MAPPING CLIMATIC AND BIOLOGICAL DISASTERS IN INDIA

Study of Spatial & Temporal Patterns and Lessons for Strengthening Resilience

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MAPPING CLIMATIC AND BIOLOGICAL DISASTERS IN INDIA

Study of Spatial & Temporal Patterns and Lessons for Strengthening Resilience

Foreword

nidm

Maj. Gen. Manoj Kumar Bindal VSM

Executive Director

राष्ट्रीय आपदा प्रबंधन संस्थान
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India is one of the world's most disaster-prone countries of the world. Both hydro-climatic and biological outbreak disasters have impacted large populations and caused high mortality. Climate change impacts are known to exacerbate these disasters and devastating consequences on natural resources, food, livelihood rural infrastructure and community resources. In this context, the spatio-temporal mapping of climatic and biological disasters in India was undertaken using historical data and scientific tools to explore options to support for relief, recovery, resilience, and adaptation through integration with existing development programmes.

Uniqueness of this study is the analysis period and approach. The entire study period is divided into three time frames to understand the impacts caused by the selected disasters. These are (i) Pre- HFA (1995-2004) i.e. the period after Yokohama Strategy for Safer World, (ii) Hyogo Framework for Action (HFA) 2005-2014 and the (iii) Post HFA i.e. the Sendai Framework for Disaster Risk Reduction (After 2015). These periods are marked by new paradigms in disaster management globally and nationally.

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, India office, along with its collaborators across local authorities and governance, research, and planning fraternities, have been undertaking strides by implementing pilots and case studies on building resilience in different parts of India. National Institute of Disaster Management has collaborated as technical partner in conducting this study for the entire India which is an attempt to bring the historical records of five hydro-meteorological and three biological disasters under a common platform so that the patterns can be well understood by research community, policy planners and implementers at various levels of government. I hope the outcome of the study serves as a key decision support resource and for future studies.

Manoj K. Bindal

Message from GIZ

The study, in concept and origin, owes it genesis to the Water Security and Climate Adaptation in Rural India (WASCA), a project of German Federal Ministry for Economic Cooperation and Development (BMZ) with the Ministry of Rural Development and Ministry of Jal Shakti, Government of India, being implemented by GIZ India in selected states. WASCA works on enhancing climate-resilient integrated water resource management and has three focus areas: (1) improving planning and financing mechanisms (2) demonstrating climate-resilient water management measures (3) strengthening cooperation with the private sector.

Following the first wave of COVID-19 last year, it became imperative to better understand the impacts of disasters on rural development programmes and approaches. Thus, WASCA and the National Institute of Disaster Management (NIDM) collaborated on an evidence-based research on mapping the major impacts of selected climatic and biological disease outbreak disasters in India. This study aimed at understanding the changing trends in spatial and temporal distribution of the disaster events and their impacts during 1995-2020, i.e., mortality since Yokohama period to the Sendai Framework period. The study also includes analysis of climate change projections, multi-level poverty indicators, key strategies and programmes in reference to addressing the impact of climate change in terms of disaster patterns.

I would like to take this opportunity to thank the NIDM team, especially Executive Director of NIDM, New Delhi, Maj. Gen. Manoj K. Bindal, for his guidance and Prof. (Dr.) Anil K Gupta, Head – ECDRM for the framework development and coordination. We acknowledge the contributions of Mr. Shashikant Chopde (Team Leader), Dr. Sreeja S Nair (DRR Expert), Ms. Swati Singh (Climate and Environment Expert) and Dr. Sonal Bindal (Climate and Biological Expert). I also appreciate the efforts of the WASCA team, specifically Dr. Vaibhav Sharma, Dr. Jagdish K Purohit, Mr. Krishan Tyagi and Ms. Meekha Hannah Paul in the development of this publication.

The learnings will contribute towards strengthening the Composite Water Resources Framework developed under WASCA project, which is being used for planning water security in 5465 Gram Panchayats across 5 states. Further, I hope this unique study will be of great value in developing climate smart and risk sensitive programmes, particularly for the vulnerable communities and sectors such as agriculture, rural development, women and child development as well as the poverty alleviation programmes including employment generation schemes such as Mahatma Gandhi NREGA and others.

Rajeev Ahal
Director, Natural Resource Management and Agroecology, GIZ India

Preface

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Resilient India - Disaster Free India
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सत्यमेव जयते
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Impacts of climate change coupled with anthropogenic anthropological, ecological and developmental changes aggravated disaster occurrences and impacts on people, infrastructure and resources. Past disaster data serves as key strategy for risk assessment as well as in prioritizing the focus on particular hazard types and geographical regions for effective risk mitigation and disaster management strategies. Various strategic interventions over the time starting from UN-IDNDR during 1990's marked national and local implications in terms of institutional, legal and policy planning impacts vis-à-vis assessing and addressing the factors of risk and vulnerability,

Recognising this fact and that the national and local programmes and schemes of development under various sectors, for example, water & sanitation, urban, rural, agriculture, health, forestry, etc., can serve as vital pathways offering key entry points for mainstreaming disaster risk reduction and climate resilience at different levels. Rural development programmes including the hygiene promotion mandates like that under WASCA, steered by Govt. of India under Ministry of Rural Development, calls for concerted efforts and also utilising the opportunities through flagship programmes like Mahatma Gandhi NREGS. GIZ in India has been stressing on promoting climatic resilience through a combination and policy and ground actions through integrated programmes at various levels and NIDM had partnered in some of these interventions to draw policy and capacity building lessons.

The current study has been undertaken to draw the patterns and present on maps to enable effective strategic interpretations and offer decision support system for prioritising resources and efforts on hazard specific and geographical scales. The study covered the key hydro-climatic disasters and biological outbreak disasters in India for three strategic periods starting pre-HFA period. The research team hopes the outcome would be useful in fine tuning risk reduction, adaptation and mitigation programmes across disaster management and climate change domains at all levels in the country.

