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Cloudburst-Triggered Natural Hazards in Uttarakhand Himalaya: Mechanism, Prevention, and Mitigation

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***Abstract*—**Thisarticle examines cloudburst-triggered natural hazards mainly flashfloods and landslides in the Uttarakhand Himalaya. It further describes mechanism and implications of natural hazards and illustrates the preventive and mitigation measures. We conducted this study through collection of archival data, case study of cloudburst hit areas, and rapid field visit of the affected regions. In the second week of August 2017, about 50 people died and huge losses to property were noticed due to cloudburst-triggered flashfloods. Our study shows that although cloudburst triggered hazards in the Uttarakhand Himalaya are natural phenomena and unavoidable yet, disasters can be minimized if preventive measures are taken up appropriately. We suggested that construction of human settlements, institutions and infrastructural facilities along the seasonal streams and the perennial rivers should be avoided to prevent disasters. Further, large-scale tree plantation on the degraded land will reduce the magnitude of hazards.

***Keywords*—**Cloudburst, flashfloods, landslides, fragile landscape, Uttarakhand Himalaya.

I. Introduction

THE Uttarakhand Himalaya represents fragile ecosystems and vulnerable landscape. Atmospheric hazards such as cloudburst-triggered flashfloods, debris-flows, landslides, and mass movements are the most common natural catastrophes that occur in the whole Uttarakhand Himalaya, causing to heavy loss of life and property. However, their intensity and frequency have increased multifold during the recent past. Cloudburst can be defined as a sudden heavy rain shower that occurs within a particular space and short span of time [1]. Instability of terrain and intensive anthropogenic activities accentuate magnitude of hazards, causing to environmental degradation [2]. These disasters are accounting for more than 70% of all economic losses and more than half of the casualties [3]. High variability and change in climate has increased the frequency and intensity of rainfall, leading to flashfloods and landslides [4], [5]. Glacial lakes outburst, which have been identified as potentially dangerous, have further aggravated flashflood intensity [6]. It is estimated that every square kilometer in the fragile Himalaya shows up at least two landslide scars [7]. Central Road Research Institute of India has observed that the Patalganga Valley of Garhwal region is highly susceptive to landslide hazards as it received frequent and intensive landslides incidences during the past decades [8]. This research article examines cloudburst-triggered natural hazards such as flashfloods, debris flow, landslides and mass-movement in the Uttarakhand Himalaya. It describes mechanism and implications of cloudburst-triggered natural hazards and suggests preventive and mitigation measures. We gathered data through personal observation after field visit of cloudburst-hit areas. Further, data of 2017 cloudburst-triggered hazards were collected after visiting Dehradun, Kotdwar, and Pithoragarh areas. Archival data were gathered from the State Government Revenue Department (SGRD), Dehradun.

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II. Study Area

Uttarakhand Himalaya, an integral part of the Himalaya, lies in almost its central part and known as the 'Indian Central Himalayan Region'. Stretching between 28°43' N – 31°28' N and 77° 34' E – 81°03'E, it has total 53,483 km^2 geographical area of which 93% is mountainous mainland. Out of its mountainous area, 16% area is snow-clad, which is the major source of India's biggest rivers – the Ganga system [9]. It has two distinct geographical entities – The Garhwal Himalaya and the Kumaon Himalaya along with 14 administrative districts. It ranges from 250 m to above 7,000 m altitude with its three dimensional landscapes – the river valleys, mid-altitudes and high Himalaya including alpine meadows and snow-clad regions. It characterises undulating and fragile landscapes, prone to natural (mainly atmospheric) hazards, and receives heavy rain showers during the four months of monsoon season, which is caused to heavy loss of lives and property. Haphazard construction of settlements mainly along the seasonal streams and perennial rivers further accentuate the magnitude of disaster. Beside cloudburst-triggered natural hazards, earthquakes influence the Uttarakhand Himalaya greatly as it falls under IV and V seismic zones.

