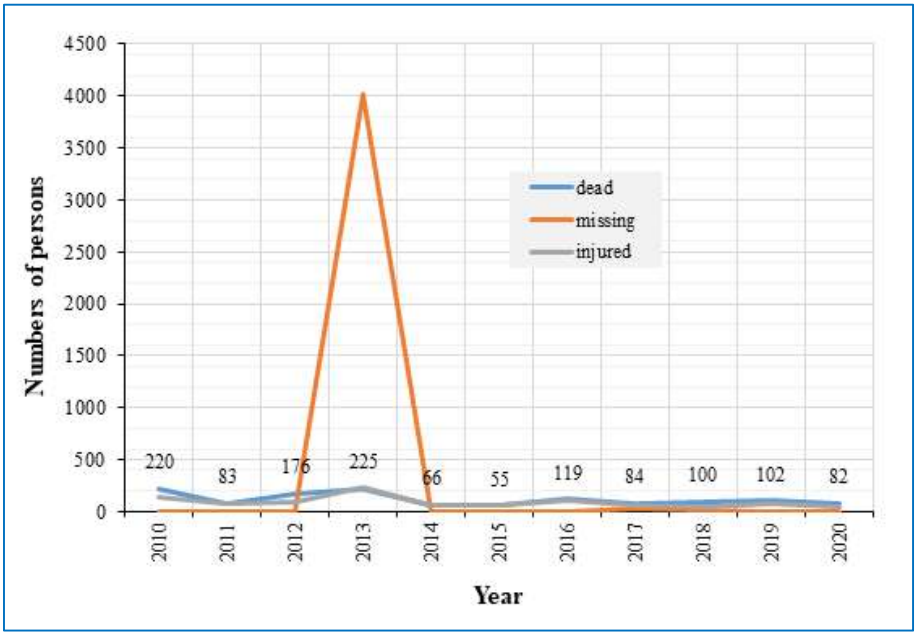

Fig. 2. Disaster induced losses in Uttarakhand between year 2010 and 2020

2. Disastrous Events of 2021

In the entire year of 2021, heavy localized precipitation or cloudbursts like incidences, landslides, flash floods, floods, and avalanches occurred in several places of the state causing massive loss of lives, property and public infrastructure. The losses incurred in disasters of 2021 in the region is given in Table 1.

3. Brief Descriptions of Disastrous Events

3.1. Rishiganga-Dhauliganga River flash flood

The flash flood disaster affected Rini and Tapoban areas situated at a distance of respectively 22 km and 15 km from Joshimath Town on Joshimath-Malari Motor Road. Rini village is located on both the banks of Rishiganga and Tapoban on the right bank of the Dhauliganga River. This flash flood inflicted massive loss of operational Rishiganga hydropower project installed capacity of 13.5 Mw and under construction Tapovan-Vishnugad hydropower project of 450 Mw power generations respectively at Rini and Tapoban wherein killing of 204 people while 360 farm animals lost (Figs. 4a, 4b). Not only local inhabitants and others, but scientists of various domains have also been surprised across the worldwide and most of them made their sincere effort to reconstruct the sequence of this disaster. Most of them expressed their views based on state-of-art techniques (Dandabathula et al., 2021; Jiang et al., 2021; Meena et al., 2021; Meena et al., 2021; Martha et al. 2021; Mehta et al., 2021; Prakesh et al., 2021; Rana et al., 2021; Shugar et al., 2021; Sain et al., 2021; Sharma et al., 2021).

Abnormal rise in temperature in the disastrous region was however observed from February 3, 2021 to February 6, 2021 from the Auli automatic weather station (AWS) located in the proximity of the same (Fig. 3). Rock fall triggered at the upper reach of Rauthi Gadhera resulting in freeze-thaw action, wedge failure and influence of Vaikrita Thrust. Subsequently, damming at four different places as (i) initial damming of Rauthi Gadhera due to detached mass of rock fall, (ii) key damming at the confluence of Raunthi Gadhera with Rishiganga, (iii) intermittent ponding N of Murunna and (iv) intermittent ponding at the confluence of Rishiganga with Dhauliganga river at Rini (Khanduri, 2021a; Rautela et al., 2021).

