Flood Disaster Management in India: Lessons from Uttarakashi and Punjab

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Abstract— India, one of the fastest-growing economies, remains highly dependent on agriculture for livelihood and food security. However, extreme weather events in 2025 severely disrupted this sector, particularly due to floods in Uttarakashi and Punjab. In Uttarakashi, intense cloudbursts triggered flash floods and landslides, causing significant loss of life, damage to infrastructure, and destruction of agricultural land in the fragile Himalayan region. Rescue operations indicated large-scale displacement and severe geomorphological changes in affected valleys. In contrast, Punjab experienced widespread riverine flooding due to prolonged monsoon rainfall, submerging nearly 2 lakh hectares of cropland and affecting thousands of farming households. Major crops such as paddy, maize, and sugarcane suffered heavy losses, resulting in an estimated decline of nearly 15% in agricultural output and substantial economic damage. The contrasting flood characteristics highlight the differing vulnerabilities of mountainous and plain regions where flash floods in Uttarakhand caused localized but intense destruction, while prolonged inundation in Punjab led to large-scale agricultural and economic losses. The study underscores the urgent need for region-specific flood mitigation strategies, climate-resilient agricultural planning, and improved early warning systems to reduce future risks and enhance sustainability in India's agrarian economy.

Keywords— Disaster, Flood, Risk, Management

I. STUDY AREA

Uttarkashi, in the northern Himalayas of India, is situated between the coordinates of 30.73° North latitude and 78.45° East longitude. It is located in the upper valley of the river Bhagirathi, which is one of the largest Ganga tributaries feeding into Haridwar and a part of the Garhwal Himalayas in Uttarakhand, India. The geographical features of the district include mountainous, valleyous, glaciated, and high-altitude river valley areas. Uttarkashi is internationally recognized as the "doorway to the holy Hindu shrines of Gangotri, the Birthplace of the Ganga, and YAMUNOTRI." Apart from its religious significance, the region is also fragile from an ecological and geographical perspective, and is prone to landslides, cloudbursts, earthquakes, and floods, in line with the young Himalayas in the region. Some researchers i.e. Chauhan et al. (2023), Ishaq (2023),

Malik et. al. (2025), Panwar et. al. (2024), Parveen et. al. (2013), Shukla et. al (2013 and Theophilus (2013) also worked in the particular field.

Punjab, situated in the northwestern part of India, extends between 29.5° N to 32.5° N latitudes and 73.8° E and 76.9° E longitudes. The province is located in the Indo-Gangetic Plain, bordered by Pakistan to the west and several other Indian provinces to the east and south. The province acquired the name "land of five rivers," which are the Sutlej, Beas, Ravi, Chenab, and Jhelum rivers, making it the most fertile region in terms of agriculture. Punjab has earned the name Granary of India as it plays an important part in the food security of the nation, especially with respect to the generation of food products like wheat and rice. The flat terrain with a vast water supply network and rich alluvial soil does not allow it to be as productive as before due to

the flood occurrence, which takes place due to the high rainfall of the monsoon season. Figure 1 shows the graphical location of two locations.
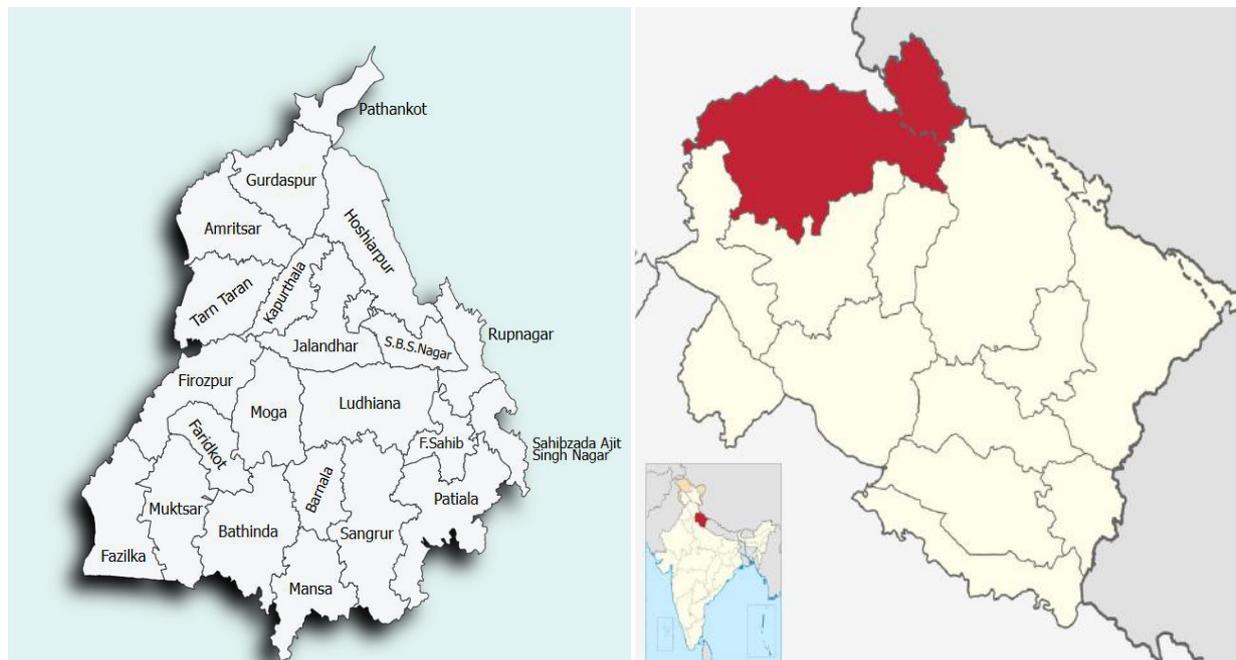

