Extreme Weather Events and Their Economic Impact

A Report prepared for the 16th Finance Commission

June 2025

WORLD BANK GROUP

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Abbreviations

ADB	Asian Development Bank
ARC	African Risk Capacity
BBB	Build Back Better
CAG	Comptroller and Auditor General
CATDDO	Catastrophe Deferred Drawdown Option
CBDRM	Community Based Disaster Risk Management
CCB	Contingency Credit Bonds
CCRIF	Caribbean Catastrophe Insurance Facility
CGE	Computable General Equilibrium
CHC	Community Health Centre
CPU	Central Process Unit
CMDRF	Chief Minister Disaster Relief Fund
CRI	Climate Risk Index
CWC	Central Water Commission
DDMA	District Disaster Management Authorities
DMF	Disaster Mitigation Fund
DPO	Development Policy Operations
DRF	Disaster Risk Financing
DRFI	Disaster Risk Financing & Insurance
DRM	Disaster Risk Management
EWE	Extreme Weather Events
FFC	XV Finance Commission
GSDP	Gross State Domestic Product
HFA	Hyogo Framework for Action

ILS	Insurance-Linked Securities
IMD	Meteorological Department
I-O	Input-Output macroeconomic model
IOFS	Integrated Operational Impact Forecasting Systems
JRDNA	Joint Rapid Damage and Needs Assessment
KSDMA	Kerala State Disaster Management Authority
KSEB	Kerala State Electricity Board
MHA	Ministry of Home Affairs
MoF	Ministry of Finance
NatCAT	Natural Catastrophe
NbS	Nature based Solutions
NCRMP	NDMA National Cyclone Risk Mitigation Project
NDMA	National Disaster Management Authority
NDMF	National Disaster Mitigation Fund
NDRF	National Disaster Response Fund
NDRMF	National Disaster Risk Management Fund
PDNA	Post-Disaster Need Assessment
PHC	Primary Health Centre
PMFBY	Pradhan Mantri Fasal Bima Yojana
PPP	Public-Private Partnerships
PWD	Public Works Department
RIO	Regional Input-Output model
RKDP	Resilient Kerala Development Program
RKI	Rebuild Kerala initiative
RMSI	Risk Management Solutions of India
RSDMA	Rajasthan State Disaster Management Authority
SAPCC	State Action Plans on Climate Change
SDMA	State Disaster Management Authorities
SDMF	State Disaster Mitigation Fund
SDMP	State Disaster Management Plans
SDRF	State Disaster Response Fund
SDRMF	State Disaster Risk Management Funds
SFC	XVI Finance Commission
SFDRR	Sendai Framework for Disaster Risk Reduction
SuCS	Super Cyclonic Storm
TNSDMA	Tamil Nadu State Disaster Management Authority
UNDRR	United Nations Office for Disaster Risk Reduction
USD	United States Dollar
VFM	Value-For-Money
VSCS	Very Severe Cyclonic Storm
WASH	Water, Sanitation, and Hygiene
WBCIS	Weather Based Crop Insurance Scheme

Executive Summary

India is facing a dramatic surge in extreme weather events (EWEs), with floods, droughts, cyclones, landslides, and heatwaves now impacting nearly every State and Union Territory. Over the past decade, these events have not only increased in frequency and intensity but have expanded into new geographies. Floods and landslides now affect arid regions, droughts have intensified in traditionally dry states like Rajasthan and Maharashtra, and frequency of severe cyclones in both the Bay of Bengal and the Arabian Sea have increased. Simultaneously, prolonged heatwaves especially across northern and central India and shifting monsoon patterns are compounding risks. These climate-driven disruptions are inflicting widespread human, economic, and infrastructure losses, pushing large populations into deeper socio-economic vulnerability.

Despite a substantial expansion in financial allocations a large share of economic losses from extreme weather events-induced disasters remains uninsured and unrecovered. This not only reflects systemic increasing financial gaps in India's disaster risk management (DRM) ecosystem but also underlines an urgent need for proactive and climate-adaptive financing strategies.

This study examines the financing needs arising from extreme weather events-induced disasters in India, with a view to informing the recommendations of the Sixteenth Finance Commission (SFC). Based on five high impact EWEs, it analyses the scale and distribution of economic losses in past events, considering both direct and indirect costs across sectors and regions. The study further assesses the gap between actual disaster impacts and available disaster risk financing, identifies the most affected sectors, and highlights emerging trends in financing needs that have evolved over the period. The following five events were analysed:

- Kerala (2018–19): Severe floods and heavy rains

- West Bengal (2020–21): Cyclone Amphan

- Rajasthan (2021–22): Prolonged drought

- Tamil Nadu (2023–24): Cyclone Michaung and associated floods

- Himachal Pradesh (2023–24): Floods, cloudbursts, and landslides

Key Findings

The following findings emerge from the assessment of five EWEs across varied geographies and hazard types.

1. **Massive Uninsured Losses & Funding Gaps:**

   Across the five events, total economic losses exceeded INR 99,000 crore. Over 90% of these losses were uninsured, exposing a vast financial protection gap, despite State Disaster Response Fund (SDRF) and National Disaster Response Fund (NDRF) disbursements. For example, Cyclone Amphan alone left a shortfall of more than INR 29,000 crore after accounting for central releases.

2. **Indirect Losses Often Exceed Direct Damages:**

   In most events studied, indirect losses such as income disruptions and prolonged recovery delays were 1.5 to 2.5 times higher than direct damages to infrastructure. For example, Tamil Nadu's Cyclone Michaung caused indirect losses 2.65 times higher than the direct damages, underscoring the need for holistic damage assessments and recovery financing strategies that address the full scale of recovery needs.

3. **Disasters Impact State Economies Significantly:**

   EWEs triggered economic contractions at the state level. Kerala's GSDP growth rate dropped from 7.4 percent to 0.9 percent in 2019–20 in the period post-floods, followed by a further plunge to -8.49 percent in 2020–21, reflecting the compounded effects of disaster recovery and the COVID-19 pandemic. Further, West Bengal's GSDP growth rate contracted from 3.1 percent to -7.6 percent in the period after Cyclone Amphan and COVID-19 impact in 2020–21. While attribution to the events alone requires a deeper analysis and a larger sample of events, these examples underscore the significant role that EWEs when compounded by overlapping shocks such as pandemics, can play in amplifying economic downturns at the state level.

4. **Low Insurance Penetration is a Critical Weakness:**

   Insurance coverage remains minimal, estimated at less than 6 percent across most events, and is often tied to bank-linked loan products with inadequate coverage. The vast majority of affected populations face disaster impacts without

effective financial protection. Estimates of insured vs. uninsured losses relied on expert consultations with the insurance industry, as official data is fragmented and largely unavailable.

5. **Critical Sectoral Impacts Compound Vulnerability:**

   Across the five events, infrastructure, housing, agriculture, public services, and ecosystems faced repeated damage. Roads, bridges, and power networks were most impacted in Kerala, Himachal Pradesh, West Bengal, and Tamil Nadu. Housing losses were widespread across most events. Agriculture and livelihoods were severely affected in Rajasthan, Kerala, and West Bengal, with crop failures and income losses among informal workers. Health and education services were disrupted as facilities were damaged or repurposed. Environmental degradation, such as the devastation caused in the Sundarbans and forest loss in Himachal, added further risk. These cascading impacts highlight the need for multi-sectoral resilience planning.

6. **Finance Commissions Have Expanded DRM Support, but Gaps Persist:**

   The Fifteenth Finance Commission substantially increased DRM allocations and supported mitigation efforts. However, fund utilization remains uneven. States with strong governance structures have managed these better, while others face absorption bottlenecks, delays, and underutilization of available funds for meeting the recovery needs from EWEs.

7. **Inconsistent Assessment Frameworks Impede Planning:**

   Post-disaster needs assessments (PDNAs) vary significantly across states and hazards, making cross-comparison difficult. For example, Kerala's flood disaster PDNA is not comparable with the PDNAs conducted for Himachal Pradesh's floods, or with the damage and loss assessment memoranda submitted after Cyclone Amphan and Cyclone Michaung.

Policy Implications

The current DRM financing system has a strong foundational design. However, there are opportunities to enhance its effectiveness by strengthening public-private collaboration and further institutionalizing pre-arranged, scalable risk financing tools can help bolster financial preparedness and resilience against future disasters.

Key Recommendations

1. **Build scalable, adaptive financing mechanisms** to complement current disaster risk financing. Funding shortfalls in extreme disasters may be met through a risk layering approach that integrates market-based instruments for rapid mobilization of financing.

2. **Accelerate and streamline fund disbursement** with flexible approaches that may include trigger-based, real-time payouts linked to pre-approved disaster thresholds, coupled with predictive risk governance for improved forecasting and financial readiness.

3. **Enhance transparency and accountability** through digital repositories for disaster finance data and enable reporting across a standard set of core content areas, covering damage, loss, recovery needs, and sectoral impacts, while allowing flexibility in format and emphasis to suit the specific regional and disaster context. This kind of consistency would enable better comparison of disaster impacts, strengthen resource allocation decisions, and support long-term resilience planning.

The Way Forward

The Sixteenth Finance Commission is uniquely positioned to advance structural reforms in India's disaster risk financing landscape. By setting performance-based conditionalities, recommending modern tools such as predictive multi-hazard risk analytics, setting-up risk-layered framework and supporting insurance-linked instruments, the Commission can help India shift decisively from response to resilience, safeguarding development gains and strengthening the financial and institutional capacity of states to withstand future climate shocks.

Introduction | 1

1.1 Extreme Weather Events in India

India ranks among the six most disaster-prone countries globally, with nearly every state and union territory vulnerable to recurring extreme weather events (EWEs), such as floods, cyclones, landslides, droughts, heatwaves, and thunderstorms. In recent years, the frequency, intensity, and geographic spread of these events have increased sharply, reflecting the growing impact of climate change. Floods and landslides are now affecting even arid and semi-arid regions; droughts have deepened in states such as Rajasthan, Maharashtra, and Karnataka; and severe cyclones in both the Bay of Bengal and the Arabian Sea have caused unprecedented destruction. Heatwaves are also intensifying, with parts of northern and central India crossing 45°C for days at a stretch.

The human and economic toll is rising. Between 1993 and 2022, India witnessed 400 EWEs, leading to 80,000 fatalities and USD 180 billion in losses, as reported by CRED (2024).

According to the Centre for Science and Environment (CSE), India experienced extreme weather on 93 percent of the days in the first nine months of 2024 alone, resulting in over 3,200 fatalities, crop damage across 3.2 million hectares, the destruction of 235,000 homes, and the death of more than 9,400 livestock. Similar patterns were also observed in 2022 also.

India is a signatory to the Hyogo Framework (2005–2015) and the Sendai Framework (2015–2030), which shifted the global focus from disaster response to proactive risk reduction and resilience. Domestically, the Disaster Management Act (2005) created institutions at the national, state, and district levels, including the National, State and

District Disaster Management Authorities responsible for disaster preparedness, response, and mitigation. The Act also provided for the creation of disaster response and mitigation funds.

The FFC built on these efforts by creating the National Disaster Risk Management Fund (NDRMF) and the State Disaster Risk Management Fund (SDRMF), recommending a total allocation of INR 1.60 lakh crore for states and INR 68,463 crore at the national level. It also introduced a cost-sharing model between the Centre and states (90:10 for Himalayan and northeastern states; 80:20 for others). Funds were to be split 80:20 between disaster response and mitigation. The FFC also earmarked INR 2,500 crore for urban flood mitigation in seven major cities and INR 1,500 crore for erosion control in nine coastal and riverine states, using the National Disaster Mitigation Fund.

Despite increased allocations and institutional reforms, the scale and nature of disasters have evolved faster than the financing systems built to manage them. Events such as Cyclone Amphan and the Kerala floods exposed how poorly current mechanisms address the magnitude of uninsured losses and long-term recovery needs. A SwissRe (2023) study found that 93 percent of climate-related disaster losses in India between 2018–22, amounting to INR 2.86 lakh crore, were uninsured. These systemic gaps, unrecovered disaster losses, along with uneven fund absorption across states, underscore the urgency for adaptive, scalable, and risk-informed disaster financing solutions.

1.2 Objectives and Scope of Work

The objective of this study is to analyze the economic impacts of major EWEs in India over the past decade and assess the adequacy of disaster risk financing mechanisms. By focusing on five significant events—Kerala floods (2018–19), Cyclone Amphan in West Bengal (2020–21), Rajasthan drought (2021–22), Cyclone Michaung and floods in Tamil Nadu (2023–24), and floods, cloudbursts, and landslides in Himachal Pradesh (2023–24)—the study provides a data-driven review of direct and indirect economic losses and the response financing mobilized. The analysis aims to generate insights into sectoral vulnerabilities, regional variations in impacts, and the extent of financing gaps. The findings are intended to inform the Sixteenth Finance Commission's recommendations on strengthening disaster risk financing frameworks.

The scope of work includes four core areas of inquiry:

1. *Economic Losses:* What is the scale of direct and indirect economic losses across states over the last decade?

2. *Sectoral Impacts:* Which sectors have been most affected, and how do losses vary?

3. *Financing Gaps:* How do current financing mechanisms match up to actual needs? Where are the biggest shortfalls?

4. *Emerging Trends:* What trends are evident in financing needs and disaster frequency over time?

These were undertaken through the following tasks:

Task 1: Data Collection on Extreme Weather Events

A comprehensive dataset documenting five major EWEs in India from 2014 to 2024 was identified and compiled. The events were selected on the basis of their significant economic and social impacts, representing a diverse range of hazards and state-specific contexts. The dataset was categorized by frequency, severity, and socio-economic impacts, with particular attention to the spatial extent of the events and their impact zones.

Task 2: Estimation of Economic Losses

Economic losses associated with the identified disasters were estimated, with both direct and indirect costs evaluated across various sectors. The analysis included an assessment of the broader impacts on livelihoods and local economies. Special attention was given to losses incurred by the private sector, in addition to those affecting the housing sector wherever such information was available.

Task 3: Analysis of Disaster-Related Expenditure and Trends

Expenditures from Central and State funds in response to the extreme weather events were reviewed, covering both immediate response efforts and long-term recovery initiatives. This analysis sought to identify funding gaps, particularly with respect to uninsured losses and dependence on post-disaster funding.

Methodology | 2

2.1 Data Sources and Collection Approach

A wide range of datasets were used to analyze the five selected EWEs. This included data on frequency, severity, and socioeconomic impacts. Together with the Sixteenth Finance Commission, data on recovery needs was sought from the five states. Further, given the variability in available data additional inputs were sourced from parliamentary responses, Finance Commission reports, National Disaster Management Authority, Ministry of Home Affairs (MHA), respective State (DMAs), Comptroller and Auditor General of India (CAG), the Ministry of Finance, and other relevant institutions.

2.1.1 Economic Loss Estimation

Economic losses were categorized as direct and indirect:

- **Direct Losses** refer to immediate damage to physical assets such as infrastructure, homes, and public facilities. These are quantifiable and generally reflect the cost of repair or replacement. In the PDNA methodology, developed by the European Union, World Bank, and the United Nations, such losses are termed as "damage."

- **Indirect Economic Losses** capture the longer-term ripple effects of disasters, including business interruptions, job losses, reduced productivity, and broader economic disruptions. These losses unfold over time and often impact sectors such as livelihoods, services, and supply chains.

The distinction is essential: direct losses require urgent physical recovery, while indirect losses demand longer-term economic and social interventions. Both compound financial burdens in the aftermath of a disaster.

FIGURE 2.1: Visual representation of direct/indirect and quantifiable/non-quantifiable losses
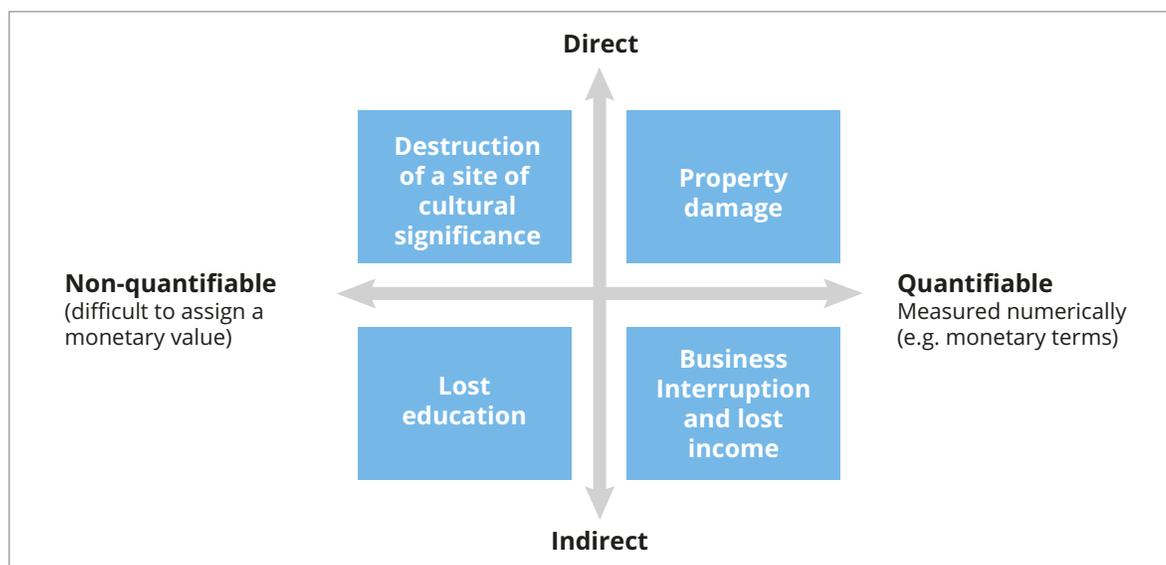
Source: UNDRR

Estimation of Direct and Indirect Losses

Direct and indirect losses were estimated using a combination of published data, modeling tools, and proxy factors from comparable events. For the 2018–19 Kerala floods and the 2023–24 Himachal Pradesh floods, official PDNAs provided disaggregated estimates for direct losses (damage to assets) and indirect losses (economic disruption). These figures were adopted as is. In the case of Cyclone Amphan (2020–21), direct loss figures were sourced from the Web-DCRA & Decision Support System, developed under the National Cyclone Risk Mitigation Project-II and installed at India Meteorological Department (IMD). Since the total loss figure was available from the official memorandum, indirect losses were calculated by subtracting the modeled direct losses. For Cyclone Michaung (2023–24), direct losses were estimated based on reported damage to infrastructure, buildings, drainage systems, and industries. As with Amphan, indirect losses were derived by subtracting direct losses from the total reported economic loss. For the 2023–24 Tamil Nadu floods, where PDNA data was not available, the direct–indirect loss ratio from the Kerala 2018 floods (a similar hydro-meteorological event) was applied as a proxy. In the case of the 2021–22 Rajasthan drought, indirect losses were estimated based on crop loss trends over the two subsequent years.