III. Result

Cloudbursts-triggered natural hazards are very common features in the Himalaya, which caused heavy damage to entire landscape and human settlements. In this section, we described past incidences of natural hazards, rainfall frequency and intensity, and recent event of cloudbursts. We also discussed mechanism and implications of cloudburst-triggered hazards and preventive and mitigation measures.

A. Past Incidences

Archival data from the SGRD, Dehradun show that the series of cloudburst triggered flashfloods and landslides have occurred in the Uttarakhand Himalaya from the last centuries, which have resulted in huge losses of lives and property. Among them Pauri (1816), Joshimath (1842), Mandakini

River (1857), Chamoli (1868), Nainital (1880), Birhi Ganga (1893), Gohnalake (1894), Helang (1906), Patal Ganga (1945), Nainital (1963), Kaliyasaur (1963), Karnprayag (1965), Upper Alaknanda (1970), Satpuli (1972) Ukhimath (1979), Kedarghati (1991), Jakholi and Devaldhar (1986), Gopeshwar (1991), Gadinigarh (1992), Kewer Gadhera (1993), Bhimtal (1996), Malpa (1998), Okhimath (1998), Fata (2001), Gona (2001), KhetGaon (2002), Budhakedar (2002), Bhatwari (2002), Uttarkashi (2003), Amparav (2004), Lambagarh (2004), Govindghat (2005), Agastyamuni (2005), Ramolsari (2005) and Kedarnath Valley, Badrinath Valleys, and Pindar Valley (2013) are prominent.

We analyzed average monthly rainfall data (2009-2014) of Uttarakhand state and observed that rainfall occurred largely during four months of summer between June and October with high variability. This is the season when cloudburst is occurred. A decrease in rainfall was also observed during the reported period (Fig. 1) however, intensity of rainfall has increased within a short period of time, which has further accentuated magnitude of cloudburst-triggered natural hazards.

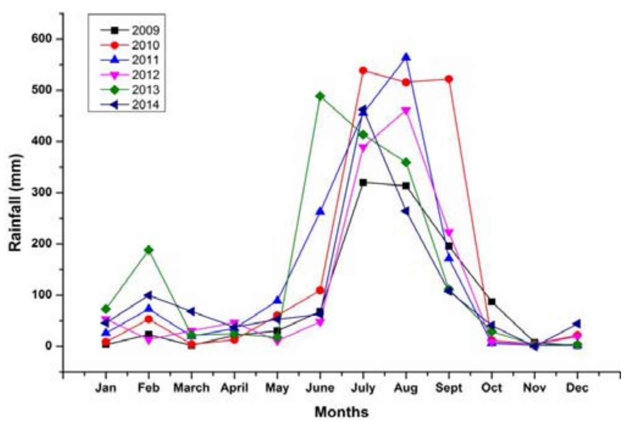

Fig. 1 Average monthly rainfall (mm) in Uttarakhand (2009-2014)

TABLE I
HEAVY RAINFALL OCCURRED WITHIN 24 HRS IN UTTARANCHAL [10]

Place	Date and Year	Rainfall in mm
Nainital	22 Sept. 1958	509.3
Tehri	22 Dec. 1957	194.8
Mukhim	19 July 1957	267.2
Narendra Nagar	1 July 1957	267.2
Kirti Nagar	8 Oct. 1956	198.8
Devprayag	9 Oct. 1956	215.9
Dhanauti	17 July 1957	188.0
Ghuttu	10 July 1957	345.7
Almora	29 Sept. 1924	222.5
Champawat	27 Sept. 1879	389.8
Kausani	3 Oct. 1910	200.8

Several localities in Uttarakhand received heavy rain within 24 hours during different years. Table I reveals that Nainital received the highest rainfall in 1958 i.e. 509.3 mm. It is followed by Champawat (389 mm) in 1879. The other places where heavy rainfall occurred during the two centuries are Tehri (194.8), Mukhim (267.2), Narendra Nagar (267.2), Kirtinagar (198.8), Devprayag (215.9), Dhanoulti (188.0), Ghuttu (345.7), Almora (222.5), and Kausani.

We also gathered data on heavy rainfall in three months – June, July and August in 2003 that occurred in various paces of Uttarakhand within 35 hours (Table II).