Anil K. Gupta

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Abbreviations

AB-PM JAY	Ayushman Bharat Pradhan Mantri Jan Arogya Yojana
ASHA	Accredited Social Health Activist
BMTPC	Building Materials and Technology Promotion Council
CDRC	Central Drought Relief Commissioner
CMG	Crisis Management Group
CRED	Centre for Research on Epidemiology of Disasters
CWWG	Crop Weather Watch Group
DDMA	District Disaster Management Authority
DENV	Dengue Virus
DISCOMs	Power Distribution Companies
DM Act	Disaster Management Act 2005
DPAP	Drought Prone Area Programme
DRR	Disaster Risk Reduction
EM-DAT	Emergency Events Database
GEAG	Gorakhpur Environmental Action Group
GoI	Government of India
GSDP	Gross State Domestic Product
HDI	Human Development Index
HFA	Hyogo Framework for Action (2005-2015)
IMD	India Meteorological Department
ISRO	Indian Space Research Organization
IWRM	Integrated Water Resources Management
JE	Japanese Encephalitis
IPCC	Intergovernmental Panel on Climate Change
Mahatma Gandhi NREGS	Mahatma Gandhi NREGS: Mahatma Gandhi National Rural Employment Guarantee Scheme
MoES	Ministry of Earth Sciences
MoHFW	Ministry of Health and Family Welfare
NCDC	National Centre for Disease Control
NCMC	National Crisis Management Committee
NDMA	National Disaster Management Authority
NDMRF	National Disaster Mitigation and Response Fund
NEC	National Executive Committee
NBSS & LUP	National Bureau of Soil Survey & Land Use Planning
NVBDCP	National Vector Borne Disease Control Program
OSDMA	Odisha State Disaster Management Authority
PDNA	Post Disaster Need Assessment
PRIs	Panchayati Raj Institutions
PWD	Public Works Department
RKDP	Rebuild Kerala Development programme
ROH&FW	Regional Offices for Health and Family Welfare
SARS	Severe Acute Respiratory Syndrome
SDMA	State Disaster Management Authority
SEC	State Executive Committee
SFDRR	Sendai Framework for Disaster Risk Reduction (2015-2030)
SW	South-West
UDA	Urban Development Authority
ULB	Urban Local Bodies
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization

Executive Summary

During 1995-2020, a total of

1058 Climatic Disaster

events (floods, cyclones, droughts, cold waves and heat waves) were reported

Spatio-temporal mapping of climatic and biological disaster outbreak in India has been undertaken using historical data and scientific tools to explore options to support for relief, recovery, resilience, and adaptation through integration with existing development programmes. Floods, Droughts, Cyclones, Heat Waves and Cold Waves, Dengue, JE and COVID-19 have been considered, given their widespread occurrences and impacts in India. In addition, multi-hazard assessments are carried out for combined climatic, combined biological and combined climatic and biological disasters. Data is compiled from hand-scanned government documents, international reports on disaster and disease outbreaks and scientific literature analysis. Three time-periods have been selected: pre-HFA (1995-2005), HFA (2005-2015) and post-HFA (i.e., Sendai period 2015-2030).

Large tracts of India are prone to Floods, Droughts, Cyclones, Cold Waves, and Heat Waves. The prominent biological disasters include Dengue, Japanese Encephalitis and COVID-19. Both climatic and biological disasters have impacted large population and caused high mortality.

The study analysed the patterns of disasters only at national and state level and not at the finer resolution given the limitations of data availability and challenges of aggregating data in the context of changing administrative boundaries at lower level. However, based on the outcome of this study, taking this assessment further down to district and lower levels has also been recommended.

Spatio-temporal distribution of disasters in India

- **Temporal**

During 1995-2020, a total of 1058 climatic disaster events (floods, cyclones, droughts, cold waves and heat waves) were reported (till end of October). A total of 420 (pre-HFA), 356 (HFA) and 282 (post-HFA) incidents were registered. Floods accounted for 33 per cent of India's overall number of climatic disaster incidents, followed by heat waves (24 per cent), drought (22 per cent), cold waves (16 per cent), and cyclones (5 per cent).

There was one per cent decrease in annual number of floods during HFA relative to pre-HFA while it increased by two per cent during the post-HFA/Sendai period. Similar pattern of temporal variation is observed for droughts, cyclones, and cold waves. However, heat waves have steadily increased over the three periods.

It is noteworthy that biological disasters (JE and Dengue) have shown increasing trend in annual average number of incidences across the three periods. Further, India currently has the largest number of confirmed cases of COVID-19 in Asia.

- **Spatial**

Floods are very common in almost entire India with highest number of incidents in Bihar, followed by West Bengal, Assam, Manipur and Tripura during 1995-2020. 33 of the 36 States and UTs experienced droughts during 1995-2020. Andhra Pradesh, Telangana and Rajasthan witnessed droughts more than 15 times, whereas states such as Karnataka, Bihar, Chhattisgarh and Odisha have faced drought more than 10 times.

During 1995-2020, 11 out of 36 States and UTs were impacted by cyclones. Highest number of cyclones occurred in the Bay of Bengal area; Andhra Pradesh experienced maximum number followed by Tamil Nadu, Odisha and West Bengal. Maharashtra had the largest number of cyclones, followed by Gujarat on the western coast of the Arabian Sea. In Andhra Pradesh, number of cyclone incidents decreased whereas it increased in Odisha and Tamil Nadu during the post-HFA period. The increase is observed in the case of Maharashtra.

Twenty-seven out of 36 States and UTs experienced heat waves during 1995-2020 with highest number in Odisha, followed by Maharashtra, West Bengal and Rajasthan.

In 24 out of the 36 States and UTs, cold waves occurred during 1995-2020. Uttar Pradesh recorded the highest number, followed by Rajasthan and Bihar. The number of incidents increased during the post-HFA period in Madhya Pradesh, Jharkhand, Gujarat, Chhattisgarh and Uttarakhand and Himachal Pradesh. Further cold wave incidences started in four states (Tripura, Arunachal Pradesh, Sikkim and Meghalaya) in post-HFA. Twelve states experienced more than 20 outbreaks of JE and Dengue during 1995-2020.

During 1995-2020, 11 out of 36 States and UTs were impacted by cyclones.