Due to the rapid two-month timeframe for this study, detailed macroeconomic modeling (e.g., Input-Output, CGE) was not feasible. Instead, a pragmatic mix of

empirical data and modeled or comparative estimates was used to arrive at credible loss figures.

Estimation of Recovery Needs

Recovery needs were estimated using a mix of official documents and proxy methodologies tailored to each event. For the 2018–19 Kerala floods and the 2023–24 Himachal Pradesh floods and landslides, recovery estimates were directly taken from the respective PDNAs, which provided detailed multi-sectoral assessments. For Cyclone Michaung (2023–24), recovery needs were derived from the official cyclone memorandum, which included both damage and recovery figures. In the case of Cyclone Amphan (2020–21), where total economic losses were reported but recovery costs were not disaggregated, the recovery need was calculated by subtracting the sum of direct and indirect losses from the total loss figure provided in the official memorandum. For the 2021–22 Rajasthan drought, in the absence of a domestic PDNA on droughts, a proxy methodology was used based on the 2015–16 Malawi drought PDNA. This event provided a relevant reference point due to similar agroclimatic conditions, including prolonged rainfall deficits, significant agricultural disruption, and rural livelihood vulnerabilities. Recovery needs for Rajasthan were estimated using ratios and patterns observed in the Malawi assessment, adapting them to the Indian context.

Estimation of Insured and Uninsured Losses

Insurance penetration in India remains low, especially for property coverage against natural disasters. Available data suggest that only about 3 to 6 percent of households have any form of housing insurance. Among these, a significant proportion are covered primarily due to mandatory loan-linked requirements. In such cases, the insurance typically covers only the outstanding loan amount, not the full market value of the property, resulting in significant underinsurance.

Reliable, publicly available data on insured losses is limited. For this study, insured loss estimates were derived from claims data validated by experienced professionals in the insurance sector, with long-standing expertise in disaster-related claims processing. Rajasthan's drought-related insured losses were the exception, as these were drawn from published data under schemes such as the Pradhan Mantri Fasal Bima Yojana (PMFBY) and the Weather-Based Crop Insurance Scheme (WBCIS). Uninsured losses were calculated by subtracting insured losses from the total estimated direct and indirect economic losses.

Estimation of Funding Gaps

Funding gaps were estimated by subtracting SDRF and NDRF releases from uninsured losses.

TABLE 2.1: List of additional data collected from the respective agencies

Sl. No.	Data	Source
1.	Weather patterns (temperature, rainfall, cyclones, droughts)	India Meteorological Department (IMD)
2.	Impact of extreme weather events (loss of life, infrastructure damage)	PDNA reports, State Disaster Memoranda, Central Water Commission reports
3.	Regional weather event data (damage, displacement)	State Disaster Management Authorities (SDMAs), State Revenue Departments
4.	Crop losses and agricultural disruptions	Ministry of Agriculture, State Agriculture departments Economic Surveys of State Governments
5.	Economic data on financial losses (infrastructure damage, productivity loss)	PDNA reports, Central Water Commission (CWC) reports, IMD reports and event specific research papers and reports

2.1.2 Data Processing and Gap Analysis

All available data sources were assessed for relevance and reliability and systematically documented based on their suitability for this study. The selected datasets, both spatial and non-spatial, were compiled into a structured, accessible database. An event-wise data availability matrix was developed to identify gaps in information across the five EWEs. This matrix tracked key parameters such as hazard intensity, severity, and socio-economic losses for each event. Each entry in the EWE database includes core attributes such as the date of occurrence, location, physical characteristics, disaster category, magnitude, and geographic extent of impact.

TABLE 2.2: Sources of disaster-related financial expenditure data and trends

Sl. No.	Data	Source
1.	Expenditure data, budget documents, and policy frameworks related to disaster risk financing. State Departments of Finance and Revenue: State specific budgetary allocations. Impact data, including loss of life, infrastructure damage, and displacement. Regional disaster impact data and state-level response efforts.	Comptroller and Auditor General (CAG) Reports, Ministry of Finance (MoF); NDMA; SDMAs; Government Reports and Documents NITI Aayog, and State Planning Boards
2.	Data on fund allocation, disbursement, and utilization for disaster management. Policy recommendations and guidelines for disaster risk financing.	Finance Commission Reports, MHA Annual Reports

Sl. No.	Data	Source
3.	State-level climate change adaptation and mitigation plan and downscaled climate change models. Information on disaster risk reduction and resilience-building initiatives.	State Action Plans on Climate Change (SAPCCs)
4.	Comprehensive plans outlining disaster preparedness, response, and recovery strategies at the state level. Institutional and financing set-up and arrangements in target states.	State Disaster Management Plans (SDMPs)

2.2 Data Collected: Attributes, Gaps, and Limitations

2.2.1 Economic and Social Disruptions

The study captures both direct and indirect economic losses, ranging from damage to infrastructure, housing, and agriculture to livelihood disruptions. It also documents key social impacts, including displacement, fatalities, and restricted access to essential services such as health care and education.

2.2.2 Disaster Response and Financial Expenditures

Disaster-related financial expenditures were mapped across government relief efforts, insured and uninsured loss data, and allocations from the SDRF and NDRF. The analysis includes trends in fund disbursement, utilization, and emerging gaps, offering insights into improving financial preparedness and response strategies.

2.2.3 Standardization in Data Formats

A major challenge encountered was the lack of consistency in data formats, particularly across PDNAs and disaster memoranda. Variations at sectoral and sub-sectoral levels hindered comparative analysis and aggregation, underscoring the need for standardized templates and reporting norms.

2.2.4 Limitations in Financial Loss Estimations

Accurately estimating financial losses, especially indirect ones, remains complex. While direct losses (e.g., asset damage) are relatively straightforward to quantify, indirect losses such as economic slowdowns, supply chain disruptions, and loss of income are often under- or overestimated due to data limitations and modeling challenges.

2.2.5 Spatial and Sectoral Data Disparities

Disaster impact data often suffer from uneven geographic and sectoral coverage, leading to critical blind spots in risk assessment. Rural and remote regions typically have limited data availability, resulting in the underreporting of losses and vulnerabilities. Similarly, sectors such as informal employment, small enterprises, and agriculture may experience high disaster exposure but are frequently overlooked in formal financial assessments.

3.1 Event Summary

In August 2018, the State of Kerala experienced one of the most severe flood events in nearly in nearly a century, triggered by unprecedented monsoon rainfall. The event affected all 14 districts (Figure 3.1), inundated 14.5 percent of the state's landmass, and impacted nearly 57 percent of its population. It caused 433 deaths and displaced over 1.4 million people. Total economic losses, including direct and indirect losses, were estimated at INR 26,720 crore (approximately USD 3.7 billion), making this the largest disaster faced by the state in recent history.

3.2 Background and Context

Kerala, a coastal and hilly state in South India, is highly vulnerable to natural hazards, including floods, landslides,

FIGURE 3.1: Kerala Floods and Heavy Rains 2018-19 – Economic losses at a glance
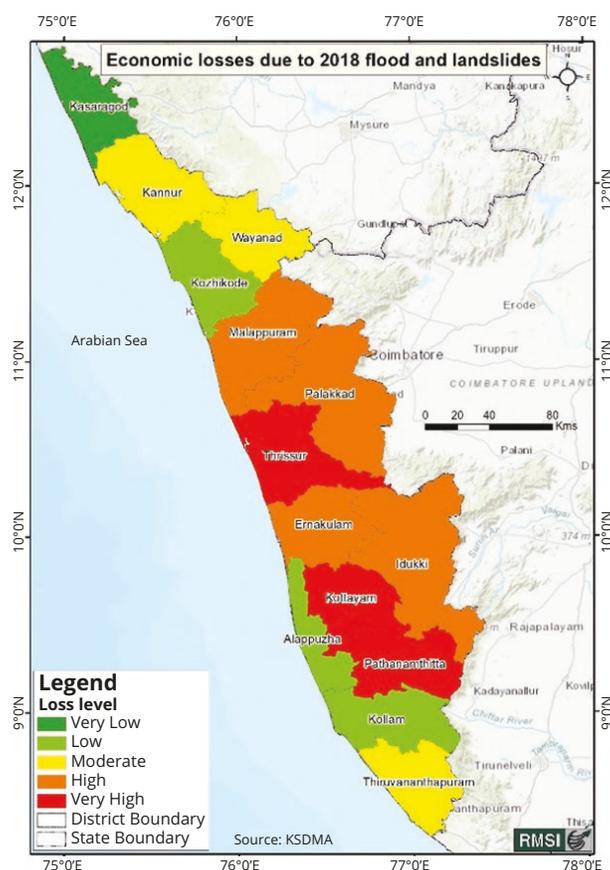
cyclones and storm surges, drought and coastal erosion. Despite leading the country in human development indicators, such as literacy, life expectancy, and access to basic services, its geographic and climatic profile makes it prone to recurrent disasters. Nearly 14.5 percent of Kerala's total land area is flood-prone, but in some districts, particularly those along rivers or in low-lying regions, up to half of the land is exposed to flooding.

In August 2018, Kerala faced one of the worst disasters in a century. The state received 42 percent excess rainfall between June 1 and August 18, with 771 mm of rain falling between August 1 and 20 alone. This intense and prolonged monsoon triggered 341 landslides across 10 districts, 143 of them in Idukki, and forced the release of water from 37 dams, many of which had reached full capacity. The sudden discharge further intensified flooding across downstream areas.

The event directly affected 5.4 million people, with 1.4 million displaced and housed in over 3,700 relief camps. A total of 483 lives were lost, and 14 individuals were reported missing. Nearly 76 percent of Kerala's villages (1,259 out of 1,664) were impacted, with Alappuzha, Ernakulam, Idukki, Kottayam, Pathanamthitta, Thrissur, and Wayanad among the worst-hit. Entire communities were submerged, requiring large-scale rescue and relief operations. The Government of India classified it as an L3 calamity, denoting a disaster of national scale that exceeds state response capacity.

The map categorizes district-level flood impacts in Kerala using a color-coded loss intensity scale. Districts with very low losses are marked in green (e.g., Kasaragod, Kannur), while those with low losses appear in yellow (e.g., Wayanad, Kozhikode). Moderate losses are indicated in orange (e.g., Malappuram, Ernakulam), high losses in red-orange (e.g., Pathanamthitta, Idukki, Alappuzha), and very high losses in red (e.g., Kottayam, Thrissur, Palakkad).

The 2018 floods highlighted Kerala's vulnerability to extreme weather events and the urgent need for disaster preparedness, improved water management, and resilient infrastructure.

3.3 Data Collection and Methodology

Data for the impact and loss assessment were collated from multiple sources, including Post-Disaster Needs Assessment (PDNA) conducted jointly by the state government and UN agencies; State and district memoranda; Inputs from the Web-DCRA platform; Consultations with state departments and ground reports.

3.4 Snapshot of Economic Losses and Recovery Needs

- Total economic impact from the 2018 floods and landslides was estimated at INR 26,720 crore (USD 3.8 billion):
  - Direct damage: INR 10,557 crore
  - Indirect losses: INR 16,163 crore

- Recovery needs were assessed at INR 31,000 crore (USD 4.4 billion), covering both public and private sector requirements.
- Insurance coverage was minimal, with less than 6 percent of households insured:
  - Insured losses: INR 2,136 crore
  - Uninsured losses: INR 24,584 crore
- Government relief funds were limited:
  - SDRF allocation (2018–19): INR 214 crore
  - SDRF & NDRF release: INR 3,097 crore
- This led to a significant funding gap of approximately INR 21,487 crore.

3.5 Assessment of Damages, Losses, and Recovery Priorities

3.5.1 Disaster Effects and Impacts

The 2018 floods and landslides in Kerala caused catastrophic damage across the state, affecting both infrastructure and livelihoods at an unprecedented scale. Homes, roads, railways, bridges, power infrastructure, communication networks, and other essential public facilities suffered extensive damage. Large tracts of agricultural land were submerged, resulting in widespread crop and livestock losses.

While the initial government estimate for recovery stood at around INR 25,787.57 crore (approximately USD 3 billion), a more detailed evaluation conducted under the PDNA significantly revised this figure upward.

The PDNA estimated:

- Total direct damages: INR 10,557 crore
- Indirect economic losses: INR 16,163 crore
- Total financial impact: INR 26,720 crore (USD 3.8 billion)

Importantly, this figure does not include losses to privately owned buildings, business establishments, shops, hospitals, educational institutions, private vehicles, or informal sector losses. Nor does it account for damages sustained by entities such as Kochi International Airport, the road transport sector, or inland waterways. If these were included, the actual total would be substantially higher.

The overall recovery needs were estimated at INR 31,000 crore (USD 4.4 billion), incorporating inputs from the Joint Rapid Damage and Needs Assessment (JRDNA) conducted by the World Bank and the ADB.

The PDNA classified the disaster's impacts into four key sectors:

- Infrastructure (e.g., transport, power, irrigation, WASH): 38% of total impact
- Cross-cutting sectors (e.g., environment, employment, governance): 27%

- Social sectors (e.g., housing, health, education): 18%
- Productive sectors (e.g., agriculture, fisheries, livestock): 17%

When it comes to recovery needs, the priority allocation is:

- Infrastructure: 51% of total recovery cost
- Social sectors: 20%
- Productive sectors: 15%
- Cross-cutting sectors: 14%

These figures underline the magnitude of reconstruction and resilience efforts required to restore Kerala's economic and social fabric after one of the most severe disasters in its history.

3.5.2 Human Impact

The 2018 floods had a profound and wide-ranging impact on the people of Kerala, affecting lives, homes, health, education, and livelihoods across all 14 districts.

Displacement and Shelter:

- Nearly 14 lakh people were forced into relief camps due to inundation of homes.
- Many others sought shelter with relatives or friends as their houses became uninhabitable.

Water and Sanitation Disruptions:

- 67 lakh people, around 20 percent of the state's population, experienced disruptions in piped water supply.
- 3.17 lakh shallow wells were damaged across six severely affected districts, impacting another 14 lakh individuals.
- Over 95,000 household latrines were destroyed, affecting close to 4 lakh people and posing significant public health risks.

Damage to Buildings and Education:

- An estimated 1.75 lakh buildings were damaged or destroyed, affecting the shelter and safety of 7.5 lakh people.
- More than 1,700 schools were converted into relief camps, disrupting education for 2 to 23 days.
- Even after reopening, student attendance remained low due to trauma, displacement, and loss of study materials.
- Concerns emerged around increased risk of school dropouts, especially among girls, and long-term psychological effects on children.

Health Services Affected:

- While no major disease outbreaks were reported, the disaster damaged:
  - 332 modern healthcare facilities
  - 61 Ayurveda institutions
  - 59 homeopathy centres
- These disruptions strained access to basic health services during a critical period.

Livelihood and Employment Losses:

- Kerala's informal workforce, which accounts for over 90 percent of the labour force, was hit especially hard.
- Nearly 74.5 lakh workers faced job and income loss, including:
  - 22.8 lakh migrant workers
  - 34,800 MSME employees
  - 35,000 plantation workers, mostly women
- Many daily wage earners reported more than 45 days of income loss, pushing already vulnerable families into deeper insecurity.

Emotional and Social Impact:

- Families in relief camps reported deep psychological distress over the loss of homes, livelihoods, and loved ones.
- In addition to economic losses, many mourned the loss of sentimental belongings such as jewellery, photographs, and religious artifacts.
- The destruction of critical personal documents, including birth certificates, graduation records, ration cards, and land titles, further complicated recovery and access to entitlements.

3.5.3 Macroeconomic Impacts

The 2018 floods inflicted a severe economic shock on Kerala, resulting in the instant loss of approximately 2.6 percent of the state's Gross State Domestic Product (GSDP) (PDNA, 2018). The disaster disrupted multiple sectors, strained public finances, and highlighted systemic vulnerabilities in the state's economic planning.

- Primary Sector Losses:
  - The agriculture sector bore the brunt of the damage, with extensive crop destruction across flood-affected regions.
  - In addition to flooding, excessive rainfall and unusually high post-monsoon temperatures compounded losses.
  - Losses in the primary sector (agriculture, fisheries, livestock) alone were estimated at INR 26,850 crore.

- Impact on Small Businesses and Traders:
  - Many small traders, especially those who had stocked up for the Onam festival season, suffered major losses.
  - GST-registered businesses that had already paid input tax on goods destroyed in the floods faced difficulties in recovering tax credits, adding to their financial burden.
- Need for Fiscal Support:
  - The situation called for immediate support measures such as loss assessment, compensation packages, and access to subsidized financing for affected enterprises.
  - Without such interventions, small and medium businesses faced the risk of permanent closure and prolonged income disruption.
- Fiscal Stability and Long-Term Planning:
  - The disaster underscored the need for a structured financial strategy that balances post-disaster recovery with long-term fiscal sustainability.
  - This includes disaster risk financing mechanisms, resilient budgeting practices, and greater investment in climate-adaptive infrastructure.

3.6 Conclusion

The PDNA provided a detailed breakdown of the sector-wise damages, losses, and recovery requirements following the 2018 Kerala floods and landslides. The findings are summarized below:

FIGURE 3.2: Share of disaster impact for different sectors

Productive 17%
Infrastructure 38%
Social 18%
Cross-cutting 27%
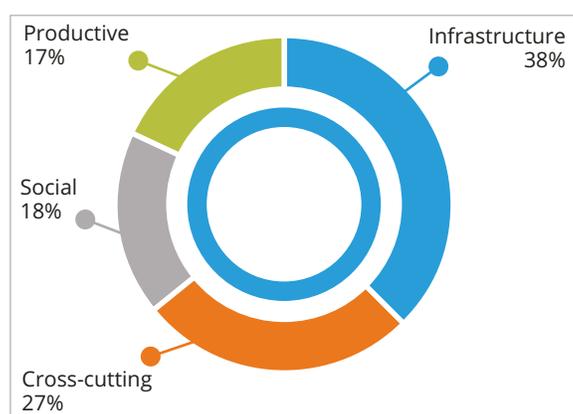
FIGURE 3.3: Share of disaster recovery needs across sectors

Productive 15%
Infrastructure 51%
Social 20%
Cross-cutting 14%

Source: PDNA.
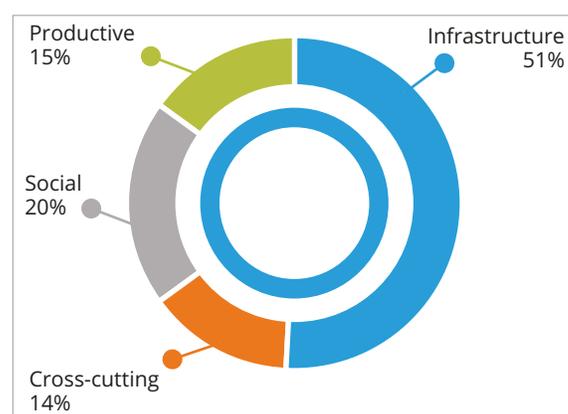
- **Social Sector:** This includes housing, health, education, and cultural heritage.
  - Damage: INR 5,739 crore
  - Losses: INR 1,452 crore
  - Total Recovery Needs: INR 6,337 crore (USD 906 million)
  - These figures highlight the extensive damage to essential social infrastructure and services, particularly housing.