Amongst all these added the discharge in streams which created the flash flood situation in downstream. A lake was also formed in this incidence over Rishiganga near the confluence of Rishiganga with Raunthi Gadhera. Because of key damming at the same place, a huge volume of water along with debris mixed with Ice deposited over Rishiganga and blocked the course of the same for 3 days between February 9 and 11, 2021 (Khanduri, 2021b). Later, Rishiganga curved out the channel from the center part of the lake on February 12, 2021.

3.2. Sumna avalanche and heavy concentrated rains in several places

On April 23, 2021 at about 1600 hours, an avalanche occurred near Sumna of Niti Valley in District Chamoli of Uttarakhand, India in which bodies of 13 labours could be recovered and 7 labours were injured while 384 people have been safely rescued by the army personal (Fig. 4c). Similarly, between May 3 and 21, 2021, heavy concentrated rains occurred at several places of Bageshwar, Rudraprayag,

Chamoli, Tehri Garhwal, Pauri and Uttarakashi Districts and ensuing landslides and flash floods caused human losses and property damages.

Though, on May 11, 2021, heavy concentrated rainfall or cloudburst like incidences occurred in many areas of Tehri Garhwal District. On the same day, an unexpected flood occurred in the Shanta Gadhera, a tributary of the Bhagirathi River after the excessive heavy rainfall or cloudburst like incidences took place around Dasharath Danda Parvat in Devprayag Tehsil of Tehri Garhwal in the evening at 5:30 PM, particularly in the area around the Devprayag Town. The same incidence came into fame on the various social and media platforms because 8 houses were destroyed and 01 pedestrian bridge was washed off in Devprayag market in this incidence. Fortunately, no human losses were however occurred in this incidence because of this incidence had happened in the evening hours.

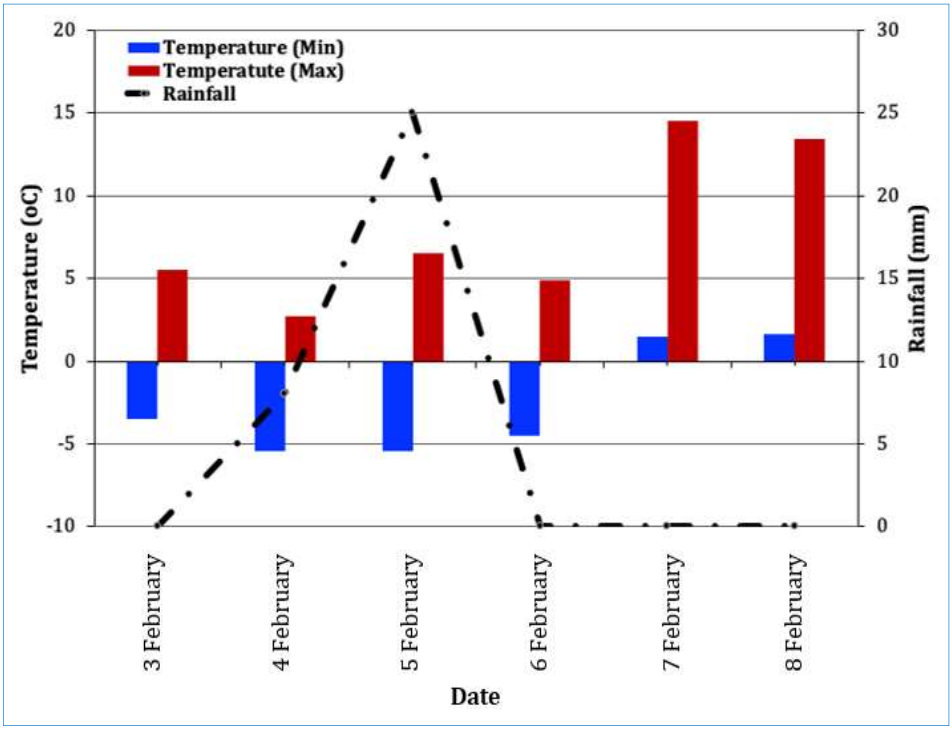

Fig. 3. Rainfall and temperature were observed at Auli in the proximity of the incidence site. Data source: Uttarakhand State Disaster Management Authority