Scale of implications of disasters—Temporal and Spatial

Spatio-temporal distribution of the impacts of the select five climatic disasters and three biological events are mapped. To compare the impacts, the statistics on loss of human lives/deaths is used as it is the only data that is consistently available across the analysis period of 1995-2020. Apart from the actual number of people affected, life loss per 100,000 population is presented temporally (across pre-HFA 1995-2005, HFA 2005-15 and post-HFA 2015-20) and spatially (across states) to capture the variation in geographical area and population density of states.

- **Floods**

There is no significant change over pre-HFA, HFA and post-HFA periods in distribution of annual average number of human-lives loss by flood. The mortality due to floods has been very high in the states of West Bengal, Uttar Pradesh and Bihar, followed by Gujarat, Andhra Pradesh, Karnataka and Kerala. In terms of annual average number of lives loss during 1995-2020, Uttar Pradesh, Bihar, West Bengal, Gujarat, Karnataka, Andhra Pradesh, Kerala and Uttarakhand, recorded more than 100 deaths. Flood mortality varies from state to state with 25 of the 36 states and UTs reporting flood related deaths.

Flood deaths per 100,000 population is highest in Arunachal Pradesh, followed by Himachal Pradesh, Sikkim and Andhra Pradesh. Although UP ranks first in the total number of fatalities, it ranks 18th in mortality per 100,000.

Flood mortality varies from state to state with 25 of the 36 states and UTs reporting flood related deaths.

- **Droughts**

Although there are no direct deaths due to drought, the agrarian crisis, increasing debt, migration and farmer suicides are the major social impacts. During the analysis period, major droughts were reported during 2002, 2009 and 2015. Number of districts declared drought affected was 383, 338 and 273, respectively during 2002, 2009 and 2015. More than 25 per cent of the districts in the country were declared drought affected during 2001, 2004, 2012, 2014, 2016 and 2018. During the Sendai Framework period, there is an increase in the frequency of drought.

- **Cyclones**

The mortality rate due to cyclonic storms was highest during the Pre-HFA period with very significant share of deadliest 1999 Orissa Super Cyclone.

The number of loss of human lives due to cyclonic events has shown a declining trend in HFA, considering the overall annual number of human life loss. Although the frequency of cyclones in Odisha is less than Andhra Pradesh and Tamil Nadu, human life loss is very high compared to other states and UTs. Mortality due to cyclone is showing an increasing trend in Tamil Nadu and Maharashtra during post-HFA.

- **Heat Waves**

The temporal distribution of human life loss due to heat waves shows that the total number of human life loss during the pre-HFA, HFA and post-HFA constitute 30, 40 and 30 percent of the total life loss during 1995-2020, respectively.

Heat Wave related deaths show an increasing trend in most of the states including Andhra Pradesh, Uttar Pradesh, Bihar, Maharashtra, Telangana and Jharkhand in Post-HFA period, while it has reduced significantly in Delhi and Tamil Nadu. Other states such as Punjab, Odisha, Madhya Pradesh and West Bengal also show a decreasing trend in post-HFA. Telangana was formed in the year 2015 and hence most of the reports are appearing in post-HFA only.

Heat Wave deaths per 100,000 population were highest in Maharashtra, followed by Kerala, Tamil Nadu and Delhi.

- **Cold Waves**

The total number of human life loss due to Cold Waves during pre-HFA, HFA and post-HFA was 35 per cent, 44 per cent and 21 per cent, respectively.

Highest number of Cold Wave related deaths were reported in Uttar Pradesh (accounting for 26 per cent of the total deaths in India), followed by Bihar and Punjab. Increasing trend is seen in several states including, UP, Jharkhand, Uttarakhand, Jammu & Kashmir, Assam, Meghalaya, Chandigarh and Tripura in the post-HFA period. In contrast, Delhi, Punjab, Haryana, Himachal Pradesh and West Bengal show decreasing trend in post-HFA.

Delhi witnessed highest number of human life loss per 100,000 population. Cold Wave related deaths decreased considerably in Delhi where it was highest in Pre-HFA period. Uttar Pradesh stands in 9th position in terms of loss of life per 100,000. Jharkhand and Sikkim are also showing increasing trend in term of loss of life.

Number of districts declared drought affected was 383, 338 and 273, respectively during 2002, 2009 and 2015.

Composite Mortality for Climatic Disasters

Four disasters have been selected for analysing overall mortality—Floods, Heat Waves, Cold Waves and Cyclones. Cyclones accounted for 48 per cent of India's overall human life loss due to climate-related disasters, followed by heat waves (26 per cent), floods (18 per cent) and Cold Waves (8 per cent).

The highest number of deaths associated with climatic extreme events was recorded in Uttar Pradesh, followed by Odisha, Bihar, Andhra Pradesh, West Bengal, Gujarat, Punjab, Maharashtra, Rajasthan, Tamil Nadu and Madhya Pradesh. Unlike the total number of deaths, the deaths per 100,000 population is highest in Arunachal Pradesh followed by Andhra Pradesh, Himachal Pradesh, Odisha, Sikkim, Uttarakhand and Mizoram. UP state that reported highest total number of deaths stands at 13th position in deaths per 100,000 population.

Biological outbreak disasters

- Dengue: The annual average number of human life loss has steadily increased across pre-HFA, HFA and post-HFA periods. Likewise, it is showing an increasing trend in most of the states. Himachal Pradesh showed highest deaths per 100,000 population, followed by Kerala.
- JE: In contrast to Dengue, the annual average number of human life loss has decreased across pre-HFA, HFA and post-HFA periods. UP ranks highest on total deaths, while Andhra Pradesh in terms of per 100,000 population.
- COVID-19: Maharashtra ranks highest in terms of deaths followed by Karnataka, Andhra Pradesh and Tamil Nadu.

Prevailing resilience mechanisms and common responses

Coping mechanisms and common responses span across local (household and community) to district to national levels. Households and communities undertake local level responses by using the available means, resources, and traditional knowledge, and understanding of local context. For example, community responses to floods comprise mitigation (e.g. raising of handpumps platforms and stilt houses) and preparedness (e.g. river-flow monitoring and early warning) apart from their role in rescue and relief. In case of droughts, communities rationalise use of available water by shifting to less water-intensive crops, protect livestock by storing extra crop residue, and revive traditional water management systems. The community response to cyclone includes mitigation (e.g. raised the platforms of tube wells and preserving coastal mangroves), preparedness (e.g. keep themselves updated and informed about cyclone situation and storing dry food and drinking water), and rescue and relief. For mitigating impacts of heat waves, there are examples of communities on adopting appropriate traditional housing designs. In addition, there are examples of changes in community behaviour during disasters such as staying indoors during heat / cold wave.