- **Productive Sector:** Encompassing agriculture, fisheries, and livestock, critical for rural livelihoods.
  - Damage: INR 2,975 crore
  - Losses: INR 4,180 crore
  - Total Recovery Needs: INR 4,498 crore (USD 643 million)
  - The scale of loss underscores the urgent need to restore livelihoods and revive local economies.

- **Infrastructure Sector:** Covering water supply, sanitation, transportation, power, and irrigation systems.
  - Damage: INR 890 crore
  - Losses: INR 471 crore
  - Total Recovery Needs: INR 15,659 crore (USD 2,236 million)
  - This sector has the highest recovery needs, reflecting the enormous cost of rebuilding critical public infrastructure.

- **Cross-cutting Sectors:** Includes employment and livelihoods, environment, disaster risk reduction (DRR), gender and inclusion, and local governance.
  - Damage: INR 953 crore
  - Losses: INR 10,060 crore
  - Total Recovery Needs: INR 4,221 crore (USD 604 million)
  - These areas are essential for building long-term resilience and improving systemic disaster preparedness.

TABLE 3.1: Sector-wise summary of disaster effects (damage and Loss) and recovery needs (modified after PDNA)

Sector/Sub-sector	Damage (INR crore)	Loss (INR crore)	Total Effect (D + L) (INR crore)	Total Effect (D + L) (USD million)	Total Recovery Needs (INR crore)	Total Recovery Needs (USD million)
Social Sector						
Housing, Land, and Settlements	5,027	1,383	6,410	916	5,443	778
Health and Nutrition	499	28	527	75	600	86
Education and Child Protection	175	4	179	26	214	31
Cultural Heritage	38	37	75	11	80	11
Sub-total	**5,739**	**1,452**	**7,191**	**1,028**	**6,337**	**906**
Productive Sector						
Agriculture, Fisheries, and Livestock	2,975	4,180	7,155	1,022	4,498	643
Sub-total	**2,975**	**4,180**	**7,155**	**1,022**	**4,498**	**643**
Infrastructure Sector						
Water, Sanitation, and Hygiene	890	471	1,361	195	1,331	190
Transportation	-	-	-	-	10,046	1,435
Power	-	-	-	-	353	50
Irrigation	-	-	-	-	1,483	212
Other Infrastructure	-	-	-	-	2,446	349
Sub-total	**890**	**471**	**1,361**	**195**	**15,659**	**2,236**
Cross-cutting Sector						
Environment	26	0.04	26	4	148	21
Employment and Livelihoods	881	9,477	10,358	1,480	3,896	557
Disaster Risk Reduction	17	583	599	86	110	16
Gender and Social Inclusion	0.9	0	0.9	0.13	35	5
Local Governance	28	0	28	4	32	5
Sub-total	**952.9**	**10060.04**	**11011.9**	**1574.13**	**4221**	**604**
Total (A)	**10,557**	**16,163**	**26,719**	**3,819**	**30,715**	**4,389**
Integrated Water Resources Management (B)	-	-	-	-	24	3
Grand total (A+B)					**30,739**	**4,392**
Grand total (Rounded Off)					**31,000**	**4,400**

- Recovery costs for roads from urban and rural infrastructure sectors are included
- In Rapid Damage and Needs Assessment, the cost of damage and loss has not been quantified
- Estimates taken from the World Bank–Asian Development Bank Joint Rapid Damage and Needs Assessment
- Note: Figures are rounded, and so column totals may not add up precisely

Case Study 2: Cyclone Amphan, West Bengal, 2020

4 4

4.1 Event Summary

Cyclone Amphan, which struck West Bengal between May 16 and 21, 2020, was the most severe disaster the state has experienced in recent years. It impacted 16 of the 23 districts, covering nearly 24 percent of the state's land area and affecting approximately 60 percent of its population. The cyclone resulted in 99 reported deaths and caused estimated direct and indirect economic losses of INR 35,018 crore.

4.2 Background and Context

On May 20, 2020, Cyclone Amphan made landfall in West Bengal as a Very Severe Cyclonic Storm (VSCS), with wind speeds of 155–165 km/h. Though it had

FIGURE 4.1: Impact of Cyclone Amphan 2020-21 at a glance
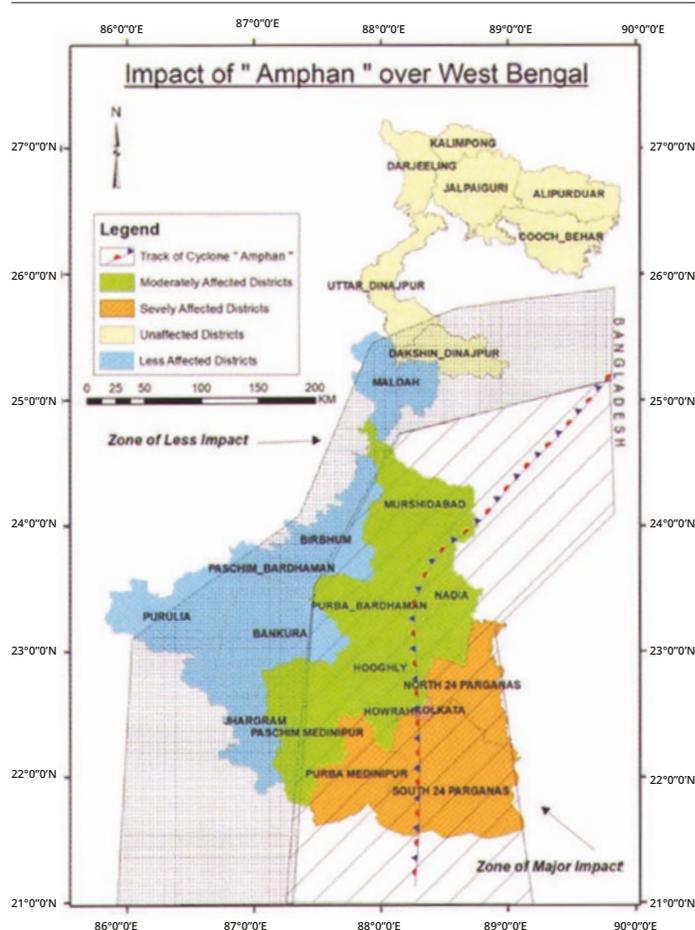
earlier intensified into a Super Cyclonic Storm, the first over the Bay of Bengal since 1999, it weakened before reaching the coast. Despite this, the storm caused widespread devastation across 16 districts, affecting millions of people and leading to INR 35,018 crore in economic losses.

The map in Figure 4.1 categorizes districts into five impact levels: severely affected (marked in orange), moderately affected (green), less affected (blue), and unaffected (yellow). The cyclone's track is also depicted, showing its movement through the state.

Amphan originated over the South Bay of Bengal on May 13, 2020, and was continuously tracked by the Indian Meteorological Department (IMD), which issued timely bulletins and warnings. The cyclone followed a northward trajectory and struck a densely populated and infrastructure-heavy stretch of the West Bengal coastline. The districts of South 24 Parganas, North 24 Parganas, Howrah, and Purba Medinipur were among the worst affected.

The severe impact of Amphan highlighted the deep-rooted vulnerability of West Bengal to tropical cyclones. The state, located on the eastern coast of India, spans 88,752 sq. km and is home to over 91 million people (Census 2011). It is one of the most densely populated regions in the country, with extensive settlements in low-lying coastal areas.

West Bengal's southern boundary is marked by the Bay of Bengal and the Sundarbans delta, the world's largest contiguous mangrove forest spanning districts like South and North 24 Parganas and Purba Medinipur. These areas are especially susceptible to storm surges, tidal flooding, and embankment breaches. Even inland districts such as Howrah, Hooghly, Nadia, and Paschim Medinipur are routinely affected due to their proximity to cyclone paths.

Historically, India's eastern coastline is one of the most cyclone-prone in the world. While only 7 percent of global cyclones form in the North Indian Ocean, their impacts on the region are disproportionately severe. Over the last century, 1,019 cyclonic disturbances have struck the Indian subcontinent, with 69 making landfall in West Bengal, accounting for 14 percent of all cyclone landfalls in India, second only to Odisha.

Cyclone Amphan thus stands as a stark reminder of the region's persistent climate risk and underscores the need for resilient infrastructure, early warning systems, and nature-based coastal protection strategies.

Data for the impact and loss assessment of Cyclone Amphan were collated from multiple sources, including:

- State memorandum prepared by the West Bengal State Disaster Management Authority (WBSDMA), based on departmental inputs and field-level assessments.
- Damage and loss submissions made by the state government to the central government under SDRF/NDRF norms.
- Modeled estimates from the Web-DCRA & DSS, developed under NCRMP-II and hosted by the IMD.

- Consultations with sectoral departments, insurance industry representatives, and experts on loss modeling.

- Given the lack of comprehensive official data and the extremely low penetration of insurance in the Cyclone Amphan impact zone, reportedly lower than even in Kerala, the estimate on insured losses relied on discussions with insurance and reinsurance experts.

Since no PDNA was conducted for Amphan, the estimates presented are based on state-reported figures supplemented by modeled loss estimates. Sectoral impacts were captured through a combination of administrative reports, field verifications, and expert assessments.

4.3 Snapshot of Economic Losses and Recovery Needs

- Total economic impact from Cyclone Amphan was estimated at INR 35,018 crore (USD 4.9 billion):
  - Direct damage: INR 21,944 crore
  - Indirect losses: INR 13,074 crore

- Recovery needs were projected at INR 67,424 crore (USD 9.4 billion), spanning both public infrastructure and private sector rebuilding.

- Insurance coverage was extremely limited, particularly in rural and cyclone-prone areas:
  - Insured losses: INR 1,051 crore
  - Uninsured losses: INR 33,968 crore

- Government relief funding was limited in scale:
  - SDRF allocation (2020–21): INR 1,348 crore
  - SDRF & NDRF release: INR 3,261 crore

- This resulted in a substantial funding gap of approximately INR 29,359 crore between uninsured losses and actual funds disbursed.

4.4 Assessment of Damages and Losses

4.4.1 Disaster Impact

Cyclone Amphan caused widespread devastation across 16 districts in West Bengal, affecting over 25,000 villages and 60 percent of the state's population. It severely impacted housing, agriculture, infrastructure, and public utilities. Sectoral damages and recovery needs were recorded through departmental submissions and WBSDMA assessments. While total combined losses were estimated at INR 1,02,442 crore, direct and indirect losses recognized under disaster financing norms amounted to INR 35,018 crore, forming the official economic loss estimate.

TABLE 4.1: Sector-wise impact summary

Sector	Impact Description	Estimated Loss (INR crore)
Housing	28.56 lakh houses damaged across affected districts	28,560
Agriculture	19.68 lakh hectares of cropland affected	15,860
Horticulture	2.5 lakh hectares of crops damaged	6,581
Fisheries & Livestock	8,007 boats, 1.48 lakh huts damaged; 21.22 lakh animals and poultry lost	2,452
Water Supply & Irrigation	Damage to piped water systems, embankments, and sea dykes	5,004
Roads & Bridges	Over 12,000 km of roads and culverts damaged	2,237
Power & Urban Infrastructure	273 power substations; damage to drainage and streetlight systems	9,980
Industries (incl. MSMEs)	Warehouses, raw materials, and industrial assets damaged	26,790
Education & Health	Damage to schools, colleges, hospitals, and anganwadis	2,405
Forests	1.58 lakh hectares of forest area affected	1,033
Miscellaneous	Transport and emergency infrastructure losses	1,540
Total		**1,02,442**

4.4.2 Human Impact

The cyclone caused 99 deaths and 221 serious injuries across affected districts.

- Highest casualties:
  - South 24 Parganas (25 deaths)
  - North 24 Parganas (22 deaths)
  - Kolkata (19 deaths)
- Most injuries:
  - South 24 Parganas (68), Nadia (62)

4.5 Summary and Road Ahead

Cyclone Amphan had a devastating impact across 16 districts in West Bengal, affecting over 60 percent of the state's population. Total economic losses were estimated at INR 35,018 crore, with recovery needs projected at INR 67,424 crore. Due to very low insurance coverage in the affected districts, most losses remain unfunded.

2020 Cyclone Amphan Economic Impacts and Funding Gaps
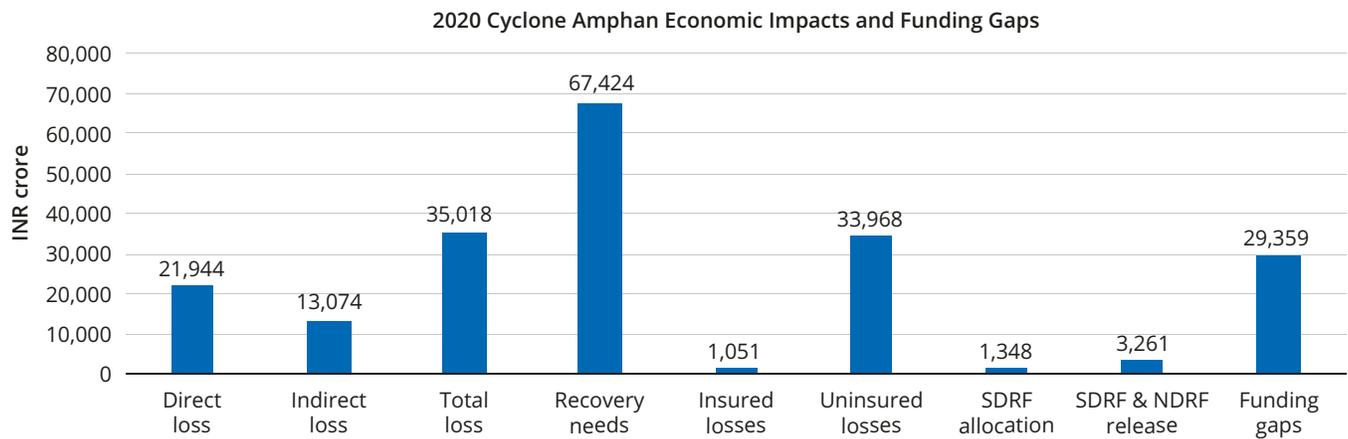
Cyclone Amphan exposed the urgent need to invest in infrastructure, preparedness, and inclusive recovery frameworks. A forward-looking, climate-resilient approach, anchored in both engineering solutions and ecosystem restoration, is essential to protect lives and livelihoods in West Bengal's vulnerable coastal zones.

Case Study 3: Rajasthan Drought, 2022–23 | 5

5.1 Event Summary

The 2021–22 drought in Rajasthan was the most severe EWE faced by the state, affecting 10 out of 33 districts. Approximately 16.6 percent of Rajasthan's total agricultural land and 8.7 percent of its population were impacted. The event led to significant disruptions in agricultural productivity and rural livelihoods, with estimated direct and indirect economic losses amounting to INR 13,945 crore.

Figure 5.1 illustrates the extent of drought-induced crop damage across various districts in Rajasthan during 2021–22. The color-coded legend categorizes the financial value of crop losses, revealing that the western and southwestern districts, including Barmer, Jalore, Pali, and Jaisalmer, faced the most severe impacts, indicated by darker shades of brown and red. In contrast, eastern and northern districts such as Jaipur, Alwar, and Bharatpur experienced relatively lower levels of crop damage, shown in lighter tones. The data, sourced from the Rajasthan State Disaster Management Authority (RSDMA), visually underscores the concentrated economic impact of drought in the state's arid and semi-arid regions.

5.2 Background and Context

In 2021, monsoon rainfall in Rajasthan was significantly below the long-term average, particularly in the western and central districts. This rainfall deficit triggered widespread drought conditions, exposing the state's acute vulnerability to climate variability and weak adaptive capacity. With nearly 90 percent of Rajasthan's annual rainfall

FIGURE 5.1: Spatial distribution of affected districts
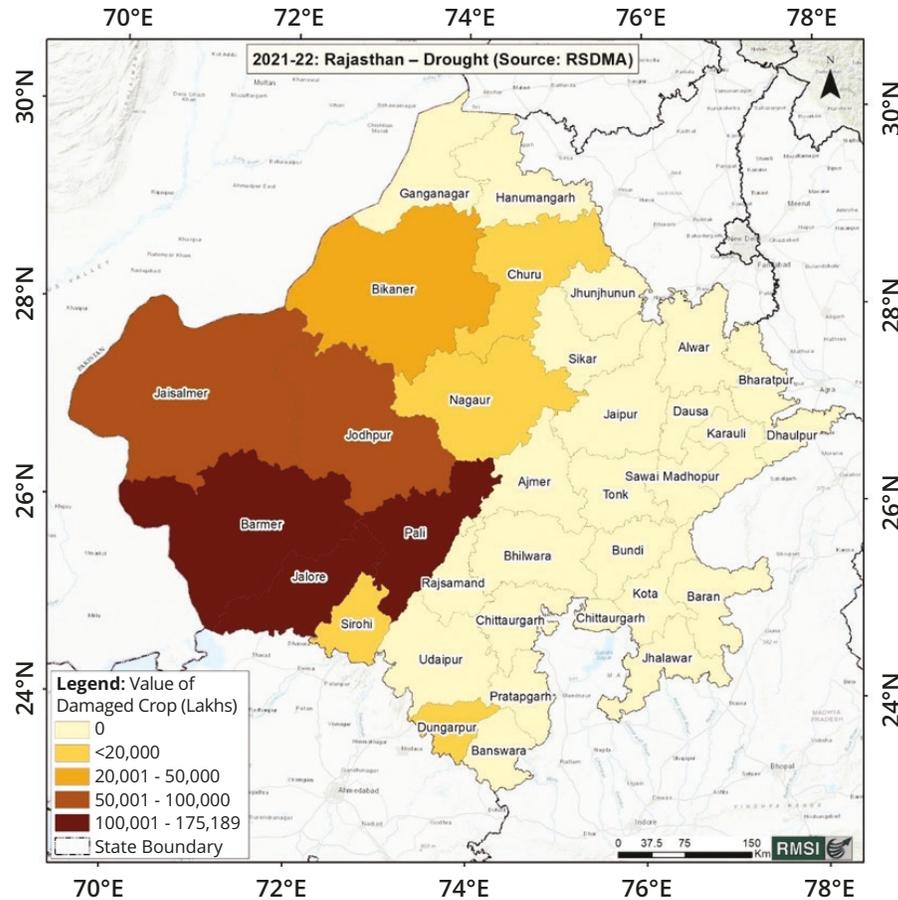
concentrated in the monsoon months, any delay or shortfall has cascading effects on agriculture, water supply, and rural livelihoods.