3.3. Localised heavy rains or cloudburst like incidence in Mando

Disastrous affected Mando Village is situated at a distance of 5 kilometers from Uttarkashi Town on the left bank of the Bhagirathi river. The affected habitation of tok is situated over the fan deposits of the Mando Gadhera which is a major tributary of the Bahgirathi River in this region (Figs. 4d, 4e).

Heavy rains were received in the third week of July, especially in the area around the Uttarkashi Town which is Head Quarter (HQ) of Uttarkashi District between July 18 and 20, 2021 (Fig. 5).

Localised heavy rains or cloudburst like incidences took place in the night hours of July 18, 2021 in the upper reaches of catchment of the tributaries of Bhagirathi River, particularly Mando Gadhera, Diya Gadhera and Siror Gad caused flash flood, debris flow and landslide in the downstream. This caused widespread devastation in Mando, Nirakot, Kankarari, Mastari, Kuroli, Mangalpur and Siror Villages in Bhatwari Tehsil of Uttarkashi District wherein 4 people killed while 1 person injured and 2 farm animals lost. Total of 4, 22, 2 houses respectively fully, severely and partially damaged while 2 bridges washed off and 6 ha agricultural lands were damaged.

3.4. Heavy localised precipitation or cloudburst like incidence in Jumma

Disaster affected Jumma Village is situated at a distance of around 18 kilometers from Dharchula Town on Dharchula-Mansarovar Motor Road and on the right bank of the Kali River. The approach for reaching the same is a pedestrian route bifurcating from the ITBP campus before Ela Gad. Heavy downpour was received in the last week of August, particularly in the area around Dharchula (Fig. 6).

On August 27, 2021 Jumma Gram Panchyat (Jamuni, Jeoldhunga, Seriudayar, Khatpoli, Rejani, Nalapani, Tusrani toks etc), Dharchula Tehsil, Pithoragarh District was hit hard by heavy localise precipitation or cloudburst like incidence ensuing debris flow, landslide and flash flood. These caused damages and destructions in the same wherein killing 7 people along with property damages (Fig. 4f)

3.5. Abnormally high precipitation events in the entire State

After the monsoon period, as forecasted by IMD the entire state received abnormally high precipitation again between October 17 and 19, 2021. It is important to note that the state received 13.5% of its average annual precipitation between October 17 and 19, 2021.

Fig. 4. Rock fall, flash flood/flood, avalanche and heavy localised rains or cloudbursts associated damages (a) washed away Rishiganga hydro project, (b) badly damaged Tapovan-Vishnugad hydro project, (c) an avalanche triggered near Sumna, (d) Ruined a house at Kankarari Village, (e) property damages in Mando Village, (f) damaged house at Jumma, (g) eroded railway track between Kathgodam and Haldwani and (h) damaged Gaula Bridge in Haldwani

