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Flash Floods in India Intensify with Climate Change, Highlighting Urgent Need for Region-Specific Risk Assessment and Preparedness

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Recent Developments:

- **Flash floods** have emerged as one of India's most destructive **hydro-meteorological disasters**, causing extensive loss of life, damage to infrastructure, disruption of livelihoods, and severe ecological degradation.
- Recent disasters in **Himachal Pradesh (2025)**, **Kerala's Wayanad (2024)**, **Ladakh (2024)**, and **Sikkim (2023)** demonstrate the increasing frequency and intensity of flash floods under changing climatic conditions.
- A recent **Indian Institute of Technology Gandhinagar** study published in **npj Natural Hazards** has mapped India's **flash flood-prone sub-basins**, identifying the **Himalayas, Western Coast, and Central India** as the most vulnerable regions while highlighting the growing influence of **climate change** in creating new flood hotspots.

Flash Floods: Meaning and Characteristics:

What are Flash Floods?

- **Flash floods** are sudden, high-intensity floods that develop within a few hours of extreme rainfall, cloudbursts, dam failures, glacial lake outburst floods (**GLOFs**), or rapid runoff, leaving very little time for warning or evacuation.
- Unlike conventional riverine floods, **flash floods** are characterised by their **rapid onset, short duration, high flow velocity, and enormous destructive potential**, particularly in mountainous and urban regions.
- India remains highly vulnerable because of its **monsoon-dominated climate, complex topography, expanding urbanisation, and increasing climate variability**.

Major Characteristics:

- **Flash floods** generally develop within **six hours** of the triggering event, although many events are preceded by prolonged wet conditions that saturate the soil.
- They transport **large quantities of sediment, boulders, debris, and uprooted vegetation**, thereby magnifying destruction to settlements, roads, bridges, and public utilities.
- Their occurrence is highly localised, making prediction more challenging than conventional floods.

Key Findings of the IIT Gandhinagar Study:

Identification of Flash Flood Hotspots:

- The study, titled "**Drivers of Flash Floods in the Indian Sub-continental River Basins**," provides one of the first detailed assessments of **sub-basin-level flash flood susceptibility** using hydrological and geomorphological characteristics.

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- The research identifies the **Himalayan Region, Western Coast, and Central India** as the country's principal **flash flood hotspots**, although vulnerability varies considerably even within the same river basin.
- Among major river systems, several sub-basins of the **Brahmaputra, Ganga, Godavari, Narmada, Tapi, Mahanadi, Brahmani, and West Coast Rivers** exhibit particularly high susceptibility to flash floods.

Regional Variations in Flash Flood Drivers:

- In the **Himalayan Region**, steep slopes, rugged terrain, high relief, drainage density, and **geomorphological characteristics** primarily determine flash flood susceptibility.
- In **Western Coastal and Central Indian** river basins, **hydrological behaviour**, especially the **Flashiness Index** reflecting the rapid rise of streamflow after rainfall, plays the dominant role in flood generation.
- Even within the **Ganga River Basin**, susceptibility differs considerably, with southern Himalayan sub-basins exhibiting much higher risk than many central basin regions, highlighting the importance of local terrain and watershed characteristics.

Major Causes Identified by the Study:

- Nearly **75%** of flash floods result from the combined impact of **extreme precipitation and antecedent soil saturation**, whereas only about **25%** are caused solely by intense rainfall.
- Saturated soils lose their infiltration capacity, causing rainfall to convert rapidly into **surface runoff**, which significantly increases flood intensity.
- The study also observes that only about **23%** of extreme rainfall events produce flash floods within six hours, indicating that prolonged wet spells are often more critical than isolated heavy rainfall events.

Climate Change and Rising Flash Flood Risk:

Changing Rainfall Patterns:

- **Climate change** has significantly increased the frequency, intensity, and spatial distribution of **flash floods** by altering atmospheric moisture content and precipitation patterns across India.
- According to the **Clausius-Clapeyron relationship**, the atmosphere can hold nearly **7% more water vapour for every 1°C rise in temperature**, resulting in more intense short-duration rainfall events and greater flood potential.
- Between **1981 and 2020**, the occurrence of **extreme rainfall** during India's **pre-monsoon season** doubled, while extreme precipitation increased by nearly **56%** during the **southwest monsoon**, **40%** during the **post-monsoon season**, and about **12.5%** during **winter**, indicating a broad intensification of hydro-meteorological extremes.
- More than **75%** of India's recorded **flash floods** between **1980 and 2018** occurred during the **southwest monsoon season**, underscoring the strong relationship between monsoon variability and flood disasters.

Emerging Flash Flood Hotspots:

- Since the mid-1990s, **flash flood occurrences** have increased considerably across the **Brahmaputra, Ganga, and Krishna River Basins**, reflecting the growing influence of climate variability on river hydrology.
- Approximately **51%** of previously non-prone sub-basins now record increasing extreme rainfall, while nearly **66.5%** exhibit rising streamflow, indicating that **climate change** is creating new areas of flash flood vulnerability beyond traditionally affected regions.
- Simultaneously, a few historically flood-prone regions are witnessing declining wet hours, demonstrating that **flash flood risk is becoming increasingly dynamic** rather than geographically static.