Rajasthan, India's largest state, spans 34.22 million hectares and is predominantly arid to semi-arid. The average annual rainfall ranges from 450 to 750 mm, but the western region often receives less than 150 mm. Summers are intensely hot, with temperatures rising above 45°C and occasionally exceeding 48°C, accompanied by dry westerly winds and dust storms.

Historically prone to droughts, Rajasthan has seen increasing frequency and severity of such events in recent years, driven by climate change. The state's economy is largely agrarian and heavily dependent on monsoonal rains. Even minor fluctuations in precipitation can lead to large-scale crop failures, food insecurity, and economic losses.

Excessive dependence on groundwater has worsened the crisis, with over-extraction causing a steady decline in water tables. Access to safe drinking water and reliable irrigation has become more difficult, especially in remote and arid regions. Rajasthan's fragile desert ecosystems also struggle to recover from extended dry spells, leading to land degradation, biodiversity loss, and advancing desertification.

5.3 Data Collection and Methodology

Data for the impact and loss assessment were collated from the following sources:

- District-wise datasets provided by the Rajasthan State Disaster Management Authority (RSDMA), including information on crop damage, affected population, livestock losses, and number of villages impacted.

- Crop insurance data from the Pradhan Mantri Fasal Bima Yojana (PMFBY) and Weather Based Crop Insurance Scheme (WBCIS).

- Kharif crop production trend data (2019–23), used to analyze agricultural performance before and after the drought event.

- Official economic loss and recovery needs estimates, with recovery calculated using a multiplier of 1.366 based on the 2015–16 Malawi Drought PDNA methodology.

- Secondary information from published climate studies to contextualize rainfall patterns, recurring drought risk, and regional vulnerability.

FIGURE 5.2: Value of Damaged crops due to 2021-22 drought

Value of Damaged Crops (in Lakhs)
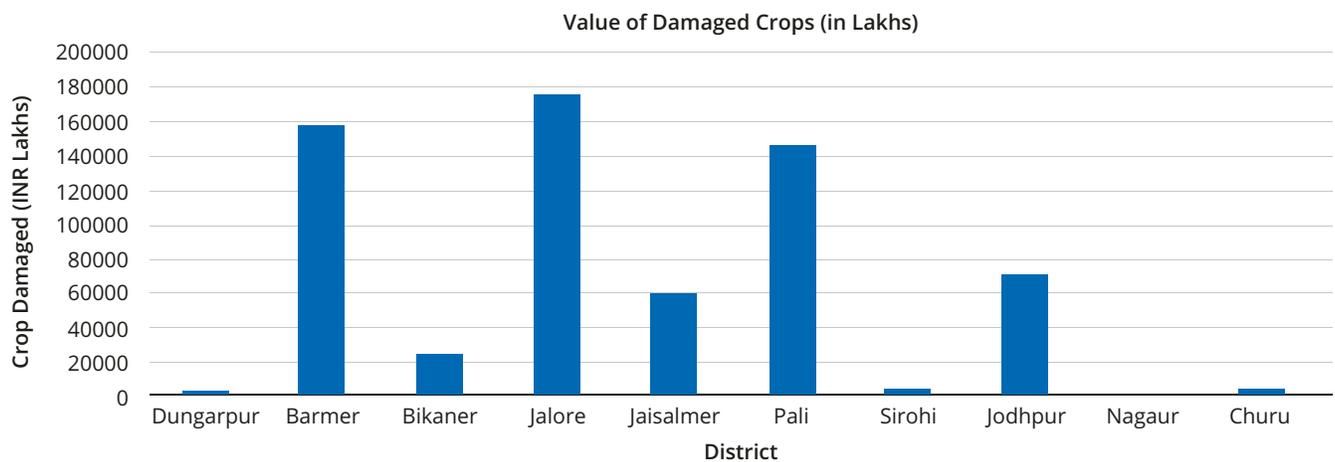
Source: RSDMA.

FIGURE 5.3: Total affected population due to 2021-22 drought

Total Affected Population (Lakhs)
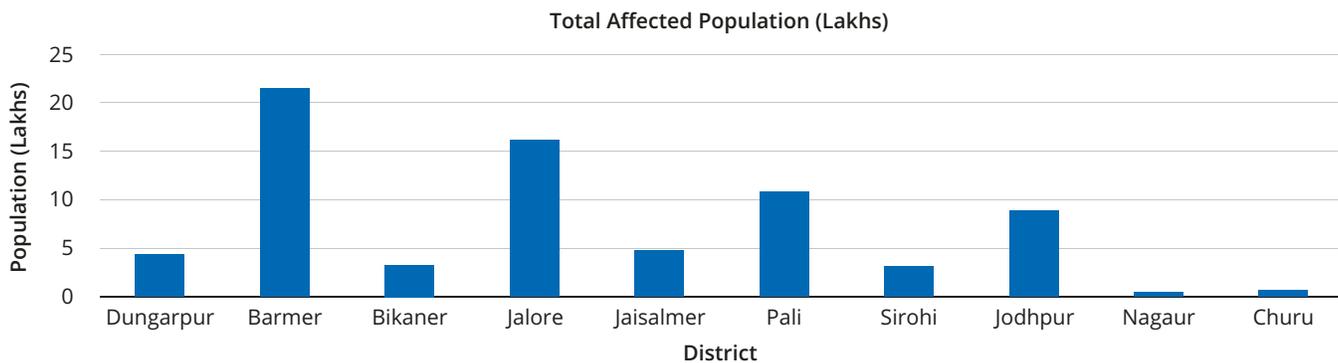
Source: RSDMA.

5.4 Snapshot of Economic Losses and Recovery Needs

- Total economic loss from the 2021–22 drought was estimated at INR 13,945 crore:
  - Direct damage: INR 6,446 crore
  - Indirect losses: INR 7,499 crore
- Recovery needs were assessed at INR 19,049 crore, based on the standard PDNA multiplier (1.366) applied to total economic loss.
- Insurance coverage was partial:
  - Insured losses (under PMFBY and WBCIS): INR 3,858 crore
  - Uninsured losses: INR 10,087 crore
- Government relief funds were limited:
  - SDRF allocation (2021–22): INR 1.58 crore
  - SDRF & NDRF release: INR 1,185 crore
- This resulted in a funding gap of approximately INR 7,322 crore, highlighting the inadequacy of current financial mechanisms in covering uninsured losses.

FIGURE 5.4: Economic impacts, insured and uninsured losses and funding gaps
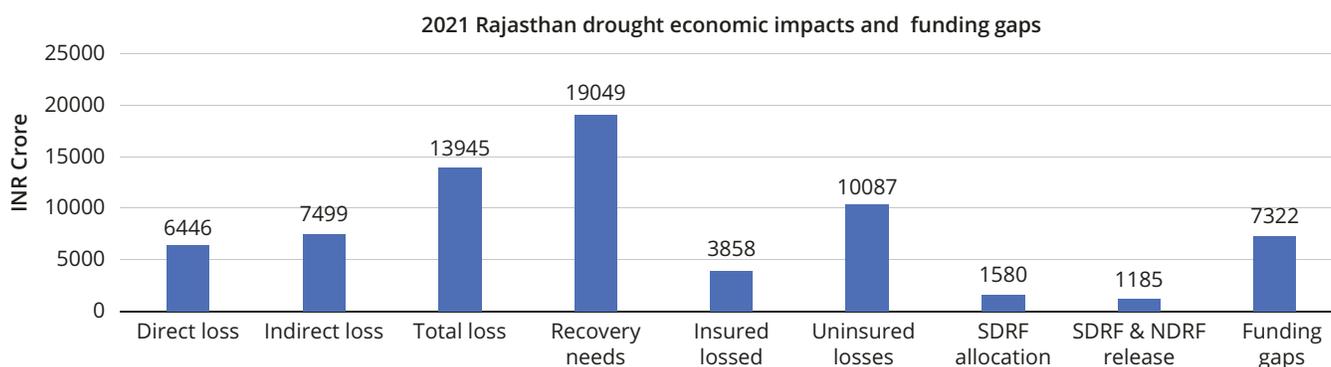
5.5 Assessment of Damages and Losses

5.5.1 Disaster and Human Impact

Agricultural and Spatial

The 2021–22 drought in Rajasthan had severe consequences for agriculture and rural livelihoods. According to data from the RSDMA, over 31.2 lakh hectares of cropped area suffered damage ranging from 33 percent to 100 percent, impacting approximately 22.6 lakh farmers. The estimated value of crop damage stood at INR 6,446 crore.

The western and southwestern districts of Barmer, Jalore, Pali, and Jaisalmer, were the hardest hit, reflecting their arid conditions and low irrigation coverage. In contrast,

eastern districts such as Jaipur, Alwar, and Bharatpur reported comparatively lower levels of damage.

Spatial data also indicated widespread drought effects across villages, livestock, and populations, with district-level disparities in vulnerability and resilience. These patterns underscore structural weaknesses in drought preparedness, water access, and agricultural dependency on monsoonal rainfall.

Population Exposure and Livelihood Disruption

An estimated 74.28 lakh people were affected across the 10 drought-impacted districts. Barmer and Jalore recorded the highest numbers, each exceeding 15–20 lakh people, followed by Pali and Jodhpur. Prolonged dry conditions not only disrupted agricultural activity but also stressed access to drinking water and fodder, particularly in vulnerable rural communities.

The event highlighted the need for timely relief interventions such as cattle camps, fodder distribution, and targeted support services for smallholder farming households, especially in drought-prone areas with limited coping infrastructure.

5.5.2 Trend Analysis

A multi-year analysis of Kharif crop production (2019–2023) reveals marked fluctuations. Output peaked in 2020–21, followed by a significant decline in 2021–22 due to the drought. A partial recovery is observed in 2022–23, though impacts linger across production cycles. These patterns, presented in Figure 5.5, reflect the long-term influence of extreme climate events on agricultural stability.

Figure 5.6 shows trends in crop insurance claims under PMFBY and WBCIS from 2019–20 to 2023–24, with a spike during and after the drought year. This underlines the financial stress faced by farmers and the growing reliance on insurance mechanisms, while also exposing gaps in coverage and adequacy.

FIGURE 5.5: Production analysis of before 2 years and after one year of 2021-22 drought event
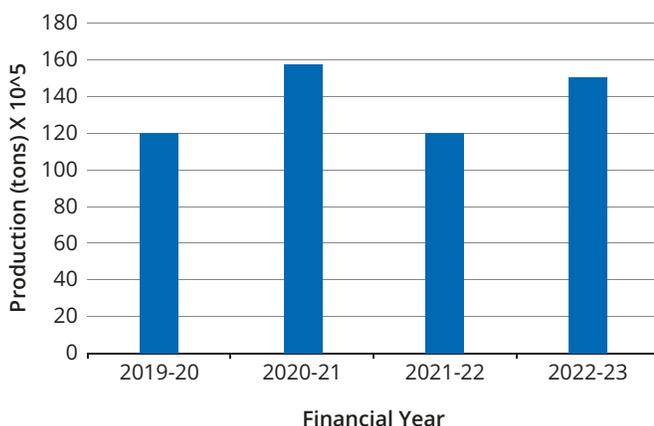
FIGURE 5.6: Insurance claimed by farmers from PMFBY and WBCIS
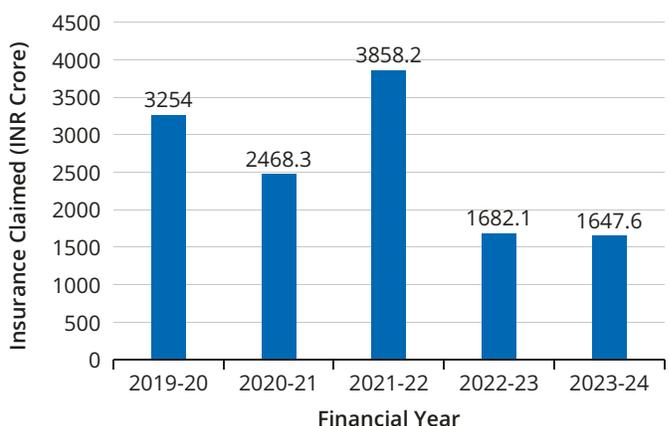
5.6 Summary and Road Ahead

The 2021–22 drought in Rajasthan was a high-impact event, affecting 10 districts, damaging over 31 lakh hectares of crops, and disrupting the lives of 74 lakh people. The total economic loss was estimated at INR 13,945 crore, with recovery needs assessed at INR 19,049 crore. Despite crop insurance coverage under PMFBY and WBCIS accounting for INR 3,858 crore, a substantial INR 10,087 crore in losses remained uninsured.

The event highlighted the persistent vulnerability of Rajasthan's arid and semi-arid regions to recurring drought, particularly in districts such as Barmer, Jalore, and Pali. Heavy reliance on monsoonal rainfall, depleting groundwater reserves, and low adaptive capacity continue to heighten the risks faced by farming households and livestock-dependent communities.

An integrated approach combining short-term relief with long-term resilience strategies will be critical for mitigating the recurring impacts of drought and ensuring the sustainability of rural livelihoods in Rajasthan.

Case Study 4: Cyclone Michaung and Floods, Tamil Nadu, 2023–24 | 6

6.1 Event Summary

Cyclone Michaung and subsequent floods in Tamil Nadu during in December 2023 constituted one of the most significant extreme weather events (EWE) of the year. The disaster affected 12 out of 38 districts, covering approximately 31.4 percent of the state's landmass and 4.7 percent of its population, resulting in 52 reported deaths and estimated direct and indirect economic losses of INR 15,645 crore.

The cyclone made landfall near the south Andhra Pradesh coast, and, consequently, brought intense and prolonged rainfall over northern and northeastern districts of Tamil Nadu including Chennai, Thiruvallur and Kancheepuram (which reorded the highest cumulative precipitation. Although Cyclone Michaung spanned December 1–6, the most severe rainfall occurred on December 3–4, leading to

FIGURE 6.1: Cumulative rainfall during Cyclone Michaung
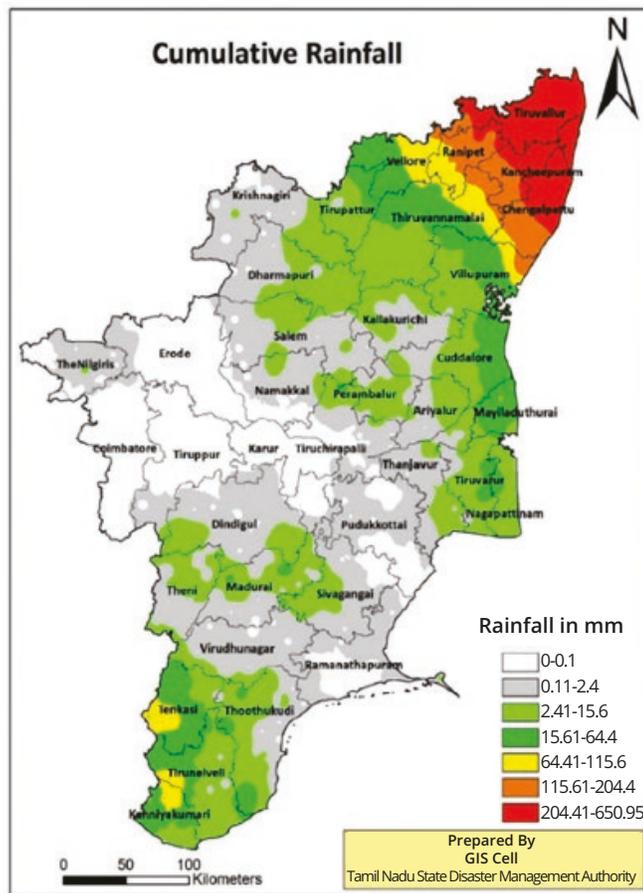
Source: TSDMA.

widespread flooding in these districts. Later in the month, on December 17–18, a second episode of unprecedented rainfall triggered further flooding in the southern districts.

Figure 6.1 illustrates the cumulative rainfall pattern during the event, showing extreme precipitation in red-marked zones. In contrast, the interior western districts such as Coimbatore, Tiruppur, and Karur received minimal rainfall. The dual impact of the cyclone and subsequent flooding caused significant disruptions to infrastructure, livelihoods, and essential services across affected regions.

6.2 Background and Context

The 2023–24 cyclone and flood event unfolded against the backdrop of Tamil Nadu's growing exposure to climate-induced extreme weather events. The December 2023 impact of Cyclone Michaung, followed by unprecedented rainfall and flooding in the southern districts, underscored the state's vulnerability to multiple and cascading hydrometeorological shocks within a short span.

Tamil Nadu's geographic and climatic profile makes it particularly prone to such disasters. With a 1,076 km-long coastline along the Bay of Bengal, the state regularly faces cyclones and depressions that bring heavy rainfall, storm surges, and widespread flooding. Unlike most other states, Tamil Nadu receives 48 percent of its annual rainfall during the Northeast Monsoon (October to December), making this period both agriculturally critical and climatically volatile.

Monsoon failure frequently results in drought, while excess rainfall, especially over short durations, overwhelms urban drainage and flood control systems. In recent years, the frequency and intensity of EWEs have increased, placing repeated stress on infrastructure, public services, and livelihoods. Major urban centres like Chennai have experienced repeated impacts, with widespread damage to homes, public infrastructure, and essential services.

The December 2023 cyclone and flood disaster reaffirm the need for long-term resilience strategies, improved early warning systems, and infrastructure capable of withstanding compounding events.

6.3 Data Collection and Methodology

Data for the impact and loss assessment were compiled from the following sources:

- Tamil Nadu State Disaster Management Authority (TNSDMA) reports and state memoranda detailing sector-wise damages, population affected, infrastructure losses, and interim relief needs.

- India Meteorological Department (IMD) rainfall data for December 1–4 and December 17–18, including daily and cumulative rainfall across affected districts.

- State estimates of direct and indirect economic losses for both Cyclone Michaung and the subsequent southern floods.

- Funding and insurance estimates based on discussions with state departments and insurance industry experts (as no official PDNA was carried out).

- For calculating recovery needs and classifying direct vs. indirect losses, PDNA loss factor ratios from the 2018 Kerala Flood PDNA were applied, as the Kerala assessment was the most recent detailed PDNA available for a comparable disaster.

6.4 Snapshot of Economic Losses and Recovery Needs

- Total economic losses from Cyclone Michaung and subsequent floods were estimated at INR 15,645 crore:
  - Direct damage: INR 4,966 crore
  - Indirect losses: INR 10,679 crore

- Recovery needs were estimated at INR 22,261 crore, combining both public infrastructure restoration and livelihood assistance:
  - Cyclone Michaung: INR 12,659 crore
  - Southern floods: INR 9,602 crore

- Insurance coverage was limited, with only a portion of losses covered through formal mechanisms:
  - Insured losses: INR 1,243 crore (across both events)
  - Uninsured losses: INR 14,402 crore

- Government relief funds were insufficient to bridge the gap:
  - SDRF allocation (2023–24): INR 1,200 crore
  - SDRF & NDRF release: INR 900 crore

- This resulted in a total funding gap of approximately INR 12,302 crore, reflecting the high proportion of uninsured and unrecovered losses.