Institutional responses at district, state and national levels are driven by policies, plans, programmes/ schemes and budget. The NDMA, SDMAs and DDMAs are responsible for prevention and mitigation, preparedness and response, and recovery and reconstruction measures at corresponding level. Authorities work with government departments through horizontal and vertical coordination. There are disaster-specific guidelines, plans and budgetary provisions (NDRMF) for disaster management in India. Institutional response mechanism for each of the selected disasters are also discussed in the report.

Understanding climate change impacts on disasters observed

This chapter explores how climate change is likely to exacerbate vulnerability of various states of India to the five climatic disasters. It also indicates which states are likely to need more efforts at reducing exposure and susceptibility. Vulnerability is multi-dimensional and comprises an array of inter-related factors. And, poverty is both cause and consequence of disasters. Given the limitations of data availability we assess vulnerability by multiplying two parameters - level of exposure in terms of number of disaster events, and poverty. Weighted overlay method is used for ranking states on scale of 1 to 5 on exposure and poverty. For poverty we consider values of Multi-dimensional Poverty Index (MPI) developed by Oxford Poverty and Human Development Initiative (OPHI) that uses data of NFHS-3 (2005-06) and NFHS-4 (2015-16).

The top-ranking states for addressing increasing impacts of climate change on frequency and intensity of disasters are: Floods (UP, Bihar, Assam); Droughts (Rajasthan); Heat Waves (Rajasthan, Maharashtra and Madhya Pradesh); Cold Waves (Rajasthan, Uttar Pradesh); Cyclones (Maharashtra, Gujarat and Kerala).

Programmes and schemes on disaster management

As per the Disaster Management Act 2005 of Government of India, funding mechanisms are to be envisaged by the Ministries and Departments within their budgetary allocations for the purpose of disaster risk management under the Centrally Sponsored Schemes (CSS). The Act lays the need for mainstreaming of the DRR by making budgetary arrangements for the purpose by the respective Ministries and Departments within their overall agenda. In addition, all Central Ministries are required to designate 25 per cent of their programmes budget of each CSS as flexi-fund that can be utilised for mitigation, prevention, recovery and restoration of activities for DRR. Specific programmes and schemes of various Ministries/ Departments along with their key features (geographical scope, thematic etc.) that address disaster risk are provided. The programmes/ schemes are grouped by: disaster management; agriculture, NRM and livelihoods; housing and infrastructure; environment protection and conservation; and insurance and risk transfer.

Strategic lessons and recommendations

The study comes up with a number of valuable lessons and recommendations for strengthening disaster reduction system and resilience in India through interventions related to policy, institutional, programmatic/ schemes and financial allocations.

The top-ranking states for addressing increasing impacts of climate change on frequency and intensity of disasters are: Floods (UP, Bihar, Assam); Droughts (Rajasthan); Heat Waves (Rajasthan, Maharashtra and Madhya Pradesh); Cold Waves (Rajasthan, Uttar Pradesh); Cyclones (Maharashtra, Gujarat and Kerala).

Introduction

"

Disaster reduction has progressed significantly, in India and globally. A key feature of shift across the three policy regimes on disaster reduction is from emphasis on vulnerability reduction (Yokohoma strategy period) to promoting a paradigm shift from response and relief-centric approach to prevention and mitigation (Hyogo) to promoting systemic (integrating SFDRR, SDG, Paris Agreement and Urban Agenda) disaster reduction

1.1. Context

Hydro-climatic disasters and related disease epidemics account for more than three fourth of disasters globally. Climate change impacts are known to exacerbate these disasters with devastating consequences on infrastructure, natural resources, food, livelihood and community resources. Damage and losses due to disasters depend on factors of vulnerability. These include an ever-growing population, socio-economic inequalities, rapid urbanisation, poorly planned industrialisation, growth intensification in high-risk areas, environmental degradation, etc. Climate change exacerbates the vulnerabilities and the impact of disasters on social, economic and environmental sectors.

As per the EM-DAT (Natural Disasters 2019, CRED, 2020) there were 396 major natural disasters recorded in the year 2019, with 11,755 deaths, 95 million people affected and 103 billion US$1 in economic losses across the world. Among the continents, Asia suffered highest level of impact and accounted for 40 per cent of disaster events, 45 per cent of deaths and 74 per cent of the total affected population. India was hit hardest and recorded nearly 20 per cent of the total deaths and 24.5 per cent of the total number of people affected. Floods were the deadliest type of disaster accounting for 43.5 per cent of deaths, followed by extreme temperatures (25 , mainly due to heat waves in Europe) and storms at 21.5 per cent. Storms affected the highest number of people (35 per cent of the total affected), followed by floods (33 per cent) and droughts (31 per cent).

Disasters are increasingly being seen as a sustainable development challenge. Although hazards are natural, disasters are the outcome of complex interactions of vulnerable condition with these natural hazards. Most of the risk assessment studies in India were actually hazard centric. Maps prepared by scientific and technical agencies like IMD, CWC, GSI mostly depict the areas prone to hazards like earthquake, floods, cyclone, etc., due to natural factors like rainfall, geological or atmospheric conditions. Building Materials and Technology Promotion Council's (BMTPC's) Vulnerability Atlas of India was one of the unique attempts for bringing together and analysing hazard maps along with both demographic and housing census data. These maps are available for three hazards only. Hazards like drought, heat wave, cold wave are not included in the BMTPC study since their impact on build environment is very limited or long-term.

Uniqueness of the present study is due to the analysis periods and approach. Present study is purely based on the impact on human life due to five major climate-related disasters and three epidemics/disease outbreaks which affects most of the country. Analysis period is same for all the disasters. Due to the non-availability of consistent state level data and time constraints, several diseases like malaria, hepatitis, jaundice, swine flu and cattle epidemics were not included in the study.