TABLE II
HEAVY RAINFALL IN UTTARANCHAL DURING 2003 [9]

Date	Place	Rainfall (mm)
8 June	Nainital	72.0
26 June	Pantnagar	72.6
5 July	Dehradun	123.1
5 June	New Tehri	142.3
5 July	Shrinagar	133.7
5 July	Rishikesh	75.0
11 July	Pantnagar	123.6
11 July	Nainital	80.2
12 July	Pantnagar	123.6
12 July	Nainital	80.2
24 July	Uttarkashi	104.5
24 July	Mussoorie	100.5
19 August	Rishikesh	118.6
19 August	Pantnagar	193.2
19 August	Nainital	105.3

Heavy rainfall occurred in Pantnagar (193.2 mm) on 19 Aug 2003, followed by 142 mm in New Tehri. The minimum rainfall was 72 mm, which occurred in Nainital on 8 June 2003. The intensity of rainfall varies from place to place depending upon location and month. July and August received the highest rainfall throughout the state.

B. Recent Events

In the second week of August 2017, cloudburst-triggered flashfloods and landslides have devastated Malpa village, Kotdwar town, and Dehradun city where a number of people died and huge property was damaged (Fig. 2).

Fig. 2 A. Bridge collapsed due to flashfloods in Kanar village, Pithoragarh; B. Huge landslide on the Gangotri pilgrimage road; C. Roads are over flooded due to cloudburst-triggered floods in Dehradun city; D. Houses collapsed along the seasonal *Nala* in Kotdwar due to cloudburst (All these incidences occurred in the second week of August 2017)

We gathered data on rainfall in the second week of August 2017 from the Meteorological Department, located at Dehradun, a state capital of Uttarakhand. Haldwani received 120 mm rain, Bageshwar 80 mm, Garud 80 mm, Didihat 80 mm, Nainital 70 mm, Kapkot 70 mm, Ramnagar 60 mm, and Munsiyari recorded 50 mm rainfall. In Garhwal, Mussoorie recorded 160 mm rain and Dehradun received 70 mm on the same period. Within 24 hours, Pantnagar recorded a whopping 52 mm of rain followed by Haridwar 48.8 mm. Heavy downpour caused havoc in many places. Form Lambagarh on the Badrinath highway to near Tanakpur national highway in Pithoragarh, more than 100 link roads were cut off for several days due to landslides. Gangotri and Yamunotri national highways were also badly damaged.

In the Kumaon Himalaya, Pithoragarh district was severely affected by the natural disasters. In Madkot village (Bangapani area, Pithoragarh), about half-a-dozen houses along with a bridge were collapsed, six people died and 56 goats were drowned due to cloudburst-triggered flashflood. About ten people were missing. Mangti *Nala* (seasonal stream) near Tawaghat was over-flooded that swept away shops and Army camp. Similarly a massive landslide hit Malpa village (Dharchula Tehsil) on the way to Kailash Mansarovar Yatra route in August 2017 [9], which washed away the settlements and killed 25 people. Several times, Kailash Mansarovar *Yatra* (a pilgrimage procession) was suspended due to these natural catastrophes. Malpa village had been also affected by a huge landslide in 1998, which killed 200 people. In Tawaghat-Pangla highway, three bridges collapsed. Cloudburst-triggered flashflood also affected Vyas valley of Pithoragarh district and Bijrani village in Almora, which washed away cowsheds, houses and agricultural land. Similarly, in Garhwal Himalaya, a number of areas were hit by cloudburst-triggered hazards. A devastating cloudburst triggered flashflood killed nine people and affected many households in Kotdwar city. Floodwater (Paniala *Nala)* entered in houses and damaged them. About 40 settlements were swept away due to cloudburst in Rauthiya village of Jakholi Block, Rudraprayag. At Pinola between Joshimath and Govindghat, about 20 metres highway was blocked by debris that hindered the pilgrims' way to Hemkund Sahib and Badrinath. The Ganga has breached the warning mark of 293 meters in Haridwar. The heavy rainfall further led to water-logging in the city. In Dehradun, Rispana Bridge was over flooded and a huge landslide occurred in Kimadi-Lambidhar-Mussoorie Road. All these incidences led to huge losses of lives and property. The whole Garhwal region is highly prone to atmospheric hazards. In a number of times, it received huge catastrophes. The Kedarnath tragedy, which is also known as the 'Himalayan Tsunami' devastated the whole region in 16 June 2013.