Impacts of Flash Floods in India:

Humanitarian and Social Impacts:

- **Flash floods** frequently cause large-scale casualties, displacement of communities, destruction of houses, disruption of education and healthcare services, and long-term psychological distress among affected populations.
- Remote mountainous settlements often remain isolated for several days because roads, bridges, communication networks, and emergency services become inaccessible immediately after flood events.

Economic Impacts:

- Recurrent **flash floods** damage **transport infrastructure, hydropower projects, irrigation systems, agriculture, tourism, telecommunications, and public utilities**, resulting in substantial economic losses.
- The destruction of productive assets and repeated reconstruction significantly increases fiscal burdens on governments while reducing livelihood security for vulnerable communities.

Environmental Impacts:

- **Flash floods** accelerate **soil erosion, riverbank instability, landslides, sediment deposition, forest degradation, and habitat destruction**, thereby weakening ecosystem resilience.
- Large quantities of debris transported by floodwaters alter river morphology, reduce reservoir storage capacity through siltation, and increase downstream flood risks.

Measures Required to Mitigate Flash Flood Risks:

Strengthen Scientific Risk Assessment:

- India should develop **high-resolution flash flood susceptibility maps** by integrating **hydrological, geomorphological, meteorological, land-use, and climate datasets** to support district and sub-basin level planning.
- Continuous monitoring of emerging flood hotspots should become an integral component of national **climate adaptation** strategies.

Improve Forecasting and Early Warning Systems:

- Greater integration among the **India Meteorological Department (IMD), Central Water Commission (CWC), National Disaster Management Authority (NDMA)**, and State Disaster Management Authorities can significantly improve real-time forecasting and community-based early warning dissemination.
- Wider deployment of **Doppler Weather Radars, Automatic Weather Stations, river monitoring sensors, satellite observations, and impact-based forecasting** can enhance preparedness before extreme rainfall events.

Adopt Region-Specific Adaptation Strategies:

- **Himalayan States** require integrated management of **landslides, glacial lake outburst floods (GLOFs), slope stabilisation, watershed conservation, and resilient mountain infrastructure**.
- **Western Coastal and Central Indian** regions should prioritise **watershed management, drainage improvement, flood-resilient urban planning, wetland conservation, and catchment restoration** to reduce rapid runoff.

Promote Climate-Resilient Development:

- **Flood-resilient infrastructure**, scientifically planned urban expansion, sustainable land-use practices, restoration of natural drainage channels, and ecosystem-based adaptation should become integral components of development planning.

- Nature-based solutions, including **afforestation, wetland restoration, river corridor protection, and sustainable watershed management**, can reduce runoff while improving long-term ecological resilience.

Conclusion:

- The growing frequency and geographical spread of **flash floods** demonstrate that **climate change** is fundamentally reshaping India's flood risk profile.
- Effective disaster risk reduction will require **science-based planning, region-specific adaptation, resilient infrastructure, integrated watershed management, climate-resilient development, and robust early warning systems**, enabling India to minimise disaster losses while strengthening long-term environmental and socio-economic resilience.

Value Addition for UPSC:

Important Institutions:

- **National Disaster Management Authority (NDMA):** Apex body for disaster management policy and coordination.
- **India Meteorological Department (IMD):** Nodal agency for weather forecasting and impact-based warnings.
- **Central Water Commission (CWC):** Responsible for flood forecasting and hydrological monitoring.
- **National Disaster Response Force (NDRF):** Specialised force for disaster response and rescue operations.

Important Government Initiatives:

- **Flash Flood Guidance Services (FFGS–India):** Provides basin-level flash flood guidance using real-time rainfall and hydrological data.
- **National Hydrology Project (NHP):** Strengthens hydrological observation networks and water resource information systems.
- **National Disaster Management Plan (NDMP), 2019:** Emphasises multi-hazard risk reduction, climate resilience, and early warning systems.
- **Sendai Framework for Disaster Risk Reduction (2015–2030):** Global framework focusing on disaster risk understanding, preparedness, resilience, and "Build Back Better."

Prelims Facts:

- **Flash floods** generally develop within **six hours** of the triggering event.
- Nearly **75%** of flash floods in India result from the combined effect of **extreme rainfall** and **antecedent soil saturation**.
- The **Himalayas, Western Coast, and Central India** are India's principal flash flood hotspots according to the **IIT Gandhinagar** study.
- The atmosphere can hold approximately **7% more moisture** for every **1°C** rise in temperature, increasing the likelihood of extreme rainfall.
- **Flash Flood Guidance Services (FFGS–India)** is jointly implemented with support from the **India Meteorological Department, Central Water Commission**, and international meteorological partners to improve early warning capability