Though the implications of climate change on water resources, agriculture, rural systems and disaster impacts have been studied and reported widely (Gupta & Nair, 2012; Clapp et al, 2017; Kelman 2017; Goyal et al., 2018; Gupta et al. 2020; etc), there are certain gaps that exist in understanding effective levers to reduce potential impacts of disasters based on a systematic analysis of past disasters (both climatic and biological), impact trends and manifestations of climate change at the national-level. It was also realised that presenting the information spatially and temporally, i.e., across evolution of international policy regimes on disaster reduction - Yokohoma strategy (pre-Hyogo period), Hyogo and post-Hyogo (Sendai) frameworks, can aid prudent decision support system for effective planning, prioritization, and mainstreaming disaster resilience and climate change adaptation into development schemes, programmes and actions. Hence, the innovative strategic study for mapping of climatic and biological disaster risks in India, considering the three international policy periods has been undertaken by GIZ and NIDM in India.

There were 396 major natural disasters recorded in the year 2019, with 11,755 deaths, 95 million people affected and 103 billion US$ in economic losses across the world.

The study period, i.e., 30 years is reasonable enough for statistically significant analysis. The entire study period is divided into three sub-periods, i.e. Pre-HFA (1995-2004) i.e. the period after Yokohama Strategy for Safer World, Hyogo Framework for Action (HFA) 2005-2014 and the Post HFA i.e. the Sendai Framework for Disaster Risk Reduction (after 2015). These periods are marked by new paradigms in disaster management globally and nationally. Recent UN Frameworks, such as the SFDRR is well linked to sustainable development goals and Paris Agreement as well. There are several common indicators in SFDRR and SDG Monitoring Frameworks.

In lines with the Yokohama strategy, Government of India initiated a central sector scheme, and holistic disaster management capacity building become a top agenda. Under this scheme, Disaster Management Centres (DMCs) were set up in Administrative Training Institutes in all the states and UTs, and a National Centre for Disaster Management (NCDM) was set-up in IIPA (under the Union Agriculture Ministry). High Powered Committee on Disaster Management was set up and its report was released in the year 2000, which paved way to the new institutional, legal, financial and technological framework of disaster management in the country. Based on the recommendations of HPC, National Centre for Disaster Management was upgraded to National Institute of Disaster Management (NIDM) in 2003.

This period also witnessed the first paradigm shift in approach from relief-centric to mitigation and preparedness-centric approach. Initiatives on setting up State Level Disaster Management Authorities and preparation of disaster management plans were at state and district levels also happened during the period. This period also marked by the GOI- UNDP (2002-2008) project. Natural Disaster Risk Management Programme was launched in 169 multi-hazard prone districts across 17 states. DM plans were prepared in all the programme districts and EOC were set up. Community Based Disaster Preparedness (CBDP) was the main objective of the programme.

Hyogo Period also witnessed several changes in the Disaster Management System of the country. Disaster Management Act was enacted in the year 2005. It is worthwhile to notice that the Act recognises damages to environment under the purview of the definition of disaster. Post DM Act institutional framework has been set up in all the States for multi-hazard disaster Management with focus on preparedness and mitigation. SDMAs and DDMAs were set up across the country and SDM Plans and DDM Plans were also formulated by most of the states. Few states set up State Institutes for Disaster Management, e.g., Gujarat, Chhattisgarh, Uttar Pradesh and so on.

National Disaster Management Policy of India was released in the year 2009 and a series National Disaster Management Guidelines were also released during 2005-10 period. This period marked the 2nd paradigm shift where environment-disaster linkages were also well recognised with climate change impacts and importance of climate adaptation and resilience in Disaster Management. Programme support by multi-lateral and bilateral agencies were also showing similar trend. Examples are GIZ- MoEF, EPDRM programme and the sub-programme EkDRM implemented by NIDM. GoI-UNDP DRM Program was followed by a Disaster Risk Reduction (DRR) Programme (2009-2013), implemented in 26 states, 78 districts, and 56 cities, which aimed to strengthen the state and district disaster management authorities and city administrations to undertake DRR activities as outlined in the DM Act 2005 and National DM Policy 2009. Subsequent to this, the GoI-UNDP Programme for "Enhancing Institutional and Community Resilience to Disasters and Climate Change (2013-2017)" was implemented to provide technical support to strengthen capacities of government, communities and institutions to fast-track implementation of the planning frameworks.

Post Hyogo i.e. Sendai Framework for DRR is the most comprehensive and integrated framework with special focus on risk reduction and building back. Inclusive DRR and Climate Smart DRR and development are the key principles of this framework. National Disaster Management Plan in lines with SFDRR was released in the year 2016. Central Ministries also came up with their DM Plans in lines with National Plans. Post Disaster Need Assessment (PDNA) methodology was customised and adapted by the Government of India in the year 2019. National Level Disaster Management Information System (NDMIS) with dedicated module on damage and loss reporting developed by MHA- NDMA with the support of UNDRR and UNDP due cater the needs of monitoring the targets under SFDRR.

The period 1995-2020, divided into three sub periods was used to understand the effectiveness of the major initiatives on DM/DRR and how far they helped in reducing the impact on human lives due to disasters. State-level analysis is carried out since DM is a state subject and district level analysis could not be done due to non-availability of disaggregated datasets.

1.2. Objectives

Overarching goal is to assess the risk of identified climate and biological disasters, using historic and current data and scientific tools to explore options to support for relief, recovery, resilience and adaptation and integration through existing development programmes and schemes.

01

To analyse spatial and temporal distribution and trends of key hydro-meteorological (climatic and biological) disasters at national- and state-levels;

02

To enumerate on causes, effects and impacts of selected disaster events and implications for the future;.

03

To assess and delineate disaster specific mitigation measures including climate adaptation and resilience building mechanisms; and,

04

To map and analyse existing development programmes and schemes, and identify pathways of climate change adaptation and disaster risk reduction integration.