6.5 Assessment of Damages and Losses

6.5.1 Disaster Impact

Geographic and Rainfall Impact

The 2023–24 event impacted 12 out of Tamil Nadu's 38 districts, with the most severe effects recorded in Chennai, Thiruvallur, Chengalpattu, and Kancheepuram. These northern and northeastern districts experienced extremely heavy rainfall during Cyclone Michaung between December 3–4, leading to widespread flooding and infrastructure disruption. Later in the month, on December 17–18, a second spell of unprecedented

rainfall caused additional flooding in southern districts, further compounding the impact. As per IMD data, the cumulative rainfall over December 3–4 reached:

- 30.47 cm in Tiruvallur
- 29.4 cm in Chennai
- 25.97 cm in Chengalpattu
- 23.57 cm in Kancheepuram

When compared to December's normal averages, the rainfall during December 1–4 was 200 percent to 291 percent above normal, with Chennai receiving nearly three times its monthly average (Table 6.1). On December 3–4 alone, rainfall spiked to levels between 1291 percent and 1876 percent higher than normal across the four districts (Table 6.2).

These exceptional rainfall intensities overwhelmed drainage systems and led to extensive inundation across low-lying areas, especially in Chennai and its suburbs, where water levels reportedly rose to 4–10 feet in several zones (Figure 6.2). In contrast, interior districts such as Coimbatore, Tiruppur, and Karur received minimal rainfall during the event, as reflected in IMD's cumulative rainfall map.

TABLE 6.1: Comparison of normal vs. Actual rainfall in cm (December 1-4, 2023)

Sl. No.	District	Normal Rainfall for December	Actual Rainfall (01.12.2023 - 04.12.2023)	% Increase
1.	Chennai	15.74	45.82	291%
2.	Tiruvallur	12.56	35.25	280%
3.	Chengalpattu	15.32	30.62	200%
4.	Kancheepuram	13.2	28.01	212%
	Total	**56.82**	**139.7**	**246%**

Source: IMD.

TABLE 6.2: Normal vs. actual rainfall on December 3-4, 2023 (in cm)

Sl. No.	District	03.12.2023 (Normal)	03.12.2023 (Actual)	04.12.2023 (Normal)	04.12.2023 (Actual)	Total (Normal)	Total (Actual)	% Increase
1.	Chennai	1.08	20.96	0.92	18.56	2	39.52	1876%
2.	Tiruvallur	0.97	14.55	0.92	14.16	1.89	28.71	1419%
3.	Chengalpattu	1.03	14.65	0.95	12.9	1.98	27.55	1291%
4.	Kancheepuram	0.86	11.5	0.67	13.23	1.53	24.73	1516%
	Total	**3.94**	**61.66**	**3.46**	**58.85**	**7.4**	**120.51**	**-**

Source: IMD.

6.5.2 Human Impact

The Cyclone Michaung and subsequent flood events in December 2023 had a significant humanitarian impact across the affected districts of Tamil Nadu. According to data from the TNSDMA, a total of 17 lives were lost due to wall collapses, electrocution, and falling trees. Ten people sustained injuries during the cyclone impact.

A total of 52,981 individuals were evacuated from vulnerable areas and sheltered in 411 relief centres set up by the state government. The events caused widespread disruption to daily life, particularly for informal and daily wage workers, many of whom lost access to income and shelter.

Housing losses were substantial, with 1,534 huts fully damaged, 498 huts partially damaged, and 157 pucca (tiled) houses reported as partially damaged. The damage to housing stock further exacerbated the vulnerability of low-income households, particularly in peri-urban and rural areas.

The floods also led to livestock losses, including 384 cattle and 1,275 poultry, impacting household income and food security. These losses, combined with crop damage and infrastructure disruptions, point to a broad and multidimensional impact on human well-being and livelihoods in both urban and rural settings.

6.5.3 Sectoral Impact

The 2023–24 cyclone and flood events caused extensive damage across key infrastructure and service delivery sectors in Tamil Nadu. Based on data submitted by various departments and compiled by the Tamil Nadu State Disaster Management Authority (TNSDMA), the total sectoral damages amounted to INR 18,143 crore. These included both temporary and permanent restoration needs across urban, rural, transport, power, and water infrastructure.

- **Urban and Local Infrastructure**
  Urban local bodies in severely affected districts, including Chennai, Chengalpattu, and Kancheepuram, reported extensive losses:
  - Greater Chennai Corporation: INR 401.5 crore (temporary) and INR 566.9 crore (permanent)
  - Municipal Administration: INR 133.5 crore (temporary) and INR 652.2 crore (permanent)
  - Town Panchayats: INR 23.6 crore (temporary) and INR 41.8 crore (permanent)

These damages covered roads, streetlights, sanitation systems, and municipal buildings.

- **Rural Infrastructure**
  Rural Development: INR 215.3 crore (temporary) and INR 1,700.7 crore (permanent) This included drinking water infrastructure, rural roads, and community assets.

- **Water Resources**

  Floodwaters severely impacted both temporary relief works and long-term water infrastructure:
  - Water Resources Department: INR 1,812.5 crore (temporary) and INR 8,722.6 crore (permanent)

- **Transport and Roads**

  State Highways suffered damage across 2,587.9 km of road surface, with 11 bridges and 271 culverts damaged. Restoration costs were reported at:
  - INR 542.3 crore (temporary) and INR 964.7 crore (permanent)

- **Power Infrastructure**

  Tamil Nadu Generation and Distribution Corporation Limited (TANGEDCO) and Tamil Nadu Transmission Corporation Limited (TANTRANSCO) incurred damages amounting to INR 706.7 crore, largely due to waterlogging in substations, damage to transformers, and transmission lines.

- **Public Buildings and Services**

  Restoration of government buildings, relief camps, and public service facilities (e.g., health centres, food distribution) totalled several crores, including:
  - Public Works (Buildings): INR 14.9 crore
  - Health Department: INR 12.8 crore
  - Police and Transport: INR 30.5 crore combined

- **Agriculture and Livelihoods**

  The floods impacted 18,755 hectares of agricultural crops, 79.6 hectares of horticulture, and 6,748 hectares of cropped land inundated. Additionally, departments estimated:
  - Livelihood assistance at INR 1,560 crore
  - Micro, Small & Medium Enterprises (MSME): INR 1,061.6 crore in damages
  - Fisheries and Animal Husbandry reported smaller but notable losses in livestock and marine assets

Sector-wise Damages

A total damage of approximately INR 18,210 crore (rounded from subtotal of reported amounts) was reported post the cyclone, details for which are given in Table 6.3 below:

TABLE 6.3: Sector-wise estimated damages

Sector	Nature of Impact	Estimated Damage (in INR crore)
Urban infrastructure (Greater Chennai Corporation, Municipal Admin, Town Panchayats)	Roads, streetlights, stormwater drains, buildings	1,819.1
Rural Development	Drinking water, rural roads, community infrastructure	1,916.0
Water Resources Department	Flood protection, canal repair, drainage works	10,535.1
State Highways	Roads, culverts, bridges (2,587.9 km affected)	1,507.0
Power Sector (TANGEDCO, TANTRANSCO)	Substations, transformers, power lines	706.7
Public Buildings	Govt. offices, community halls	14.9
Health, Transport, Police	Equipment, facilities, service disruption	35.1
Livelihood Assistance	Compensation for wage loss, informal workers	1,560.0
Agriculture, Horticulture	18,755 ha crops + 6,748 ha inundated	31.9
MSMEs, Fisheries, Animal Husbandry	Asset damage, livestock/fish loss	1,084.6

Monetary and non-monetary damages, as per TNSDMA Memoranda, are detailed in Table 6.4 and 6.5 below:

TABLE 6.4: Sector-wise estimated monetary damages

Sector	Amount (INR Crore)	Remarks
Livelihood Assistance	1560	For people affected by floods
Power Sector (TANGEDCO & TANTRANSCO)	706.71	Restoration of electrical infrastructure
State Highways (Temporary Restoration)	542.32	Damages to roads, bridges, and culverts
State Highways (Permanent Restoration)	964.69	Permanent repairs
Public Buildings	14.93	Restoration of damaged government buildings
Water Resources (Temporary Restoration)	1812.48	Flood relief works and repairs
Water Resources (Permanent Restoration)	8722.55	Permanent infrastructure restoration
Greater Chennai Corporation (Temporary)	401.53	Restoration and relief efforts
Greater Chennai Corporation (Permanent)	566.86	Permanent repairs
Municipal Administration (Temporary)	133.5	Restoration of municipal infrastructure
Municipal Administration (Permanent)	652.18	Permanent restoration

Sector	Amount (INR Crore)	Remarks
Town Panchayats (Temporary)	23.59	Repairs to roads, streetlights, etc.
Town Panchayats (Permanent)	41.78	Permanent infrastructure restoration
Rural Development (Temporary)	215.3	Restoration of drinking water, roads, etc.
Rural Development (Permanent)	1700.67	Permanent infrastructure restoration
Chennai Metro Water Supply (Temporary)	69.06	Restoration of sewer/water mains, pumps
TWAD Board (Temporary Restoration)	11.66	Repairs to water supply systems
TWAD Board (Permanent Restoration)	3.26	Permanent restoration
Grand Total	**18,143**	

TABLE 6.5: Sector-wise estimated non-monetary damages

Category	Number	Remarks
Loss of Life	17	Due to floods, wall collapse, electrocution, tree fall
Injured	10	Cyclone impact
Huts Fully Damaged	1534	-
Huts Partly Damaged	498	-
Pucca Houses Damaged	157	Tiled houses, partially damaged
Cattle Loss	384	-
Poultry Loss	1275	-
People Evacuated	52,981	Shifted to relief shelters
Relief Centres	411	Shelter facilities provided
Road Damage (Surface) in km	2587.88	State Highways
Bridges Damaged	11	-
Causeways/Culverts Damaged	271	-
Drain/Medians Damaged	130	-
Agricultural Crops Affected (in Hectares)	18,755.49	Flood-affected land
Horticultural Crops Affected (in Hectares)	79.62	-
Crops Inundated (in Hectares)	6748.47	Underwater due to flooding

6.6 Summary and Road Ahead

In December 2023, Cyclone Michaung and the subsequent unprecedented flooding in Tamil Nadu, caused widespread damage across 12 districts. The state experienced estimated economic losses of INR 15,645 crore, with recovery needs rising to INR 22,261 crore. Despite existing insurance coverage and government relief mechanisms, a significant funding gap of INR 12,302 crore remains, underscoring the scale of uninsured and unrecovered losses.

FIGURE 6.2: Economic impacts, insured and uninsured losses and funding gaps

2023 Michuang and Floods Economic Impacts and Funding Gaps
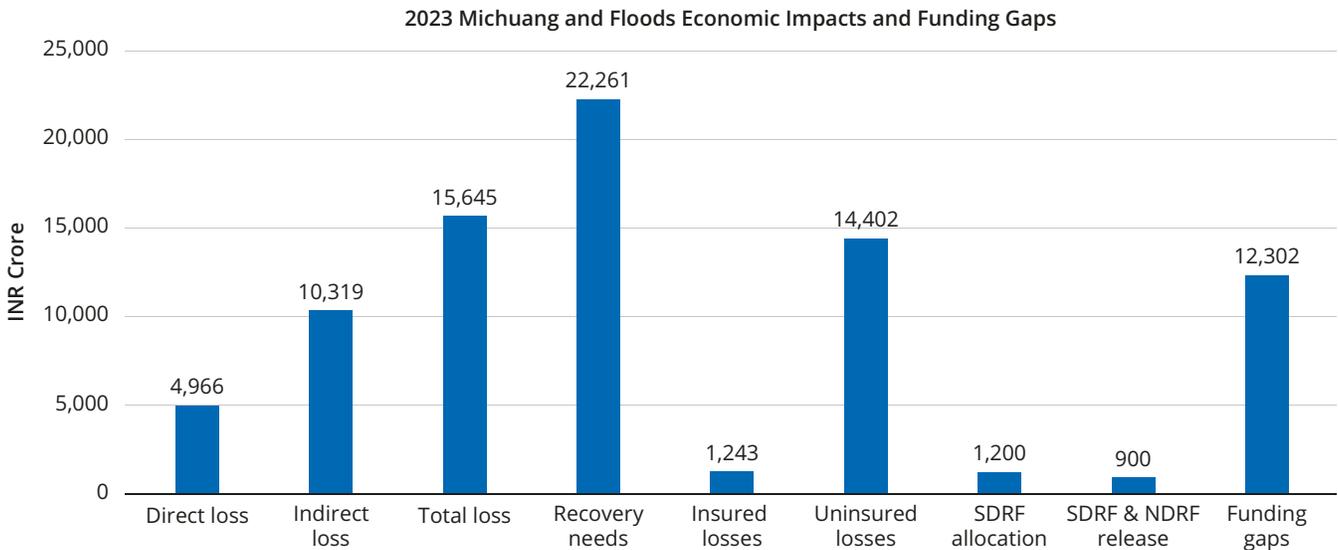
The event underscored Tamil Nadu's high vulnerability to cyclonic storms and monsoon-driven floods, particularly during the Northeast Monsoon season. With the increased frequency and intensity of such events, the need for systemic, long-term adaptation measures has become urgent.

A forward-looking recovery strategy will require coordination between state departments, urban local bodies, and climate finance mechanisms to ensure investments not only restore what is lost, but also reduce vulnerability to future events.

Case Study 5: Himachal Pradesh Floods, Cloudbursts and Landslides, 2023-24

7

7.1 Event Summary

Between June 1 and September 15, 2023, Himachal Pradesh experienced one of its worst monsoon seasons in recent history. A combination of intense monsoon rainfall and western disturbances triggered a cascading series of floods, cloudbursts, and landslides across the state.

All 12 districts were affected, with the disasters impacting approximately 63.6 percent of the state's geographical area and 0.03 percent of the population. The events

FIGURE 7.1: Spatial distribution of affected districts in terms of direct plus indirect economic loss
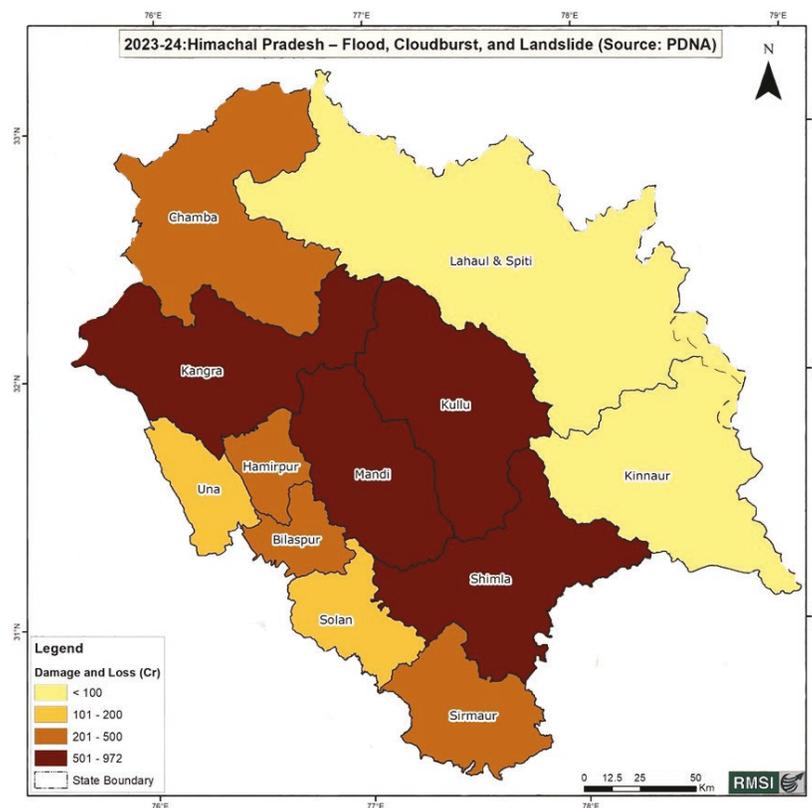
led to the loss of around 500 lives and caused an estimated INR 8,304 crore in direct and indirect economic damage.

The worst-affected districts, Kullu, Mandi, Shimla, and Sirmaur, incurred losses exceeding INR 500 crore each, while Chamba, Kangra, Hamirpur, and Bilaspur experienced moderate damage. Lahaul & Spiti and Kinnaur saw comparatively minimal losses.

The event exposed the fragility of Himachal Pradesh's mountainous terrain and its growing vulnerability to climate-induced disasters. It also underscored the need for resilient infrastructure, stricter building norms, and improved early warning systems.

7.2 Background and Context

7.2.1 Flood and Landslide

In 2023, Northern India experienced severe monsoon activity intensified by western disturbances, triggering widespread floods and landslides. Himachal Pradesh was among the hardest-hit states due to its fragile and mountainous terrain.

Three intense rainfall spells struck the state between July and August:

July 7–11: Brought 223 mm of rain, 436 percent above normal, triggering landslides, flash floods, and major infrastructure damage. Kinnaur, Kullu, and Solan were especially affected by road blockages and overflowing rivers.

August 11–14 and August 21–23: Further worsened the crisis, impacting Hamirpur, Kangra, and Una, overwhelming local relief capacity and resulting in cumulative destruction.

Frequent cloudbursts, a characteristic hazard of the Himalayas, added to the devastation by causing sudden landslides and road collapses. Across the season, relief operations were severely stretched, with authorities forced to evacuate residents and shut down schools to ensure safety.

7.2.2 Rainfall Trend Analysis

A rainfall trend study using IMD data (2014–23) at key stations, Mandi, Shimla, Bhuntar, Kangra, and Kalpa, shows that 2023 witnessed an unprecedented surge in rainfall, even during the pre-monsoon months (April–May).

- In Mandi, April rainfall rose from 33 mm (2014) to 185.2 mm (2023).
- July rainfall reached 528.7 mm.
- Kangra recorded 628.3 mm in August, among the highest in the state.
- Even Kalpa, typically in a rain-shadow region, reported above-normal precipitation.

Notably, despite high cumulative rainfall, the number of rainy days declined, pointing to fewer but more intense rainfall events, a signature of climate-driven variability.

The consequences were stark:

- Over 5,400 landslides
- 45 cloudbursts and
- 83 flash floods across districts.

These intense downpours triggered slope failures in higher altitudes and flash floods in valleys, disrupting infrastructure and threatening agriculture and settlements. Underlying causes such as unregulated construction, deforestation, and encroachment on water channels exacerbated these hazards. Road expansion projects without slope stabilization further destabilized already fragile terrains.

The state government utilized satellite-based pre- and post-event assessments to evaluate damage. Analysis confirmed that mapped landslides closely correlated with rainfall anomalies recorded during July–August.