Fig.1: Geographical Map of Punjab and Uttarkashi

II. RAINFALL ANALYSIS DURING MANSON SEASON FOR PUNJAB

The rainfall data indicate that August and September received significantly higher precipitation than normal, contributing to an above-average monsoon season in 2025. In contrast, June and July rainfall remained close to the long-term average, indicating an uneven temporal distribution of rainfall. Table 1 and Figure 2 shows the rainfall distribution in 2025.

Flood Impact Assessment in Punjab (2025)

Owing to exceptionally heavy rainfall and a significant rise in the water levels of the Ravi and Beas rivers, coupled with the regulated discharge from the Ranjit Sagar Dam, the state of Punjab experienced severe flood conditions beginning on 27 August 2025. The situation rapidly escalated into a large-scale hydro-meteorological disaster, affecting all 23 districts of the state.

According to consolidated data received from the State Emergency Operations Centre, Punjab, a total of 2,287 villages were impacted by flooding. The cumulative assessment of damages and losses recorded from 01 June 2025 onwards indicates substantial human, infrastructural, and agricultural losses. A total of 52 human fatalities were reported, while 4 individuals remained missing and 25 persons sustained injuries. The floods affected approximately 3,87,907 people, necessitating large-scale evacuation and rescue operations. In total, 23,049 individuals were safely rescued or evacuated to safer locations. Residential infrastructure suffered extensive damage, with 7,406 houses affected, including 5,379 pucca houses and 2,027 kutcha houses. The agricultural sector experienced significant losses, with approximately 1,80,412.229 hectares of cultivated land inundated, adversely impacting crop productivity and rural livelihoods. Relief and rehabilitation measures included the establishment of 219 relief camps, sheltering 7,604 displaced persons. Additionally, the flooding caused severe damage to border infrastructure, particularly along the Indo-Pak border. Approximately 80 km of Border Security Fence was damaged, 3 Border Outposts (BOPs) were completely washed away, 67 BOPs were partially damaged, and 15 BOPs were fully vacated, while 118 BOPs were partially vacated as a precautionary measure. Table 2 shows the impact of the flood in Punjab during 2025.

Table 1: Monthly Rainfall Distribution in 2025 in the Manson Season (IMD-2025)