1.3. Study rationale and selection of disasters

BMTPC has prepared a Vulnerability Atlas of India for four hazards viz. Earthquake, Flood, Wind, Landslides and Thunderstorm, and states have conducted HRVCA (Hazard Risk Vulnerability and Capacity Analysis) as part of their SDMPs and Climate Change Vulnerability Analysis in SAPCCs. However, there is no comprehensive assessment at the national level as to which regions/states have experienced most (frequency and intensity) disasters by types (for example, floods or droughts) across the changing international disaster reduction policy regimes, namely the Yokohoma strategy period (1995-2005), Hyogo period (2005-2015) and Sendai period (2015-2030). Such an analysis is particularly important to understand and assess how various (paradigm) shifts in disaster reduction have benefitted/impacted India that could lead to drawing recommendations for improving disaster reduction frameworks. This study attempts to answer some of these questions.

Specifically, disaster reduction has progressed significantly, in India and globally. A key feature of shift across the three policy regimes on disaster reduction is from emphasis on vulnerability reduction (Yokohoma strategy period) to promote a paradigm shift from response and relief-centric approach to prevention and mitigation (Hyogo) to promoting systemic (integrating SFDRR, SDG, Paris Agreement and Urban Agenda) disaster reduction.

The internationally accepted classification system of natural hazards puts them in five categories–Geophysical, Hydrological, Meteorological, Climatic and Biological. As per the National Disaster Management Plan (NDMP 2019), natural hazards in India comprise: Cyclone and Wind (Tropical Cylones and Storm Surge); Flood; Urban Flood; Earthquake; Tsunami; Landslides and Snow Avlanches; Drought; Cold Wave and Frost; Thunderstorm, Lightning, Squall, Dust Storm and Strong Wind; Cloudburst and Hailstorms; Glacial Lake Outburst Flood (GLOF); and Heat Wave.

Major disaster types were identified for analysing temporal and spatial patterns using the following criterion:

A. Disasters that have impacted large areas/ populations and have been more recurrent; and associated with the impact of climate change;

B. Availability of consistent long-term data since the first international policy regime on disaster reduction i.e., the Yokohoma strategy period beginning 1995;

C. The study also analysed how the current disasters are likely to be exacerbated due to climate change in future, the study is limited to selecting only those disasters that had direct link with hydrological, meteorological and climatic phenomenon.

D. Given the focus also on biological disasters, their selection depended on availability of long-term consistent data records; and,

E. Finally, availability of data for drawing comparison across states was limited. There were challenges in the availability of consistent data at the district-level due to administrative re-classification of districts.

Applying the above criterion, the study shortlisted the disasters by reviewing secondary data, websites, government programmes/schemes/reports, which led to identifying the following eight disasters:

- Five related to climate change--Floods, Droughts, Cyclones, Heat Waves and Cold Waves;
- Three related to biological–Dengue, JE and COVID-19

A short description on key feature of each of the disasters in India is presented below.

1.4. Key features of selected climatic disasters in India

A. Floods

Climate change is likely to increase the frequency and intensity of floods. Changes in land use and land cover combined with climate change increases flood risk. Observed and projected increase in air temperature and change in monsoon seasonal (June–September) rainfall pattern and extreme rainfall are likely to lead to severe floods in the Indian sub-continent.

Floods have been a recurrent natural phenomena in India from times immemorial. Almost every year in the summer monsoon season, floods of varying magnitude affect various parts of the country. From flood proneness consideration, the country can be broadly divided into the following four regions:

- The Brahmaputra River Plains: This region consists of the rivers Brahmaputra and Barak and their tributaries, and covers the states of Assam, Arunachal Pradesh, Meghalaya, Mizoram, Manipur, Tripura, Nagaland, Sikkim and the northern parts of West Bengal.
- The Ganga River Plains: River Ganga has many tributaries, the important ones being Yamuna, Sone, Ghagra, Raphti, Gandak, Burhi Gandak, Bagmati, Kamla Balan, Adhwara group of rivers, Kosi and the Mahananda. It covers the states of Uttarakhand, Uttar Pradesh, Jharkhand, Bihar, south and central parts of West Bengal, parts of Punjab, Haryana, Himachal Pradesh, Rajasthan, Madhya Pradesh and Delhi. The flooding and erosion problem is serious in the states of Uttar Pradesh, Bihar and West Bengal.
- The North-West River Plains: The main rivers in this region are the Indus, Sutlej, Beas, Ravi, Chenab and Jhelum. This region covers the Union Territory of Jammu and Kashmir, Punjab and parts of Himachal Pradesh, Haryana and Rajasthan.
- The Central India and Deccan Region: Important rivers in this region are the Narmada, Tapi, Mahanadi, Godavari, Krishna and Cauvery. These rivers have mostly well-defined and stable courses. They have adequate capacities within the natural banks to carry the flood discharge except in the delta areas. This region covers the states of Andhra Pradesh, Karnataka, Tamil Nadu, Kerala, Odisha, Maharashtra, Gujarat and parts of Madhya Pradesh. The region does not have a serious flood problem except that some of the rivers in Odisha state, namely Mahanadi, Brahmini, Baitarani, and Subarnarekha are prone to floods every year.

According to the estimate of the Rashtriya Barh Ayog (National Commission on Floods), the area prone to floods in the country is of the order of 400 lakh (=40 million) hectares, out of which it is considered that 80 per cent, that is 320 lakh (=32 million hectares), can be provided with a reasonable degree of protection by various types of structural measures.

B. Droughts

India has a long history of droughts and famines. At present, around 68 per cent of India's net sown area is prone to droughts in varying degrees. As per the Irrigation Commission Report (1987), 102 districts across 13 states of India are chronically drought prone (Ministry of Agriculture, 2009).

- India receives mean annual rainfall of 750-1125 mm which is considered as "drought-prone". Three-fourth of India falls in arid, semi-arid and sub-humid regions.

- Arid zone (19.6 per cent): Mean annual precipitation (MAP) of 100-400 mm (water deficit throughout the year); parts of Rajasthan, Haryana and Gujarat. Droughts are severe in this zone.
- Semi-arid zone (37.0 per cent): MAP of 400-600 mm (water surplus in some months and deficit in other months); parts of Rajasthan, Haryana, Punjab, west Uttar Pradesh, west Madhya Pradesh, and most of the peninsular parts of the Western Ghats. Drought can be moderate to severe in this zone.
- Dry sub-humid zone (21.0 per cent): MAP of 600- 900 mm; parts of northern plains, central highlands, eastern plateau, parts of eastern Ghats and plains and parts of western Himalayas. Droughts are moderate in this zone.
- Humid[1] and per humid regions, such as Assam and other north-eastern states rarely face drought.