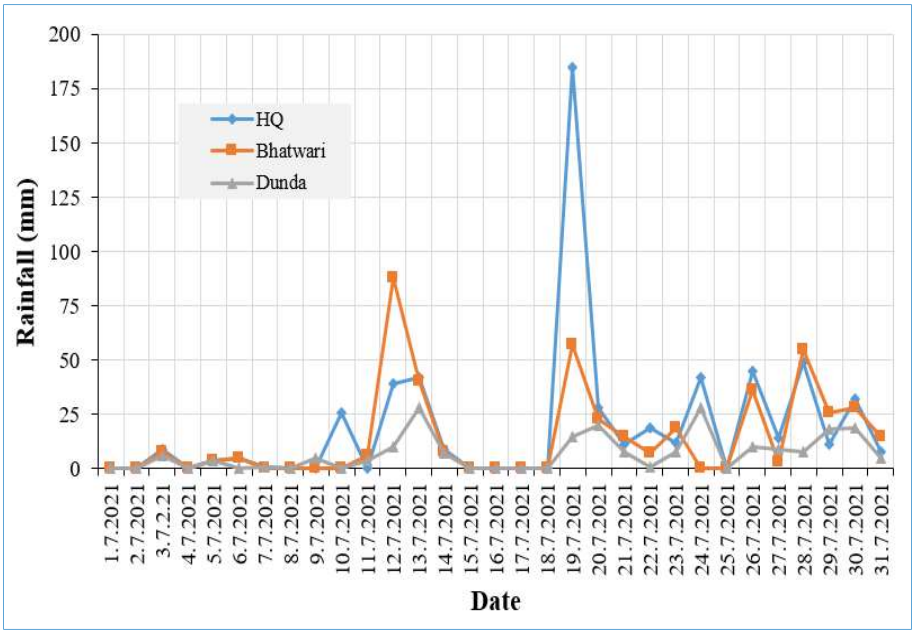

Fig. 5. Daily rainfall data of July 2021 in proximity to the affected region of Uttarkashi district (Source: District Disaster Management Authority, Uttarkashi)

The intensity of rains was much higher, particularly in the districts as Nainital, Champawat, Udham Singh Nagar, Pithoragarh, Bageshwar and Almora (Fig. 7). Ensuing landslides and floods caused 72 persons were killed, 4 persons went missing while 24 persons were injured and 224 houses were damaged in these incidences. This heavy rainfall resulted in flash floods and landslides at a number of places throughout the state in which mobility was severely disrupted due to the washing away of roads, bridges and railway treks (Figs. 4g, 4h). Because of large numbers of persons were thus stranded at various places.

4. Causes of Disastrous Events of 2021

During the entire year of 2021, the region experienced excessive heavy rains, localised heavy precipitations or concentrated heavy rains and cloudbursts events resulting in landslides and flash floods/floods. These caused enormous loss of lives, property and infrastructure along with natural resources.

The Geo-dynamically active nature of the region and peculiar hydrometeorology made this region highly susceptible to natural hazards.

Moreover, anthropogenic activities like unplanned hill slope cutting, lacking early warning system while working in proximity of the streams, construction of houses without taking care of seismic safety and construction in the unsuitable ground without investigations of suitable firm ground aggravated the problems. Some of the major causes of damages and destructions in the region are given below:

- Steep slope, high relief and weak rocks and natural materials in the area,
- Adverse topography, destructive geomorphology and peculiar hydrometeorology,
- Rocks are broken by freeze-thaw action in the high altitude region,
- Wedge failure and planner failure in rocks due to numbers of discontinuities,
- Blockade of streams because of narrow gorge, landslide, excessive sediments load and the confluence of the tributary,
- Excessive erosion of the banks during spate in streams resulting in aggradation in low lying areas,
- Climatic variability and change in rainfall pattern during winter months,
- Lack of identification of past disastrous incidences history of the region,
- Increasing trend of heavy concentrated rains or heavy localised precipitations, even during pre-monsoon and post-monsoon periods,
- Abnormally heavy precipitations or cloudbursts during the monsoon period,
- Rains added discharge of rivers and their tributaries
- Human intervention in the proximity of streams without taking care of proper early warning system,
- Encroachment over rivulet and low lying area and construction over loose soils/overburden deposits.

5. Suggestions for DRR

Though, disastrous events cannot be stopped in the Himalayan region because it's the younger mountainous belt where earthquakes, landslides and floods/flash floods are common and recurring phenomena.

The same events would be happened at anytime and anywhere in the region. By considering these important aspects can be safeguarded against disasters which are given in the sections below.