C. Mechanism, Implication, Prevention and Mitigation

The Uttarakhand Himalaya, characterized by rough, rugged, and precipitous terrain, is ecologically fragile, and vulnerable to landslides and mass movements. Debris-flow and flashfloods further accelerate their intensity. Heavy rainfall (termed as cloudburst) during the monsoon season, fragile and unstable landscape, narrow valleys, and high slope gradient are the major causes of natural hazards. Location of human settlements, business avenues and governmental and non-governmental institutions along the river valleys and fragile slopes accelerate the magnitude of hazards and it converts hazards into disasters. Irrational development activities, over human pressure on land, deforestation and climate change are the mechanism of occurring cloudburst-triggered hazards in the Uttarakhand Himalaya, which result into heavy loss to lives and poverty, degradation of landscape – arable land and forestland, and huge damage to infrastructural facilities (Fig. 3).

Preventive measures are inevitable to avoid and minimize the cloudburst-triggered natural hazards. Hazards can be prevented through construction of settlements in the suitable areas, avoiding their construction along the seasonal *Nala* and fragile slopes. It needs suitability mapping of the entire mountainous mainland of the state. Imparting training to the rural people for minimizing damage and preparedness are the prominent preventive measures. Further, migration measures are essential. Among the mitigation measures, deployment of trained personnel in the hazard prone areas, proper rehabilitation of the affected people, proper distribution of medicinal facilities and food, and deployment of NDRF, ITBP, and SDRF are prominent.

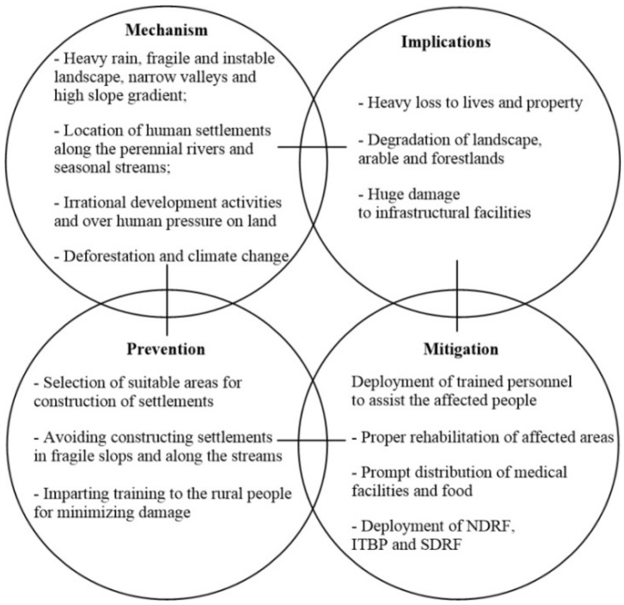

Fig. 3 Mechanism, implications, prevention and mitigation of cloudburst triggered natural disasters in Uttarakhand

IV. Discussion

Several driving forces have been causing to increase in frequency and intensity of cloudbursts-triggered disasters in the Himalaya, and climate change has been observed as a major driver [10]. The Himalaya receives huge rain showers during the monsoon season between June and October. Studies suggest that the Himalaya is highly vulnerable to global warming [11], [12]. Flashfloods are extremely vulnerable, further aggravating poverty in the Himalaya [13]. Large-scale deforestation in the degraded slopes has aggravated the intensity of disasters.