FIGURE 7.2: Cumulative Rainfall in 2023 (modified PDNA)

SOURCE: Indian Meterological Department, Shimla

7.3 Data Collection and Methodology

The data presented in this chapter is drawn primarily from the Post-Disaster Needs Assessment (PDNA) conducted by the Government of Himachal Pradesh. The assessment aimed to quantify sector-wise damage, loss, and recovery needs across the state's 12 districts.

Sources of Data

- PDNA, 2023, led by the Government of Himachal Pradesh.
- Primary inputs from line departments and district administrations.
- Field-level assessments coordinated by state agencies.
- IMD rainfall data (2014–23) to assess meteorological triggers and deviations.
- Satellite-based imagery and GIS mapping to identify landslide zones and flood-affected areas.

- Secondary sources including:
  - Census 2011 for population estimates.
  - Economic survey and GSDP data (2023–24) for baseline economic indicators.
  - Technical consultations with insurance and reinsurance industry experts for insured loss estimates.
- Recovery needs were calculated by assessing how much it would cost to replace or repair each damaged structure, adjusting for the extent of damage (partial or full), and following department-specific reconstruction standards such as those set by the Himachal Pradesh Housing and Urban Development Authority (HIMUDA) and the Public Works Department (PWD).

Limitations

- Insurance data is indicative and based on consultations; actual penetration may vary.
- Population figures are projections from Census 2011 and may not reflect current demographic shifts.
- Landslide mapping is based on available satellite data but may underreport micro-level impacts.

TABLE 7.1: District wise number of landslides and rainfall

District Name	No. of landslides	Area of landslide (sq.km)	Rainfall (mm) (1st June to 15th Sep 2023	Deviation from normal rainfall (%)
Bilaspur	172	1.14	1258.4	62
Chamba	437	7.36	852.9	6
Hamirpur	287	1.39	1298.9	40
Kangra	366	2.3	1671.5	8
Kinnaur	144	2.48	267.1	21
Kullu	634	4.73	755.7	49
Lahaul and Spiti	56	1.33	209.5	-39
Mandi	1257	10.4	1525.5	45
Shimla	644	3.79	1001.3	71
Sirmour	924	6.35	1642.5	46
Solan	787	3.92	1455	77
Una	40	0.25	865.4	-5
Total	**5748**	**45.44**	**840.6**	**22**

Source: IMD.

7.4 Snapshot of Economic Losses and Recovery Needs

- Total economic losses from floods, cloudbursts, and landslides were estimated at INR 8,304 crore:
  - Direct damage: INR 6,554 crore
  - Indirect losses: INR 1,750 crore

- Recovery needs were estimated at INR 9,403 crore, including social, infrastructure, and productive sectors:
  - Social sector: INR 2,944 crore
  - Infrastructure sector: INR 4,900 crore
  - Productive sector: INR 823 crore
  - DRR & Environment: INR 375 crore

- Insurance coverage remained low, with a significant share of damages unfunded:
  - Insured losses: INR 415 crore
  - Uninsured losses: INR 7,889 crore

- Government relief allocations were limited relative to total need:
  - SDRF allocation (2023–24): INR 401 crore
  - SDRF & NDRF releases: INR 1,148 crore

- This resulted in a total funding gap estimate of approximately INR 6,340 crore, underscoring the need for expanded risk financing and resilient infrastructure planning.

7.5 Assessment of Damages and Losses

7.5.1 Post-Disaster Needs Assessment (PDNA)

The PDNA was conducted by the Government of Himachal Pradesh to comprehensively assess the impact of the 2023 monsoon-induced floods, landslides, and cloudbursts. The assessment covered three primary sectors, social, infrastructure, and productive, with each further divided into sub-sectors. It aimed to quantify damage, economic loss, and estimate recovery needs for both short- and long-term rehabilitation.

- Total damage and loss: INR 8,304.21 crore
- Total recovery needs: INR 9,042.66 crore
  - Of this, INR 375 crore was estimated for Disaster Risk Reduction (DRR)

FIGURE 7.3: District wise housing damage by housing type

Pattern of only housing damage by housing type across the 12 districts
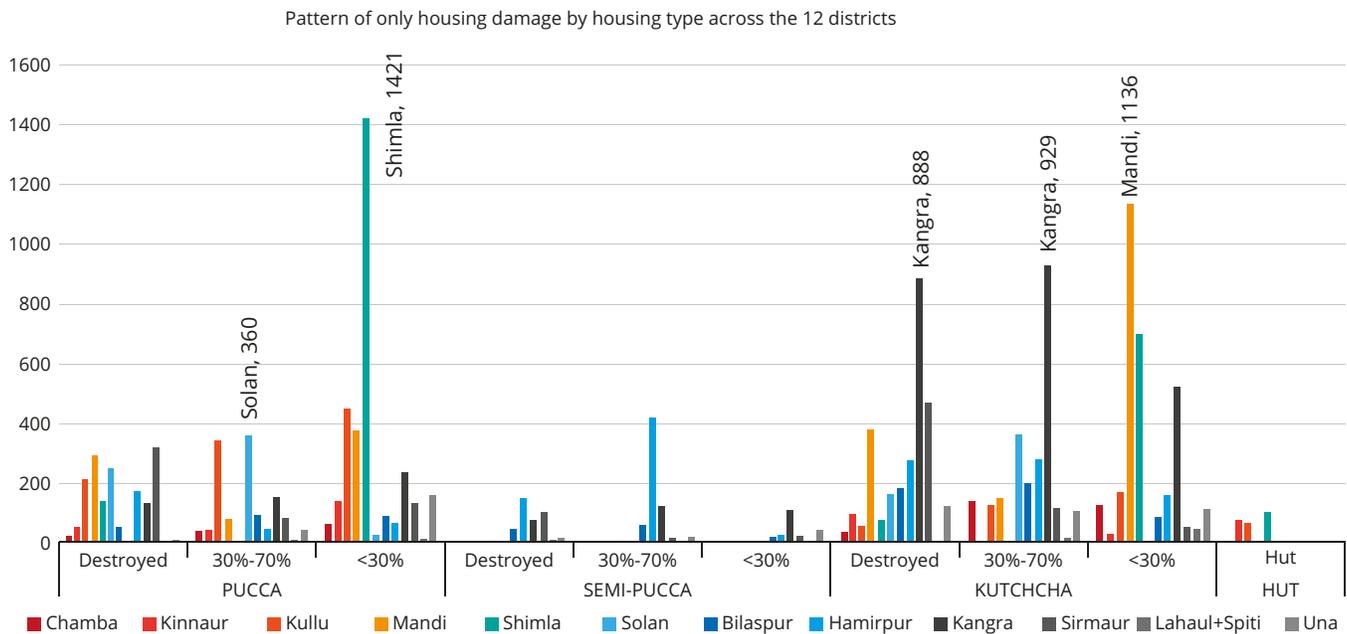
Source: PDNA.

7.5.1.1 Social Sector (Housing, Education, Health, Public Buildings and Civic Amenities)

7.5.1.1.1. Housing Sector Damage and Recovery Assessment

The 2023 monsoon-induced landslides and land subsidence caused widespread damage to housing across Himachal Pradesh. While some well-built structures withstood the impact, many homes, particularly those built in geologically vulnerable zones, collapsed or were severely compromised. In numerous cases, buildings remain standing but at risk of future failure.

Key Factors Contributing to Damage:

- Poor site selection, particularly on unstable slopes, without geological assessments
- Blocked natural drainage and prolonged heavy rainfall triggering slope failures
- Non-compliance with safety norms, especially in expanding urban settlements
- Removal of retaining walls during road-widening works, increasing vulnerability

Specific Observations:

- In Milwan village (Kangra district), where annual flooding is typically manageable, the Beas River overflowed and eroded a 150 meter stretch of the embankment, resulting in the loss of multiple homes. Residents recommended raising the embankment by 4 meters to prevent future incidents.
- Cattle sheds, critical for rural livelihoods, were widely damaged.

- Essential in-house infrastructure, septic tanks, water connections, electrical wiring, was also lost or rendered non-functional.
- Many homes lacked earthquake-resistant construction, further increasing risk.

Recovery Constraints:

- Retrofitting of partially damaged buildings is possible in some cases, but only after geological clearance confirms ground stability.
- While a few buildings were insured, most housing losses remain uninsured.

Cost Estimates:

- Damage Estimate: INR 2,284.34 crore
- Loss Estimate: INR 24.57 crore
- Total (Damage + Loss): INR 2,308.91 crore
- Recovery Needs: INR 2,353.65 crore

7.5.1.1.2. Education Sector Damage and Recovery Assessment

The PDNA assessed the impact on the education sector across all 12 districts through a two-phase evaluation in August and September 2023. Damage estimates were based on data from state authorities, field visits, and replacement cost analysis.

TABLE 7.2: Damage, loss and recovery estimates for educational facilities

District Name	Damage (INR Crore)	Damage + Loss (INR Crore)	Recovery needs (INR Crore)
Bilaspur	90.18	90.23	90.18
Chamba	13.79	13.79	13.79
Hamirpur	22.64	22.72	22.64
Kangra	56.08	56.13	56.08
Kinnaur	0.05	0.05	0.05
Kullu	23.91	23.91	23.91
Lahaul & Spiti	1.03	1.03	1.03
Mandi	17.49	17.49	17.49
Shimla	82.11	82.12	82.11
Sirmour	29.45	29.46	29.45
Solan	25.35	25.36	25.35
Una	7.05	7.07	7.05
Total	**369.13**	**369.36**	**369.13**

Source: PDNA.

Extent of Structural Damage:

- 66 schools were completely destroyed
- 204 schools suffered severe damage
- 486 were partially damaged
- 409 sustained minor damage

Impact on Supporting Infrastructure:

- 219 boundary walls damaged
- 88 WASH units required reconstruction
- 187 retaining walls were cracked, collapsed, or tilted
- 71 mid-day meal kitchens were affected, disrupting nutrition services
- 23 school access roads were washed away or narrowed
- 82 schools required bench repairs
- 11 computer labs were destroyed due to water damage to CPUs

Response and Recovery Planning:

- The state government initiated immediate relief by clearing debris and enabling schools to resume operations.
- The PWD assessed severely damaged schools and recommended that some be abandoned for safety reasons.
- A comprehensive, long-term recovery strategy is required, focused on:
  - Restoring and strengthening core infrastructure
  - Rebuilding WASH and support systems
  - Integrating climate-resilient designs
  - Exploring financial instruments and risk transfer mechanisms

The School Education Department must adopt a multi-stakeholder approach to ensure resilient reconstruction and uninterrupted education services. As per HIMUDA norms, reconstruction will follow Build Back Better principles. Land costs for relocating schools, where required, are not included in current estimates.

Cost Estimates:

- Damage (based on replacement cost): INR 369.14 crore
- Total damage and loss estimate: INR 369.39 crore
- Recovery needs: INR 369.14 crore
- Most affected districts: Bilaspur, Shimla, Kangra

7.5.1.1.3. Health Sector Damage and Recovery Assessment

The health sector faced moderate but significant damage during the 2023 extreme weather events. Primary health facilities across districts were impacted by flooding, landslides, and structural collapse, affecting service delivery at multiple levels.

TABLE 7.3: Damage, loss and recovery estimates for health facilities

District Name	Damage (INR Crore)	Damage + Loss (INR Crore)	Recovery needs (INR Crore)
Bilaspur	12.39	12.54	12.39
Chamba	9.72	9.72	9.72
Hamirpur	16.84	16.9	16.84
Kangra	36.8	37.01	36.8
Kinnaur	2.08	2.08	2.08
Kullu	19.11	19.11	19.11
Mandi	25.95	25.95	25.95
Shimla	11.73	11.73	11.73
Sirmour	32.92	33.07	32.92
Solan	1.89	1.89	1.89
Una	14.66	15.17	14.66
Grand Total	**184.09**	**185.18**	**184.09**

Source: PDNA.

Damage Assessment Approach

Estimates were based on:

- Adequate functional area of health facilities
- Standard unit replacement costs
- A damage severity factor reflecting the extent of structural impact

Scope of Damage:

- Affected facilities included:
  - Sub-Centres, Primary Health Centres (PHCs), and Community Health Centres (CHCs)
- Key elements damaged:
  - Physical infrastructure (walls, roofing, foundations)
  - Water and sanitation systems
  - Retaining walls, particularly in hilly terrain
  - Essential medical equipment and storage facilities

Recovery Strategy:

- The recovery plan focuses on restoring physical infrastructure and services using Build Back Better principles.
- Rebuilding priorities include:
  - Upgrading damaged health centres
  - Ensuring structural safety and climate resilience
  - Replacing essential utilities and WASH infrastructure

Limitations:

- The recovery estimate excludes costs for:
  - Capacity-building, such as staff training
  - Psychosocial support, including mental health services
  - These are intended to be covered under mid- and long-term planning frameworks

Cost Estimates:

- Damage estimate: INR 184.09 crore
- Total damage and loss: INR 185.18 crore
- Recovery needs: INR 184.09 crore

7.5.1.1.4. Public Buildings and Civic Amenities

Public buildings and civic amenities, essential for community services and administrative functioning, suffered considerable damage during the 2023 floods and landslides. These included government offices, community halls, and early childhood care centres such as Anganwadis.

Extent of Damage:

- 135 public buildings were affected:
  - 76 Pucca structures
  - 52 Semi-Pucca
  - 7 Kutcha
- Of these:
  - 28 were fully destroyed
  - 58 were severely damaged
  - 50 were partially damaged
- 102 Anganwadi Centres were also impacted:
  - 96 Pucca and 6 Kutcha
  - 22 were totally damaged

- 39 severely affected
- 41 partially damaged

Support Infrastructure Losses:

- Damage was also reported under the Rural Development Department, which oversees:
  - Local community buildings
  - Civic utility spaces for rural welfare

Table 7.4 shows total reported damage:

- Anganwadi centres: INR 638.03 lakh
- Rural development assets: INR 3,266.86 lakh

TABLE 7.4: Total damage on community infrastructure

	Anganwadi (INR lakhs)	**Rural Development Department (INR lakhs)**
Phase 1	277.33	2,061.50
Phase 2	360.70	1,205.36
Total	**638.03**	**3,266.86**

Source: PDNA.

Recovery Approach:

- Focused on:
  - Rebuilding and repairing essential service infrastructure
  - Enhancing structural resilience of public facilities
  - Ensuring continuity of administrative and community services

Reconstruction efforts will incorporate resilient design standards to withstand future disasters.

Cost Estimates:

- Total damage: INR 37.04 crore
- Recovery needs: INR 38.95 crore

7.5.1.2. Infrastructure (Roads and Transport)

7.5.1.2.1. Roads and Transport

The 2023 floods and landslides severely disrupted Himachal Pradesh's road infrastructure, which forms the backbone of connectivity in this mountainous state. With over 73,230 km of road network and only 317 km of rail lines, the road sector bore the brunt of the damage, especially in rural and high-slope regions.

Extent and Nature of Damage

The PDNA covered damage in six key districts, but losses were reported state-wide:

- Key impacts included:
  - Washed-away roads and bridges in flood-prone valleys
  - Landslide-induced road collapses and slope destabilization
  - Blocked or sunken roads in villages and hill-cut zones

District-Wise Highlights:

- Kullu, Mandi, Shimla, and Kangra were among the worst affected.
- Kullu and Mandi accounted for nearly 40% of total losses.
- Kullu and Bilaspur together contributed over 45% of the state's recovery needs.

Figure 7.4 illustrates that Kullu (27 percent) and Kangra (25 percent) made up over half the road damage.

FIGURE 7.4: District wise percentage of damage occurred for road and transport sector
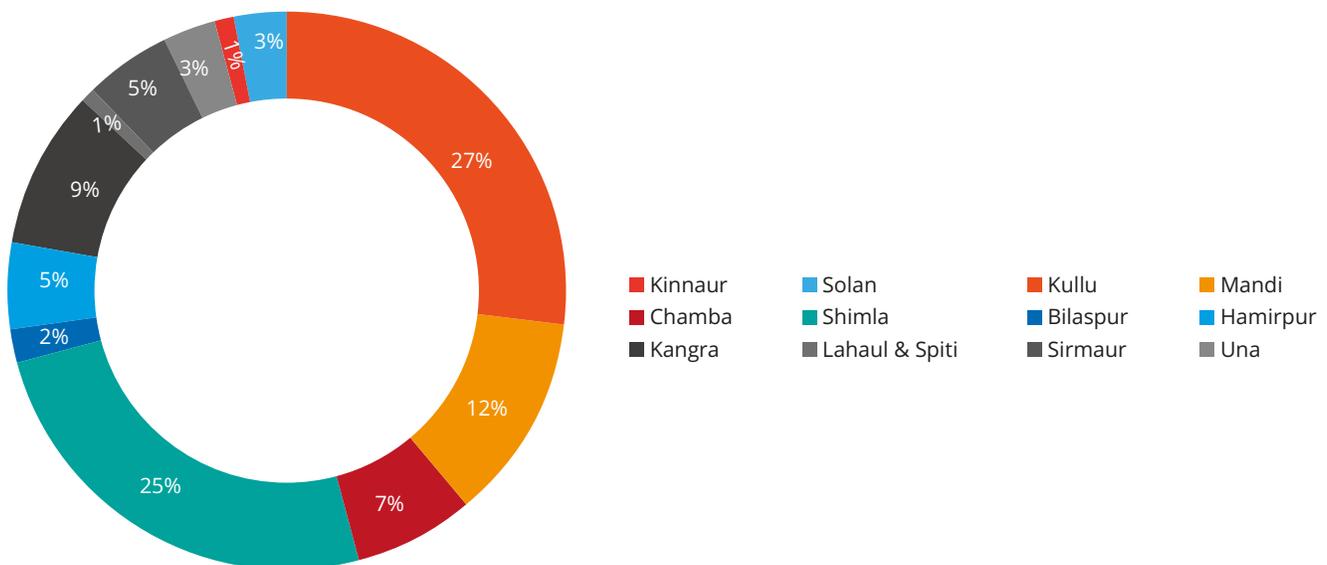
Recovery Measures:

- Removal of debris and temporary restorations were initiated as emergency relief.
- Recovery strategy includes:
  - Reconstruction of retaining walls, culverts, and embankments
  - Stabilizing landslide-prone road stretches
  - Building climate-resilient and geotechnically sound roads
- An additional INR 36 crore was allocated for Build Back Better (BBB) actions.

Cost Estimates:

- Damage: INR 1,506.40 crore

- Loss: INR 126.40 crore

- Total damage and loss: INR 1,632.80 crore

- Recovery needs: INR 2,458.30 crore

7.5.1.2.2. Productive Sector (Agriculture, Horticulture, Animal husbandry, Fisheries, Tourism)

The productive sector in Himachal Pradesh experienced moderate losses due to the 2023 floods, landslides, and cloudbursts. While no detailed narrative assessment was provided in the PDNA, the sector-wise estimates highlight the economic disruptions caused to key livelihood areas such as agriculture, horticulture, livestock, fisheries, and tourism.