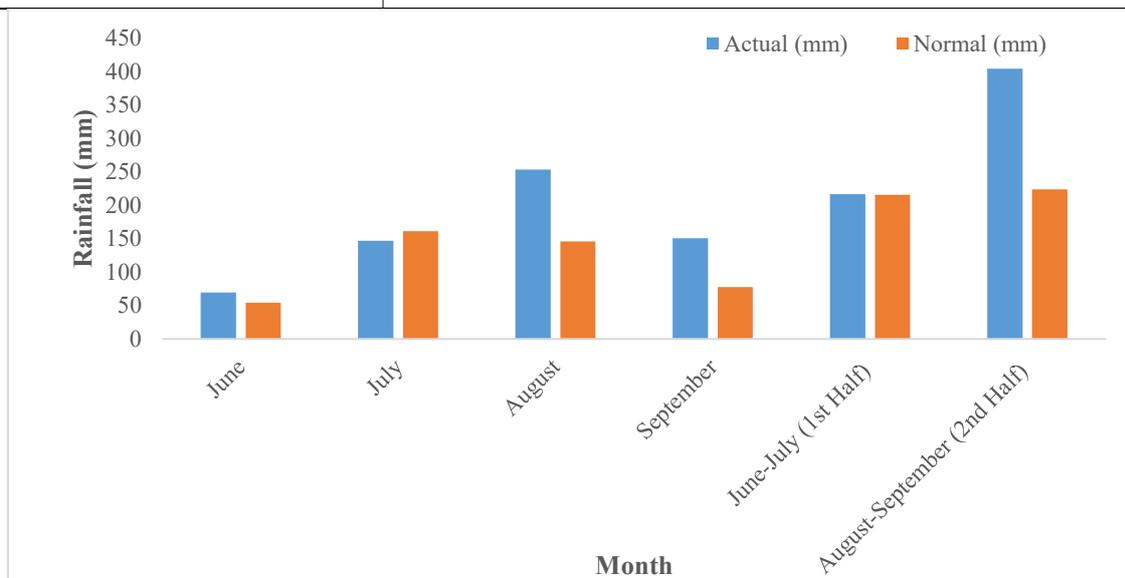| Months	Actual (mm)	Normal (mm)
June	69.7	54.5
July	146.9	161.4
August	253.7	146.2
September	150.6	77.7
June-July (1st Half)	216.6	215.9
August-September (2nd Half)	404.3	223.9

Fig.2: Rainfall analysis for the Manson season for July-September 2025

Table 2: Summary of Flood Impact in Punjab (2025) (IMD-2025)

Category	Details
Period of Impact	From 01 June 2025 onwards
Cause of Flooding	Heavy rainfall, rise in water level of Ravi & Beas rivers, discharge from Ranjit Sagar Dam
Total Districts Affected	23
Total Villages Affected	2,287
Population Affected	3,87,907
Deaths	52
Missing Persons	4
Injured Persons	25
People Rescued / Evacuated	23,049
Total Houses Damaged	7,406
Pucca Houses Damaged	5,379
Kutcha Houses Damaged	2,027
Agricultural Loss	1,80,412.229 hectares of cropped area affected
Number of Relief Camps	219
Inmates in Relief Camps	7,604

Border Security Fence Damaged	80 km
BSF Border Outposts (BOPs) Washed Away	3
BSF BOPs Partially Damaged	67
BSF BOPs Fully Vacated	15
BSF BOPs Partially Vacated	118

(a)

(b)

(c)

Fig.3 (a, b, and c): Flood incident in Punjab in 2025

III.   RAINFALL ANALYSIS DURING MANSON SEASON FOR UTTARAKHAND

The rainfall data reveal that August recorded the highest precipitation, significantly exceeding the normal average, indicating intense monsoonal activity. Although July received slightly lower rainfall than normal, overall monsoon rainfall remained above average due to substantial rainfall in June and September. Table 3 and Figure 4 show the rainfall distribution in 2025.

Table 3: Monthly Rainfall Distribution in 2025 in the Manson Season

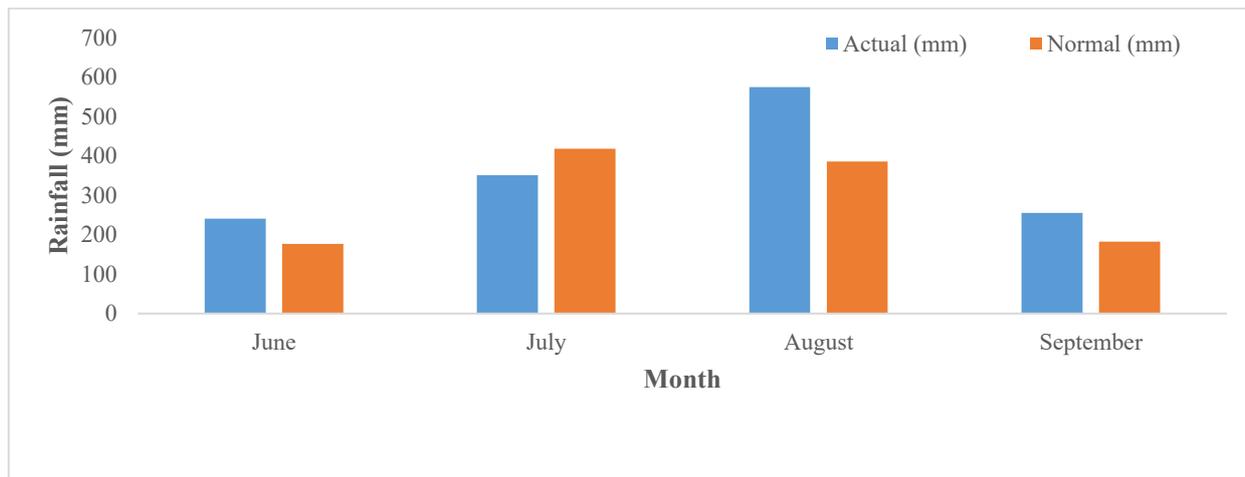| Months	Actual (mm)	Normal (mm)
June	240.7	176.8
July	350.7	417.8
August	574.4	385.7
September	255.2	182.4