- records keeping of past events and identification of present risk of the region, accordingly planning of developmental activities,
- any type of constructional activities must be done

considering the seismic coefficient design of structures as per seismic safety norms,
- avoidance of high risk-prone areas for any type of developmental activities,
- the dense network of hydro-meteorological equipment's to understand the actual rainfall behaviour,
- establishment of robust early warning system in high altitude regions for reducing the risk of flash flood downstream by aware local inhabitants,
- rehabilitation of landslide affected habitation in safe suitable places for safety of local inhabitants,
- treatment of unstable zones for minimizing the risk, particularly in the vicinity of habitated areas,
- awareness generation and capacity building of local inhabitants,
- training of engineers and other stakeholders in best practices of planning and construction,
- formulation of plan, policy and stranded operation procedure (SoP) for planning, constructions and awareness activities.

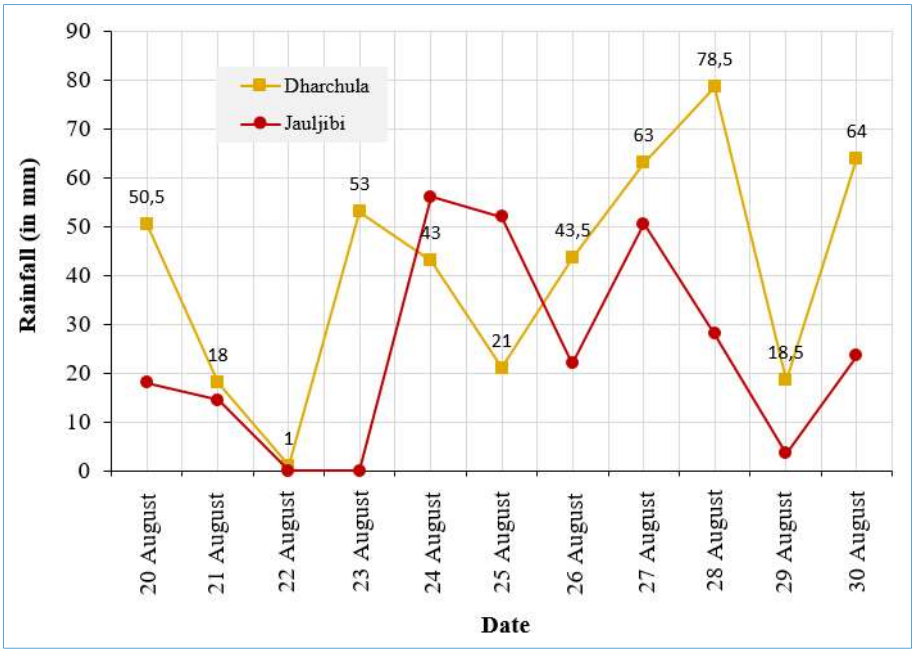

Fig. 6. Rainfall received in Dharchula and Jauljibi areas of Pithoragarh district during August 20 to 30, 2021 (Source: Uttarakhand State Disaster Management Authority)