Summary of Damage and Loss:

- Agriculture: INR 200.01 crore

- Horticulture: INR 289.20 crore

- Animal Husbandry: INR 53.40 crore

- Fisheries: INR 15.63 crore

- Tourism: INR 264.41 crore

Total damage and loss (Productive Sector): INR 822.65 crore

Total recovery needs: INR 822.65 crore

These figures reflect crop loss, damage to livestock and related infrastructure, disruption in fisheries operations, and sharp economic decline in tourism-dependent districts. Detailed field-level data was not included in the PDNA narrative but is expected to inform sectoral recovery planning.

TABLE 7.5: Sectoral damage and loss estimation

Sector	Sub-Sector	Damage Estimate (INR crore)	Loss Estimate (INR crore)	Damage + Loss (INR crore)	Recovery Estimate (INR crore)
Social	Housing	2,284.34	24.57	2,308.91	2,353.65
	Education	369.14	0.25	369.39	369.14
	Health	182.55	1.09	183.64	182.55
	Community Buildings and Amenities	38.95	0	38.95	38.95
	Total	**2,874.98**	**25.91**	**2,900.89**	**2,944.29**

Sector	Sub-Sector	Damage Estimate (INR crore)	Loss Estimate (INR crore)	Damage + Loss (INR crore)	Recovery Estimate (INR crore)
Infrastructure	Roads	1,506.40	126.4	1,632.80	2,458.30
	Drinking Water and Sanitation	1,849.59	818.72	2,668.31	2,228.48
	Power	213.94	65.62	279.56	213.94
	Total	**3,569.93**	**1,010.74**	**4,580.67**	**4,900.72**
Productive	Agriculture	7.81	192.2	200.01	200.01
	Horticulture	28.39	260.81	289.2	289.2
	Animal Husbandry	17.82	35.58	53.4	53.4
	Fisheries	11.22	4.41	15.63	15.63
	Tourism	43.83	220.58	264.41	264.41
	Total	**109.07**	**713.58**	**822.65**	**822.65**
Disaster Risk Reduction	DRR and Environment	0	0	0	375
	Total	**0**	**0**	**0**	**375**
Grand Total		**6,553.98**	**1,750.23**	**8,304.21**	**9,042.66**

Source: PDNA.

Insurance Coverage and Funding Gaps

Insurance penetration in Himachal Pradesh remains low, particularly in rural and hazard-prone areas. As a result, the vast majority of economic losses from the 2023 floods, cloudbursts, and landslides remain uninsured.

Total economic loss (direct + indirect): INR 8,304 crore

- Insured losses (estimated): INR 415 crore
- Uninsured losses: INR 7,889 crore

These insurance figures are based on informal estimates and discussions with sector experts, as disaggregated claim data was not available at the time of assessment.

7.6 Summary and Road Ahead

The 2023–24 monsoon events in Himachal Pradesh, marked by intense rainfall, floods, cloudbursts, and landslides, exposed critical vulnerabilities in infrastructure, housing, and service delivery systems across all districts. While the PDNA offers a comprehensive assessment of damages and recovery needs, the event also underlines the urgent need for systemic risk reduction and climate-resilient planning in the context of mountain states.

The total direct economic damage is estimated at INR 6,554 crore, with an additional INR 1,750 crore in indirect losses. Of the combined losses, only INR 415 crore was covered by insurance, leaving INR 7,889 crore in uninsured losses, pointing to a significant protection gap.

FIGURE 7.5: Economic impacts, insured and uninsured losses and funding gaps

2023 Himachal Floods Economic Impacts and Funding Gaps
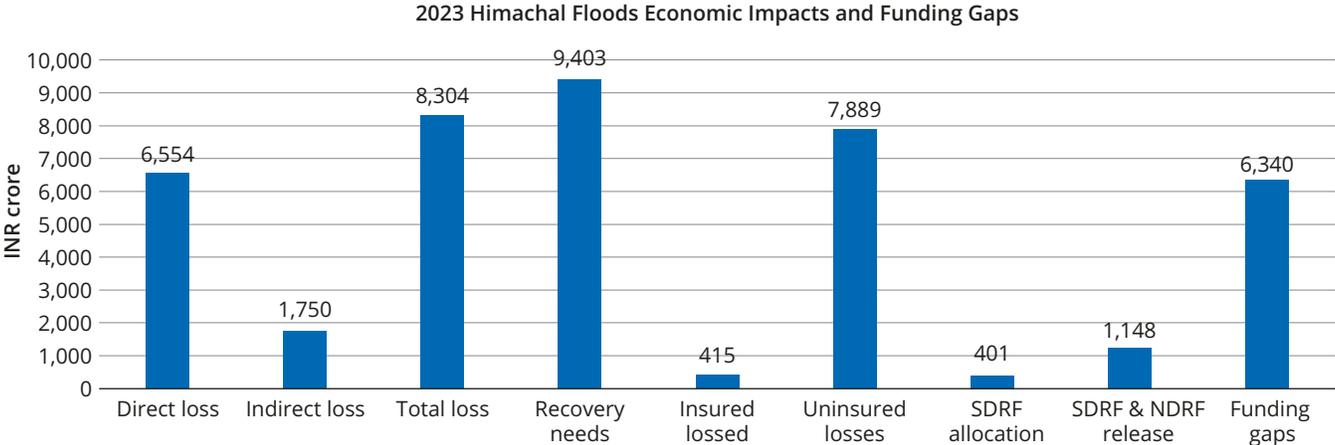
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8.1 Scale of Economic and Indirect Losses

8.1.1 Disaster Losses Are Massive, and Mostly Uncovered

Across the five EWEs analyzed, total economic losses exceeded INR 99,000 crore, of which over 90 percent were uninsured. Major events such as the 2018 Kerala Floods and 2020 Cyclone Amphan alone accounted for INR 26,720 crore and INR 35,018 crore in losses, respectively, revealing a misalignment between actual recovery needs and existing financial allocations. This underlines a critical and recurring underestimation of disaster financing requirements.

8.1.2 Indirect Impacts Surpass Visible Damage

While direct damages, such as destruction of infrastructure and housing, were severe, indirect losses often surpassed them. Losses from income disruption, service interruptions, and sectoral slowdowns ranged from INR 1,750 crore in Himachal Pradesh (2023) to over INR 16,000 crore in Kerala (2018). In the case of Cyclone Michaung (2023), indirect losses were 2.65 times higher than direct damages, highlighting the cascading impact of EWEs on local economies.

8.1.3 Insurance Coverage Remains Critically Low

Insured losses accounted for less than 6 percent of total losses in all events except the Rajasthan drought. States like Himachal recorded just INR 415 crore in insured claims, while Tamil Nadu's stood at INR 1,243 crore. By contrast, uninsured losses ranged from INR 7,889 crore to INR 33,968 crore, pointing to a vast financial protection gap that leaves households and state budgets deeply exposed.

8.1.4 Recovery Needs Overwhelm Available Resources

Estimated recovery costs, INR 31,000 crore for Kerala and INR 67,424 crore for Amphan, far exceeded the funds made available through SDRF/NDRF. These massive gaps exacerbate post-disaster vulnerability and impede timely reconstruction, demanding systemic reform in how recovery is financed.

Key insight: Disaster-related economic losses are systematically underestimated, with indirect impacts and uninsured losses driving a growing financial protection gap.

8.2 Persistent Underfunding and Financing Gaps

8.2.1 Disaster Financing Falls Drastically Short

Available data reveals a consistent and significant shortfall between estimated disaster losses and actual financing through SDRF and NDRF. For instance, the 2018 Kerala Floods resulted in economic losses of INR 26,720 crore, but only INR 3,097 crore was released via central and state disaster funds. Similarly, Cyclone Amphan caused losses of INR 35,000 crore, while financial support over five years remained under INR 6,000 crore.

8.2.2 Most Losses Are Uninsured and Absorbed by States

Low insurance penetration, below 6 percent in most events, means that the fiscal burden of recovery falls squarely on state governments and households. In the case of the 2018 Kerala floods, over 92 percent of total losses were uninsured, severely straining state budgets and delaying recovery. In the absence of scalable contingent financing, states are forced into reactive, slow, and piecemeal recovery measures.

8.2.3 Recovery Becomes Unsustainable Without Scalable Tools

These funding gaps not only delay recovery but also compromise long-term development planning. The current disaster financing architecture lacks instruments that scale with risk. Without pre-arranged, scalable financial buffers, states are locked into a reactive relief cycle. Tools like parametric insurance, catastrophe bonds, and contingency credit lines offer a way forward, but remain underutilized.

8.2.4 Unspent SDRF Can Block NDRF Assistance

Fund utilization inefficiencies further weaken the financing system. Under current rules, NDRF disbursements are reduced if SDRF balances remain unspent at the start of a financial year. This penalizes states during high-impact events. For instance, despite severe flooding in Kerala, the presence of unspent SDRF funds disqualified the state from receiving additional NDRF assistance, illustrating how rigid rules can undercut response capacity.

Key insight: Disaster financing in India suffers from both quantum inadequacy and procedural inflexibility. When funding is both insufficient and inaccessible, states are doubly disadvantaged, unable to respond at scale or plan ahead with confidence.

8.3 Delays in Fund Disbursement and Procedural Bottlenecks

8.3.1 Multi-layered Approval Processes

Accessing funds from the NDRF involves multiple steps: the state must submit an interim memorandum; an Inter-Ministerial Central Team (IMCT) must conduct field assessments; and final decisions are made by a High-Level Committee (HLC). This comprehensive process ensures thorough evaluation but can extend timelines, as seen during the 2018 Kerala floods, where central assistance was released in phases over several months aligned with procedures considerations along side relief requirements.

FIGURE 8.1: **Visual showing timeline of Kerala 2018 floods occurrence and release of Central Assistance**
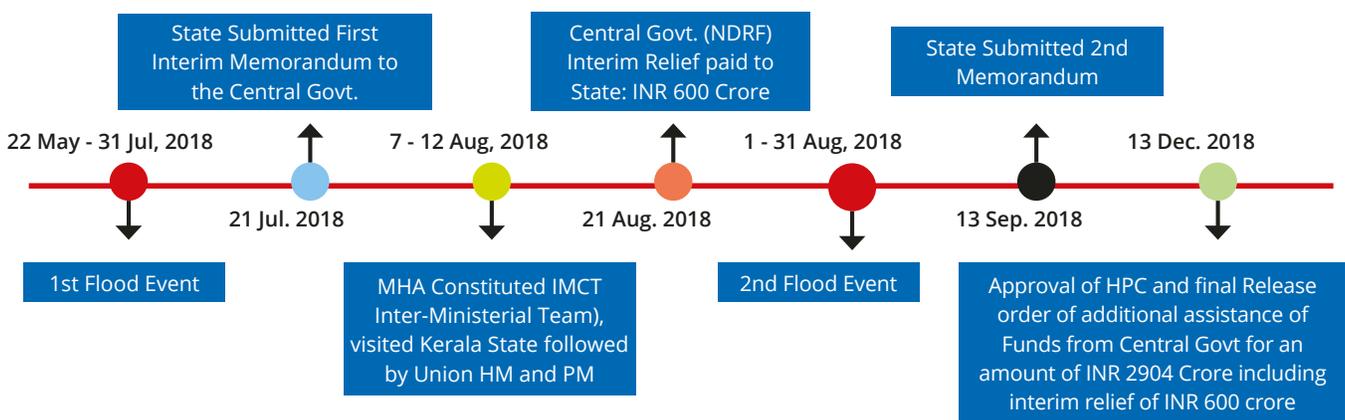
8.3.2 SDRF Release Is Conditional and Tranche-Based

The SDRF is also released in two tranches: the first between May–June, and the second only after the state submits utilization certificates, detailed expenditure statements, and maintains minimal unspent balances. These conditions, though aimed at financial prudence, often delay funds during crises when state machinery is already overstretched.

Key insight: Ensuring timely access to disaster finance is critical for its effectiveness. Beyond the total amount of funding, the ability to mobilize and disburse resources swiftly and flexibly plays a central role in meeting urgent disaster response needs.

8.4 Fragmented Data and Assessment Challenges

8.4.1 Lack of Public Access Limits Oversight

Much of India's disaster-related financial and damage data is not publicly available. Memoranda, insurance loss estimates, and even sectoral damage breakdowns are rarely published, making it difficult to track fund flows, recovery outcomes, or financing gaps. This undermines transparency and weakens evidence-based planning.

8.4.2 Inconsistent Formats Hinder Comparability

Post-disaster data, whether from memoranda or PDNA reports, varies widely in structure and depth. For example, the 2018 Kerala PDNA included detailed sub-sectors under cross-cutting themes like environment and livelihoods, while the 2023 Himachal PDNA limited this to just disaster risk reduction (DRR). Such inconsistencies obstruct inter-state learning and coordinated planning.

8.4.3 Missing & Incomplete Loss Data Skews Understanding

Reliable, disaggregated data on insured and uninsured losses is sparse, especially for private assets and informal livelihoods. This distorts the overall understanding of disaster impact and perpetuates the financial protection gap, as planning remains biased toward direct, visible damages.

8.4.4 Need for High-Resolution Socioeconomic Data

State- and district-level planning requires granular data on vulnerabilities, particularly for marginalized communities. Without this, fiscal support mechanisms may miss the most affected groups, reducing both equity and efficiency of disaster risk finance.

Key insight: Without credible, standardized, and publicly accessible data, India's disaster risk financing architecture risks being reactive, opaque, and inequitable.

8.5 Sectoral and Macroeconomic Impacts

8.5.1 Critical Sectors Repeatedly Disrupted

Across the five events studied, floods, cyclones, and droughts triggered widespread damage in key sectors:

- Infrastructure: Roads, bridges, and electricity networks were badly hit in Kerala, Himachal, West Bengal, and Tamil Nadu, delaying both response and recovery.

- Housing: Extensive housing damage occurred in rural and hilly districts, especially during the Kerala floods and Himachal landslides.

- Agriculture and Livelihoods: Cyclone Amphan, Kerala floods, and Rajasthan's drought caused major crop and livestock losses, hitting daily wage earners and informal workers hardest.

- Health and Education: Health infrastructure was damaged and schools were repurposed as relief shelters, especially in Kerala and Himachal.
- Environment: Cyclone Amphan devastated the Sundarbans' fragile mangrove ecosystem, while Himachal saw major forest loss and soil erosion.

8.5.2 Growth Slowdowns Follow Major Disasters

The relationship between EWEs and state-level GSDP growth rates indicates negative impacts, with the severity and economic consequences varying by event and region and compounded with the impact of COVID19 pandemic. In Kerala and West Bengal, major disasters such as the 2018–19 floods and Cyclone Amphan corresponded with sharp contractions in GSDP growth, coinciding with significant disruption to housing, infrastructure, and key economic sectors. Kerala's GSDP dropped from 7.4 percent to 0.9 percent in the period after the 2018 floods, and then to -8.5 percent in 2020–21 following COVID-19. West Bengal's growth fell from 3.1 percent to -7.6 percent in the period after Cyclone Amphan and COVID. Tamil Nadu and Himachal Pradesh experienced moderate slowdowns following floods and cyclones, while Rajasthan's drought effects were less immediately visible in GSDP but likely had lingering impacts due to agriculture's economic significance.

FIGURE 8.2: Analysis of state GSDP for last 10 years (2014-24)
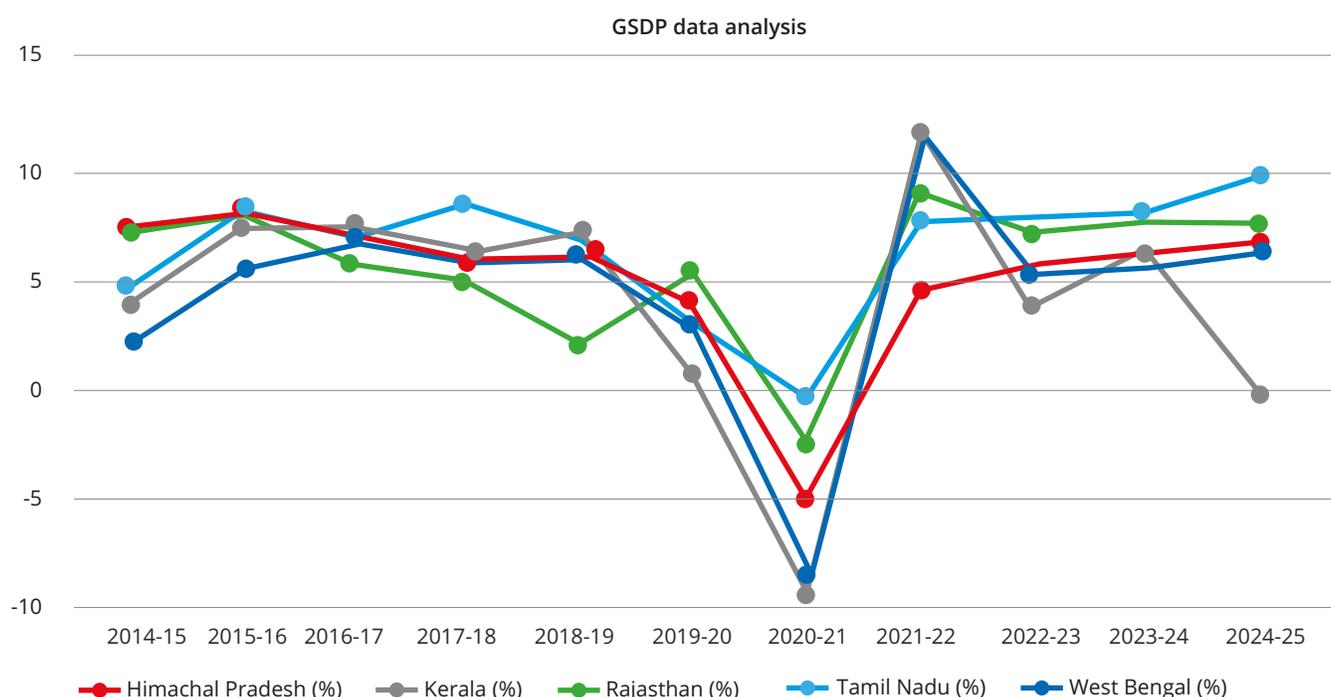
However, establishing a definitive causal relationship and quantifying the precise economic impact of both the event and recovery financing require deeper, more comprehensive analysis. Factors such as overlapping crises, variation in sectoral vulnerabilities, and the timing and pace of recovery all influence observed growth

trends. Therefore, while the initial data for these specific events indicate correlations between EWEs and economic slowdowns, further detailed macroeconomic modeling and multi-year assessments are necessary to fully understand the direct and indirect economic effects and to guide targeted financing and resilience-building efforts.