Fig.4: Rainfall analysis for the Manson season for July-September 2025

Table 4: Summary of Flood Impact in Uttarakhand (2025) (IMD-2025)

Category	Details
Cloudburst	Occurred in Dharali village, Uttarkashi district on 05 August 2025 at 13:50 hrs
Waterlogging	Reported at Yamunotri National Highway, Syanchatti on 21 August 2025 at 16:25 hrs
Deaths	71
Missing Persons	99
Injured Persons	69
Total Houses Affected	2,682
Fully Damaged Houses	308
Partially Damaged Houses	2,374
Cow Sheds Damaged	50
Total Livestock Lost	204
Large Animals	89
Small Animals	115

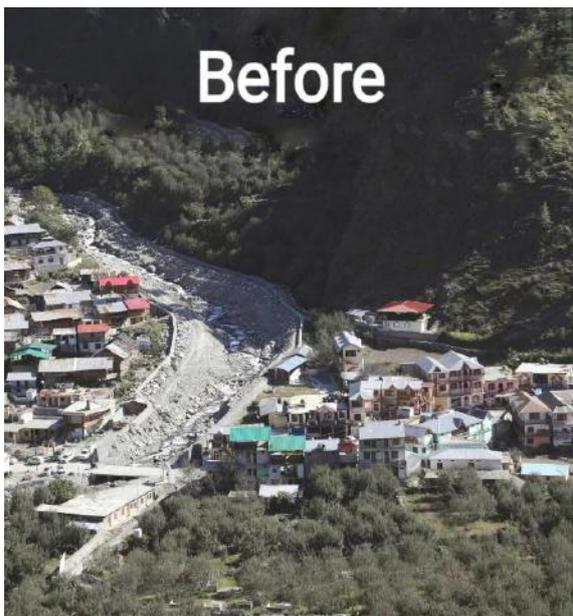**Monsoon Situation in Uttarakhand (2025)**

During the ongoing southwest monsoon season of 2025, the state of Uttarakhand has experienced multiple hydro-meteorological disasters resulting in significant human, infrastructural, and livestock losses. One of the major incidents was a cloudburst event reported on 05 August 2025 at approximately 13:50 hours in Dharali village, Uttarkashi district, which triggered sudden flash flooding and extensive local damage. In addition, severe

waterlogging was reported along the Yamunotri National Highway near Syanchatti on 21 August 2025 at around 16:25 hours, disrupting transportation and posing serious risks to pilgrims and residents.

According to the consolidated damage assessment reports, the cumulative impact of the ongoing monsoon has been substantial. A total of 71 human fatalities have been reported, while 99 persons remain missing and 69 individuals sustained injuries due to flood- and landslide-related incidents. Residential infrastructure suffered considerable damage, with 2,682 houses affected, of which 308 houses were fully damaged, and 2,374 houses were partially damaged. The disaster also resulted in significant losses to livestock and rural livelihoods. A total of 204 livestock deaths were recorded, comprising 89 large animals and 115 small animals, along with damage to 50 cow sheds. These losses have had a direct adverse impact on the agrarian and pastoral communities of the affected regions. Table 4 shows the impact of flood analysis in Uttarakhand 2025 and Figure 5 (a, b and c) shows the flood condition in different region of Uttarakhand.