C. Heat Waves

Higher daily peak temperatures of longer duration and more intense heat waves are increasing in frequency globally due to climate change. As stated in the State Level Climatic Monologue (IMD), "State averaged summer mean maximum temperatures have increased over Andaman and Nicobar, Andhra Pradesh, Goa, Himachal Pradesh, Karnataka, Kerala, Lakshadweep, Maharashtra, Mizoram, Rajasthan, Sikkim, and Tamil Nadu." Extreme temperatures combined with high humidity and resultant atmospheric conditions adversely affect people living in these regions leading to physiological stress, sometimes even death. Unusual and uncomfortable hot weather can impact human and animal health and cause major disruption in community infrastructure such as power supply, public transport and other essential services.

D. Cold Waves

Cold Wave is a rapid fall in temperature within 24 hours to a level requiring substantially increased protection to agriculture, industry, commerce, and social activities. Cold Wave conditions for the plains, when the minimum temperature is 10 degrees Celsius or below and is 4.5 degrees Celsius (oC) less than normal for two consecutive days. For coastal stations, the threshold value of minimum temperature of 10 degree Celsius is rarely reached. However, the local people feel discomfort due to the wind chill factor, which reduces the minimum temperature by a few degrees depending upon the wind speed. A wind chill factor is a measure of the cooling effect of the wind on the temperature of the air. India's 'core cold wave zone' covers Punjab, Himachal Pradesh, Uttarakhand, Delhi, Haryana, Rajasthan, Uttar Pradesh, Gujarat, Madhya Pradesh, Chhattisgarh, Bihar, Jharkhand, West Bengal, Odisha and Telangana. In 23 of the last 38 years (1980-2018), the human death toll in India due to cold waves was higher than that due to heat waves.

E. Cyclones

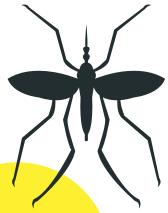
India has a long coastline of about 7,516 km of which 5,400 km is along the mainland. Entire coast is affected by cyclones with varying frequency and intensity. There are 96 cyclone prone districts in India covering 13 states and UTs, out of which 12, 45, 31 and 8 districts are in very high, high, moderate and low categories of proneness, respectively (NCRMP, NDMA). In general, the coastal districts of West Bengal, Orissa, Andhra Pradesh and Tamil Nadu are more prone and are in the high to very high category. The cyclone hazard proneness factor is very high for the districts of Nellore, East Godavari, and Krishna in Andhra Pradesh; Yanam in Puducherry; Balasore, Bhadrak, Kendrapara and Jagatsinghpur in Odisha; and South and North Parganas, Medinipur and Kolkata in West Bengal (NDMA).

1. As per Trewartha's Scheme, per humid region lies along the west coast of India, South of Goa and some part of North-eastern India. The humid climate prevails all along the coast adjoining per humid region covering Northern West Bengal and neighbouring parts of North-east India.

1.5. Key features of selected biological disasters in India

A biological disaster causes sickness and fatalities in human beings and animals at a mass scale, when they come in contact with biological hazards, such as, bacteria, virus, fungi, etc., causing epidemics and pandemics. India is witnessing an epidemiological transition from communicable to non-communicable diseases. However, under the strong influence of climate change, the Indian population is exposed to various infectious diseases (vector-borne, water-borne, chronic diseases and zoonotic diseases) which are bringing back the concern of communicable diseases (Global Risks report, 2021). Extreme weather events like floods, resulting from monsoon rains, turn into vector-borne diseases such as dengue, Japanese encephalitis, typhus, etc. The rising temperature increases the survival time of bacteria in the water that causes water borne diseases like cholera and diarrhoeal disease. Increase in temperature and other changes in weather also affect malaria transmission. Further, vector borne and zoonotic diseases such as chikungunya fever and dengue are also influenced by climate change, including changes temperature and precipitation (Javad Babaie et al., 2015). India is experiencing numerous human health effects because of climate change resulting in growths in extreme weather events which leads to morbidity and mortality (V. R. Dhara, 2013).

The study also includes coronavirus and fungal diseases under biological disasters. The recent COVID-19 pandemic is the first pan India biological disaster being handled by the legal and constitutional institutions of the country. Multi-stakeholder engagements have been established to address disaster vulnerabilities in the country and across the world. The same engagements can be utilised for addressing pandemic risks.



Extreme weather events like floods, resulting from monsoon rains, creates conducive environment for vector-borne diseases such as Dengue and Japanese encephalitis. The rising temperature increases the survival time of bacteria in the water that causes water borne diseases like cholera and diarrhoeal disease.

A. Dengue

Dengue has become a major public health problem in India. It is caused by dengue virus (DENV, 1–4 serotypes), one of the most important arboviruses in tropical and subtropical regions. In India, the number of dengue cases has steadily risen over the last twenty years (Data source: NCDC). Dengue is driven by complex interactions between the host, vector and virus that are affected by climatic factors. In 2007, the Intergovernmental Panel on Climate Change warned that between 1.5 -3.5 billion people worldwide would face the risk of dengue fever infection in the 2080s due to climate change.

Temperature and precipitation are significant climatic factors affecting the mosquito population and the dynamics of disease transmission. Temperature change influences mosquito growth, mortality and reproductive behaviour. Precipitation provides the water that is used as a shelter for larvae and pupae. Warm temperatures and high humidity favour increased survival of adult mosquitoes and shortened viral incubation in vector and blood-feeding periods, leading to faster multiplication of the virus and increases transmission rate. However, the weather-dengue relationship differs with geographical locations and socio-environmental strata. In recent years, the number of dengue cases has gradually increased in India. The climate data from 1980 to 2017 show that the dengue transmission potential is expanded during the period 2000–2017 when compared with the period 1980–1999. Similarly, the projection shows that the potential occurrence of dengue cases in various geographic regions of India. Both RCP4.5 and RCP8.5 show that the dengue transmission potential was higher in South India and Central India as compared to North India (Kakarla et al., 2020).