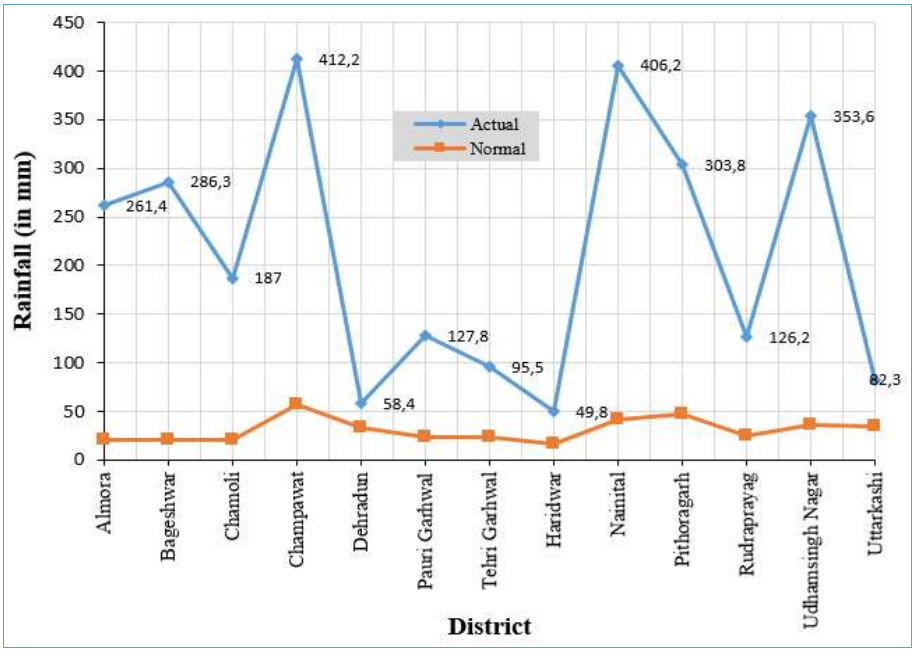

Fig. 7. District-wise rainfall in Uttarakhand between October 17-19, 2021

In addition, traditionally most of the habitations have been situated far away from steep slope/escarpment areas and streams, on middle hill slopes, spurs of ridges, and firm grounds in the region (Khanduri, 2020). In view of safeguarding against disaster, we must follow the endogenous knowledge of traditional practices of habitation and other developmental activities accordingly.

6. Discussion and Conclusion

Located in the Central Himalayan sector to the South of Tibbet, the state of Uttarakhand is a young mountainous belt that is highly vulnerable to a number of natural hazards like earthquakes, landslides, floods, flash floods, avalanches and droughts because of adverse climatic conditions, fragile geology, active tectonics, high seismicity and peculiar hydrometeorology.

Change in rainfall pattern along with climatic variability because of global warming due to which concentrated heavy rainfall and cloudburst incidences are frequently occurring in the region. However, this region has a long history of disasters wherein thousands of fatalities while enormous property and infrastructure damages occurred.

Before the creation of the state of Uttarakhand, a number of major disastrous events had happened in the same region. These include the Sher-Ka-Danda landslide, Nainital of 1880, Birahi landslide of 1893, Alaknanda flood of 1970, Okhimath landslide of 1998, Malpa landslide of 1998, Uttarkashi earthquake of 1991 and Chamoli earthquake of 1999 wherein thousands of fatalities and tremendous property losses occurred. Subsequently, after the creation of the state of Uttarakhand, the same region faced various disastrous events that caused also enormous property losses along with thousands of fatalities. After the cloudburst disasters of 2012 in Okhimath and Ashiganga respectively in Rudraprayag and Uttarkashi Districts, the disaster of June 2013 was the biggest disaster faced by the state since its creation wherein alone more than 4000 persons went missing and 225 people were confirmed dead among those death certificate issued.

During the pre-monsoon, monsoon and post-monsoon periods of the year 2021, a number of disastrous events happened that caused the killing of more than 300 people, and immense property and infrastructure losses occurred in the region. Rishiganga-Dhauliganga flash flood of February 7, 2021, was one of the worst unexpected disaster faced by the Uttarakhand as well as worldwide during the winter season wherein alone 204 people were killed while massive loss of property and infrastructure together with natural resources.

Increasing anthropogenic initiatives in proximity to streams and over thick overburden deposits, less or without taking consideration of these important factors as (i) the previous history of natural hazards and its impacts, (ii) lithology and structural discontinuities, (iii) overburden/Quaternary deposits, (iv) change in land use pattern, (v) stability condition of the landforms and (vi) seismicity and previous earthquake-affected localities, further enhanced the potential of disaster in the same region.

The disastrous events are unexpected in nature and difficult to predict, nobody knew when and where these hazards will occur but it is possible to reduce the risk to human lives and property damages by taking some prevention measures. Safeguarding against disastrous events, the author suggested (i) mapping of overburden/quaternary deposits, (ii) identification of hazard-prone areas, (iii) rehabilitation of high-risk prone habitations, (iv) follow up indigenous knowledge of traditional habitation practices and (v) construction of seismic coefficient design of the structure. Considering all these aforementioned aspects can be definitely minimized the disastrous impacts within the region.

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