Most of the losses due to disasters are sweeping away of settlements, agricultural land and other avenues causing to a huge loss of life and property. Most of the settlements are constructed on the fragile hilly slopes and along the river valleys even in several places, settlements are constructed on the debris, deposited by the rivers during the past. Heavy construction on roadsides and river valleys further accelerate losses to property and lives. These places are very fragile and susceptive to landslides. During the monsoon season, heavy rain occurs which leads to flashfloods and landslides and affects the settlements. Flashfloods of 2013 is an example when more than 10,000 people died due to sweeping away of settlements mainly along the river valleys. Anthropogenic activities have caused severity in disaster [14] and thus, it can be said that most of the disasters are manmade.

V. Conclusion

The study revealed that the Uttarakhand Himalaya is highly vulnerable to natural hazards. There is a vital need to frame comprehensive policy measures to reduce both risk and disasters. Suitable land for construction of settlements should be identified. It is essential to avoid settlements' construction along the river valleys to prevent disasters. We should also avoid construction of roads mainly along the fragile slopes and in lieu of it, bridges can be constructed. Ropeways are suitable in the fragile landscape of Uttarakhand, which can connect the rural settlements from the main routes so that occurrence of landslides can be minimized. Construction of hydroelectricity projects should be done in the suitable areas, which are uninhabited and their sizes should be at micro-level.

References

[1] Sati, V. P., Maikhuri, R. K., Cloud-Burst- A Natural Calamity. Him Prayavaran News Letter. 1992, pp 11-13.

[2] Sati, V. P., Natural Resources Management and Sustainable Development in the Pindar Basin, Himalaya, Dehradun, Bishen Singh Mahendra Pal Singh, 2008.

[3] Sati, V. P., Climate Disasters in the Himalaya: Risk and Vulnerability, International Conference on Climate Change and Natural Hazards in Mountain Areas, Dushanbe Sept. 19-21, 2011.

[4] Chalise, S. R., Khanal, N. R., An introduction to climate, hydrology and landslide hazards in the Hindu Kush-Himalayan Region. In Tianchi, L; Chalise, SR; Upreti, B.N. (eds) *Landslide Hazard Mitigation in the Hindu Kush-Himalayas,* Kathmandu: ICIMOD, 2001 pp. 51-62.

[5] ICIMOD, *Flash Flood Hotspot Mapping in the Hindu Kush-Himalayan Region* (draft DVD ROM). Kathmandu: ICIMOD, 2007.

[6] ICIMOD, *Inventory of Glaciers, Glacial Lakes and Identification of Potential Glacial Lake Outburst Flood (GLOFs) Affected by Global Warming in the Mountains of the Himalayan Region* (DVD ROM). Kathmandu: ICIMOD, 2007.

[7] Bhandari, R.K., Landslide Hazard Mapping in Sri Lanka - a Holistic Approach. Proceeding of National Symposium on Landslides in Sri Lanka, 1994, pp: 271- 284

[8] Kumar, K., Subramanya, P., and Kanuijia, V. K., Geological & Geotechnical Investigations of Patalganga Landslide adjacent to NH-58, Garhwal, Uttaranchal – A Case Study, Proceedings of Indian Geotechnical Conference, Chennai, 2006.

[9] Retreat from http://www.q8india.com/blog/2017/08/15/uttarakhand-cloudburst

[10] J. D. Ives, B. Messerli, *The Himalayan Dilemma: Reconciling Development and Conservation.* London: John Wiley and Sons, 1989

[11] Solomon, S; Qin, D; Manning, M; Chen, Z; Marquis, M; Averyt, KB; Tignor, M; Miller, HL (eds.), *Climate Change 2007: The Physical Science Basis.* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge and New York: Cambridge University Press, 2007.

[12] Du, M. Y.' Kawashima, S., Yonemura, S., Zhang, X. Z., Chen, S.B., Mutual influence between human activities and climate change in the tibetan plateau during recent years.*Global and Planetary Change*, 2004,41: 241-249

[13] Bandyopadhyay, J., Gyawali, D., Himalayan water resources: ecological and political aspects of management. *Mountain Research and Development*, 1994,14(1): 1-24

[14] Sati, V. P. *Disaster Management and Risk Reduction*, Aavishkar Publications, Jaipur, 2013.

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