(a)

(b)

(c)

Fig.5: (a, b, and c): Flood incident in Uttarakhand in 2025

IV.   MITIGATION AND PREVENTION OF FLOOD DISASTER OCCURRENCES

The frequent occurrences of flood events in the regions of Punjab and Uttarakhand during the monsoon season in the year 2025 have established a clear necessity to develop an integrated flood risk management plan. Taking into consideration the rising trends of hydro-meteorological extreme events, a multi-dimensional plan should be formulated.

1. Enhancing Hydrological Data Gathering and Early Warning Mechanisms

Modules for advanced hydro-meteorological monitoring should also be augmented over sensitive river basins, especially the Ravi, Beas, and Himalayan river basins. Real-time monitoring systems of rainfall, river discharges, and water levels of reservoirs combined with satellite-based forecasting systems should greatly improve early warning systems. These should be followed by effective communication systems of early warnings through digital media, mobile communication systems, and administrative channels for early evacuations, thereby preventing loss of lives.

2. Scientific Reservoir Operation and Dam Management

Procedures for the coordination of reservoir operations must be formulated for large hydraulic structures like the Ranjit Sagar Dam. Real-time flow forecasting-based rule curves must be provided to control the controlled water releases to avoid flood risks. Collaboration of the agencies of the dam, the agency of disaster management, and the administrative units of the locations must be ensured.

3. Enhancing Flood Control Infrastructure

Embankment reinforcement, riverbank protection, desilting of rivers, and flood protection walls in vulnerable areas should receive high priority among structural measures. In a region like Uttarakhand, with mountains, protective measures like check dams and debris barriers will help significantly in reducing landslide and flood hazards.

4. Land-Use Planning and Zoning Regulation

The enforcement of the zoning rules of land use is vital in preventing the emergence of unplanned settlements in floodplains and high-risk areas. Flood hazard maps created using geographic information systems must be used to develop the areas in the future. The relocation of the vulnerable settlements to a safe area must be achieved through the rehabilitation of the area.

5.   Strengthening Community-Based Disaster Preparedness

The community awareness initiatives concerning flood preparedness, evacuation, and first response drills need to be upgraded. Formation of community disaster response teams and conducting drills can be a great way to improve flood preparedness and quick response to the event.

6. Climate-Resilient

Climate-resilient standards must be adopted in infrastructure development projects in flood-prone areas. Elevated roads, flood-resistant housing, strengthened drainage infrastructure, and flood-protected public utilities should be used to withstand severe flooding conditions.

7. Ecosystem-Based Approaches and Environmental Conservation

Wetlands, floodplains, and drainage channels can be restored for increased retention of water and mitigation of peak runoff. Tree planting in upland catchments, especially in the Himalayan region, is critical in enhancing the management of runoff, landslide prevention, and control of soil erosion.

V.   CONCLUSION

The 2025 flood events in Uttarakhand and Punjab clearly demonstrate the increasing intensity and spatial variability of hydro-meteorological disasters in India, driven by extreme rainfall, altered river regimes, and growing anthropogenic pressures. In Uttarakhand, cloudburst-induced flash floods and landslides resulted in 71 fatalities, 99 missing persons, 69 injuries, and damage to 2,682 houses, along with the loss of 204 livestock. These impacts were concentrated in fragile Himalayan terrains, where steep slopes, high relief, and unregulated development amplified disaster severity. Conversely, Punjab experienced widespread riverine flooding, affecting 2,287 villages and 3.87 lakh people, with 1.80 lakh hectares of agricultural land inundated and 7,406 houses damaged. This highlights the vulnerability of intensively cultivated floodplains to prolonged monsoonal rainfall and regulated dam releases.

The scale of damage spanning 52 human fatalities, 23,049 evacuations, and extensive agricultural and infrastructural losses in Punjab, alongside severe geomorphological and livelihood impacts in Uttarakhand, emphasizes the inadequacy of existing flood preparedness and response mechanisms. The data clearly indicate that while Uttarakhand disaster profile is dominated by short-duration, high-intensity events such as cloudbursts and landslides, Punjab faces prolonged inundation due to river overflow and backwater effects, necessitating region-specific mitigation strategies.

These findings underscore the urgent need for an integrated flood risk management framework incorporating real-time hydro-meteorological monitoring, reservoir operation optimization, and advanced early warning dissemination

systems. Strengthening land-use planning, enforcing floodplain zoning, restoring natural drainage and wetlands, and adopting climate-resilient infrastructure are essential to reducing future losses. Furthermore, community-based preparedness, combined with institutional coordination among disaster management, irrigation, and meteorological agencies, is critical for enhancing adaptive capacity.

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