8.5.3 Uneven Recovery and Impact on Growth

Uneven recovery from the five extreme weather events studied likely contributes to prolonged development challenges, especially where delayed or incomplete financing leaves key economic sectors disrupted. While economic slowdowns followed these events, contractions cannot be attributed solely to them based on GSDP data given overlapping crises and sectoral differences. However, there is increasing evidence on the correlation between unrecovered disruptions to infrastructure, productive capacity, and supply chains with sustained economic drag and slower growth recovery. Further research is needed on detailed causal pathways, sector-specific vulnerabilities, the role of recovery financing timing and adequacy, and how these factors interact to shape the pace and equity of post-disaster economic resilience and development.

Key insight: Recovery and growth are deeply interlinked: the correlation between recovery lags and development outcomes needs to be better understood in the context of EWEs.

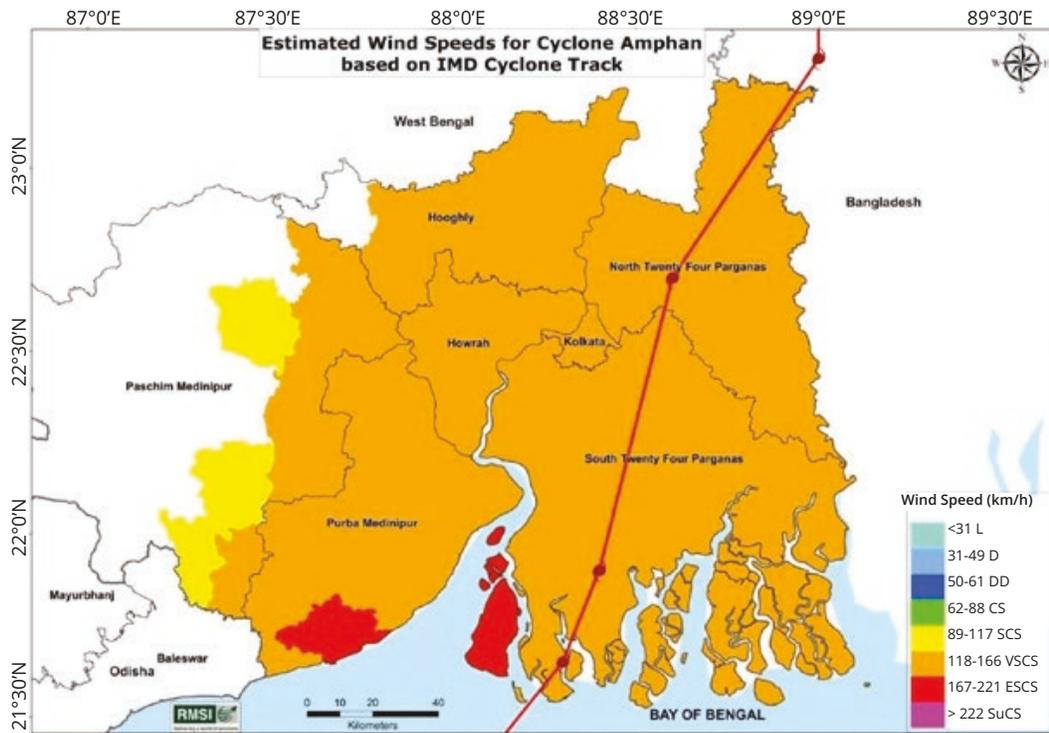## 8.6 From Relief to Resilience: The Way Forward

India's disaster risk financing system stands at a critical juncture. This study highlights persistent underfunding, massive uninsured losses, and systemic delays that undermine timely disaster response and long-term recovery. The Sixteenth Finance Commission's recommendations can address some of these challenges by enabling adaptive financing and encouraging states to adopt risk layering approaches rather than relying on singular sources of disaster funding. With the right mix of foresight, funding, and flexibility, the Finance Commission can help India move from relief to resilience.

<div align="right">

Annexure | 9

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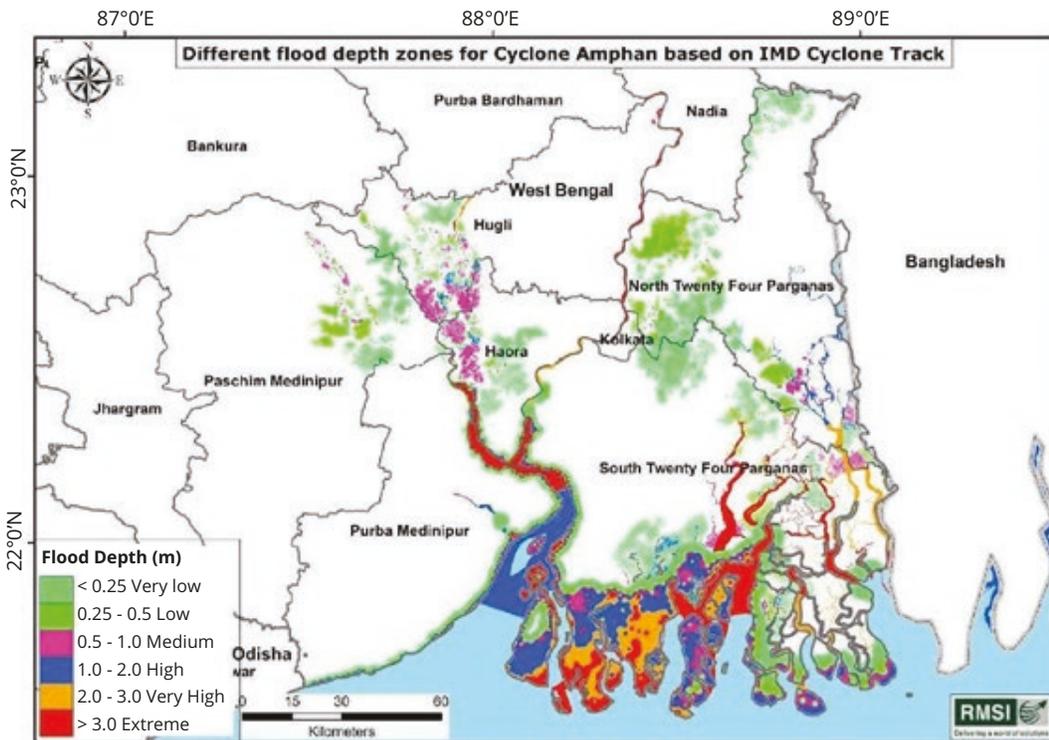## 9.1 Cyclone Amphan in West Bengal (2020-21)

Modeling of Amphan Cyclone damages and losses during the year 2020-21 was conducted using the Cyclone Web-DCRA & DSS Application, developed under the NCRMP-II program for dynamic Cyclone Impact Forecasting. The tool provided estimates of wind speed, affected population, and sector-wise and district-wise losses in the cyclone-affected areas. A sample outcome is shown below:

- Figure 9.1 indicates the estimated wind speed for cyclone Amphan based on the IMD cyclone track on 19th May 2020.

- Figure 9.2 shows the different flood depth zones for cyclone Amphan based on the IMD cyclone track on 19th May 2020.

- Figure 9.3 shows the storm surge inundation associated with cyclone Amphan.
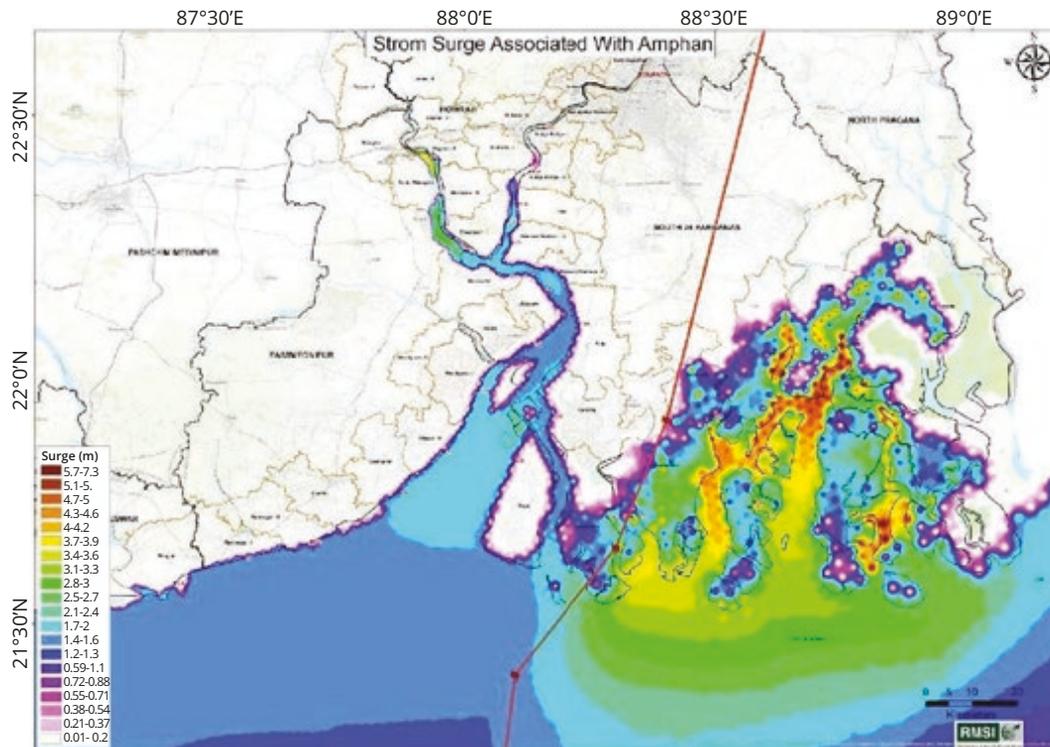
FIGURE 9.1: Estimated wind speed for cyclone Amphan based on IMD cyclone track on May 19, 2020

FIGURE 9.2: Different flood depth zones for cyclone Amphan based on IMD cyclone track on May 19, 2020

9.2 Cyclone Michaung & Floods in Tamil Nadu (2023-24)

9.2.1 Data available with RMSI

Cyclone Michaung (2023) was modeled using the Web-DCRA & DSS application. Administrative boundaries were based on the 2011 Census of India. The application provided estimates of wind speed, affected population, and losses categorized by sector and district level in the cyclone-affected areas. Figure 9.4 shows the estimated wind speed during Cyclone Michaung in Tamil Nadu, while Figure 9.5 presents the estimated wind-related losses.

FIGURE 9.4: Estimated wind speed during cyclone Michaung

Hazard Map - Wind Speeds for Cyclone Michaung Wind

Disclaimer: The hazard estimated are for the study area up to 10 m above sea level.

LEGEND

☐ State Boundary	☐ District Boundary	☐ Tehsil Boundary	☐ Village Boundary

Wind Speed (Less than 31 Km/h) Wind Speed (31-49 Km/h) Wind Speed (49-61 Km/h)

Wind Speed (61-88 Km/h) Wind Speed (88-117 Km/h) Wind Speed (117-166 Km/h)

Wind Speed (166-221 Km/h) Wind Speed (Greater than 221 Km/h)
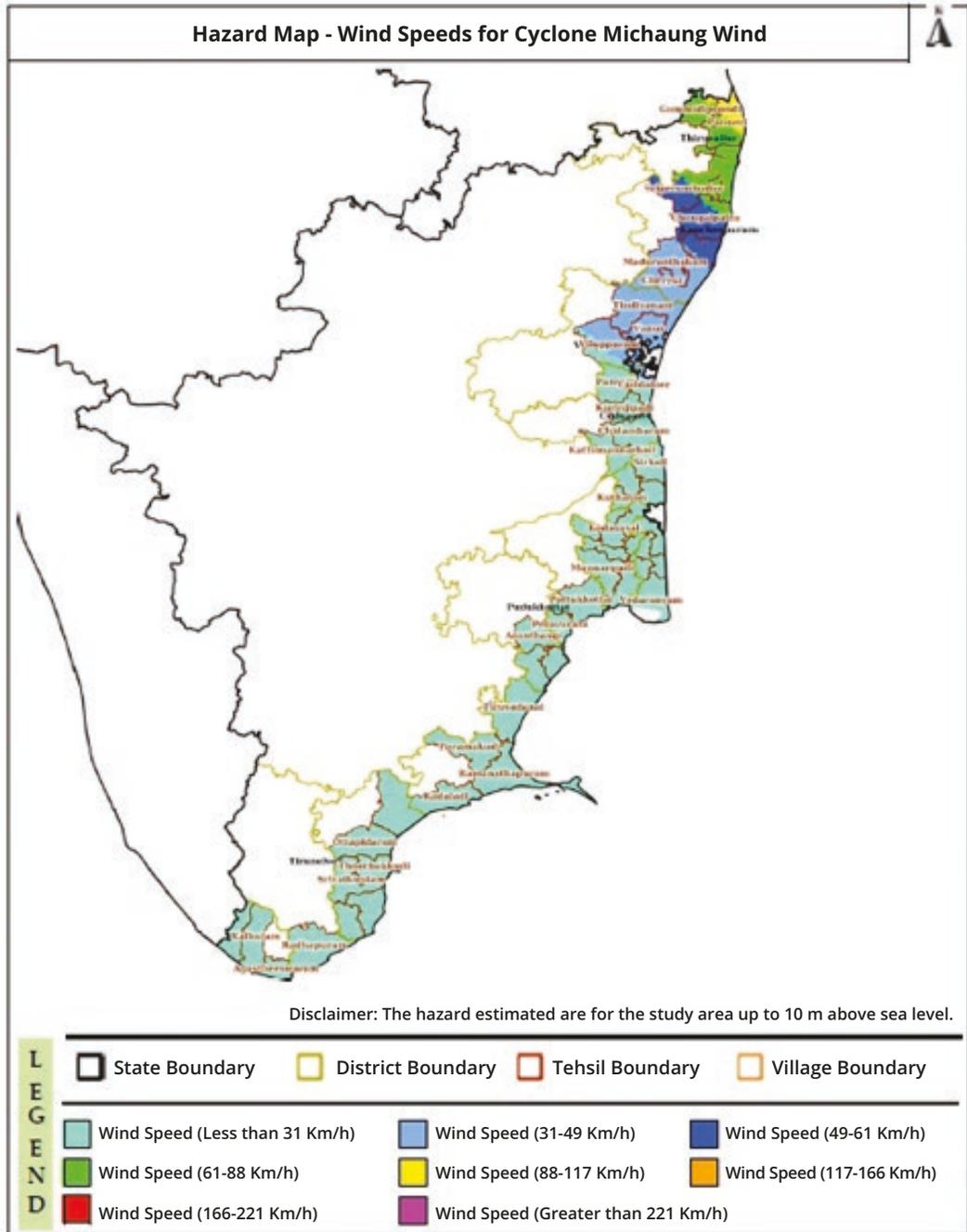
FIGURE 9.5: Estimated wind losses during cyclone Michaung

Loss Map - Losses for Cyclone Michaung Wind

Disclaimer: The losses estimated are for the study area up to 10 m above sea level.

LEGEND

- State Boundary
- District Boundary
- Tehsil Boundary
- Village Boundary

- Very Low (Less than 100 Lakhs)
- Low (100 to 500 Lakhs)
- Moderate (500 to 1,000 Lakhs)
- High (1,000 to 10,000 Lakhs)
- Extreme (Above 10,000 Lakhs)
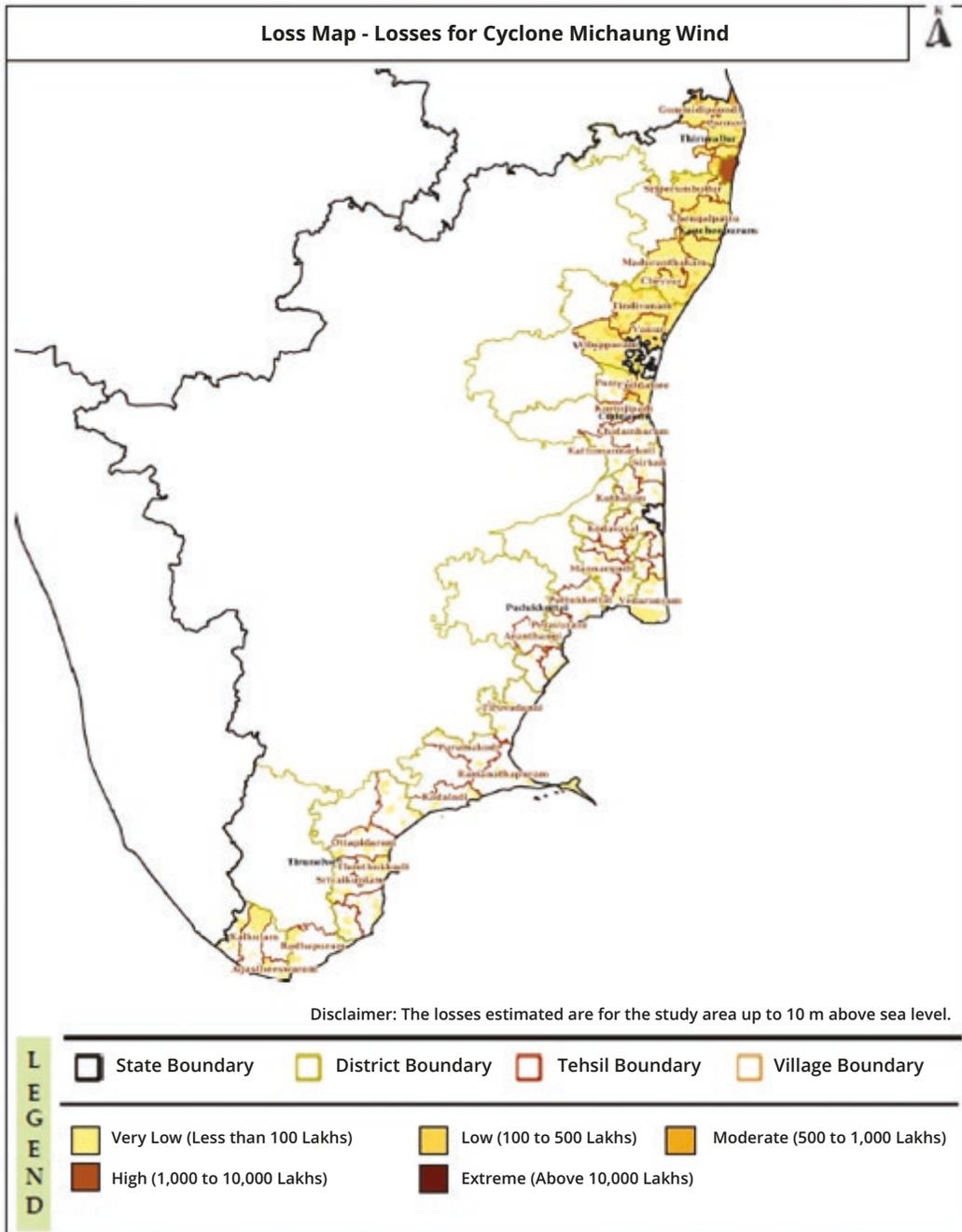
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