B. Japanese Encephalitis

Japanese encephalitis (JE) is a major public health problem in India. When the first case was reported in 1955, the disease was restricted to south India. The disease spread to north India and the first ever case was reported in 1978. Extensive and recurrent outbreaks of JE have been reported since then.

A common mosquito-borne flavivirus encephalitis is Japanese Encephalitis (JE). It is one of the world's leading types of viral encephalitis, mainly prevalent in eastern and southern Asia, covering an area with a population of over three billion. Most JE infections are asymptomatic. However, it causes substantial morbidity and mortality. Though underreported, an estimated 50,000 cases and 15,000 deaths are caused by JE annually in Asia (Tiwari et al. 2012). Owing to its epidemic potential and elevated fatality rate, JE is a disease of public health significance. The highest age-specific attack rates in endemic areas occur in children aged 3 to 6 years of age. Around one third of patients die, with half of the survivors suffering from serious neuropsychiatric disease sequelae.

C. COVID-19

The pandemic in India is part of the worldwide pandemic of coronavirus disease 2019 (COVID-19) caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The first case of COVID-19 in India, which originated from China, was reported on 30 January 2020 in Kerala. By mid -2020, India had the highest number of daily new cases in the world and has sustained the highest number of daily cases spike after the USA (https://www.worldometers.info/coronavirus).

As of February 7, 2021, India had the largest number of confirmed cases in Asia and second-highest number of confirmed cases in the world after the United States, with more than 10.84 million reported cases of COVID-19 infection and more than 1,55,118 deaths (https://www.covid19india.org/). The pandemic has left a severe impact on the Indian economy, leading to a negative growth rate for the first time in decades. Nevertheless, the economy started to rebound after the lockdown was eased.

1.6. Methodology

Mapping of climatic disaster and biological outbreaks in a developing country like India requires an exhaustive compilation of data from multiple sources. For this purpose, data exploration has been done relying on hand-scanned government documents, international reports on disaster and disease outbreaks and scientific literature analysis. Based on the auxiliary information and data retrieved from the validated sources, expert consultations were carried out, and disasters were classified into two broad headings - climatic disasters and biological outbreaks. Under the climatic disasters, flood, drought, cyclone, heat wave and cold wave have been included, whereas Japanese encephalitis, dengue and COVID-19 were covered in the biological disasters, as depicted in Figure 1.

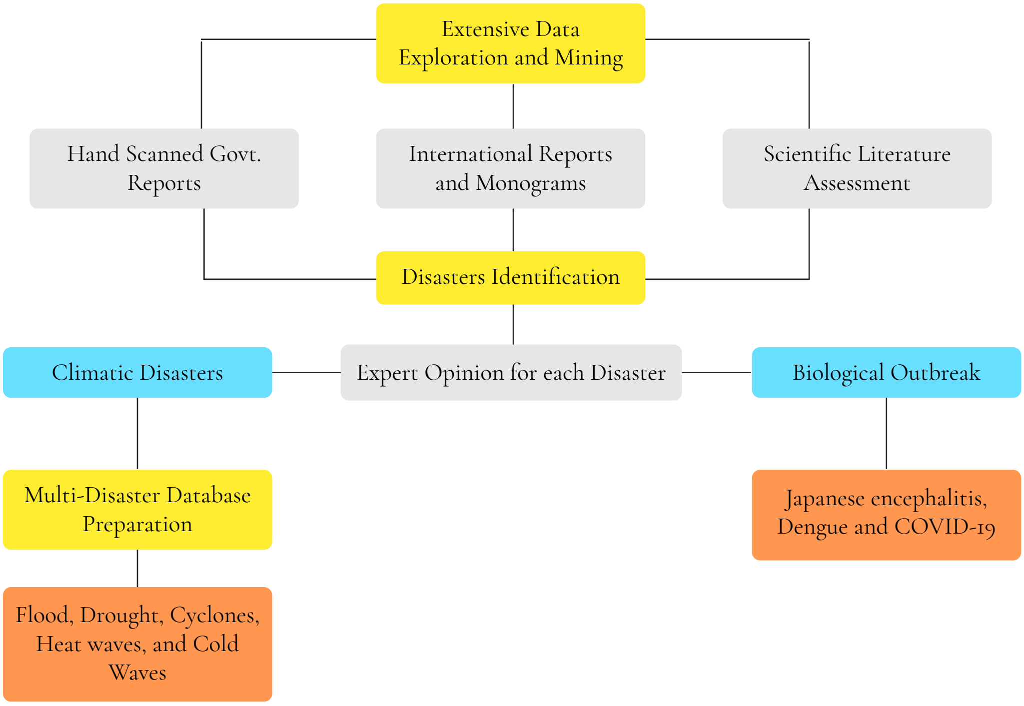


Figure 1: Methodology of identification and grouping of climatic and biological disasters

As mentioned earlier, three time series have been chosen to cover the historic as well as the ongoing SFDRR period (2015-2020) incidents. Yokohama strategy (i.e. pre-HFA 1995-2005), Hyogo Framework (2005-2015) and Sendai framework (i.e. post-HFA 2015-2030)[2] are the three broad time-spans selected for the study as depicted in figure 2.

2. The First World Conference on Natural Disasters in Yokohama, Japan from May 23 to 27, 1994, adopted the Yokohama Strategy for a Safer World: Guidelines for Natural Disaster Prevention, Preparedness and Mitigation and its Plan of Action, endorsed by the UN General Assembly in 1994. The 1995 to 2005 is the Yokohama Strategy period. The Hyogo Framework for Action (2005–2015): Building the Resilience of Nations and Communities to Disasters was an outcome of the 2005 conference. The Hyogo Framework for Action (HFA) - 2005-2015 was the first plan to explain, describe and detail the work required from all different sectors and actors to reduce disaster losses. The Sendai Framework for Disaster Risk Reduction (2015–2030) is an international document which was adopted by UN member states between 14th and 18th of March 2015 at the World Conference on Disaster Risk Reduction held in Sendai, Japan and endorsed by the UN General Assembly in June 2015. It becomes important to see the disasters in the context of this time series to understand the paradigm shift and DRR approaches in the disaster management field.

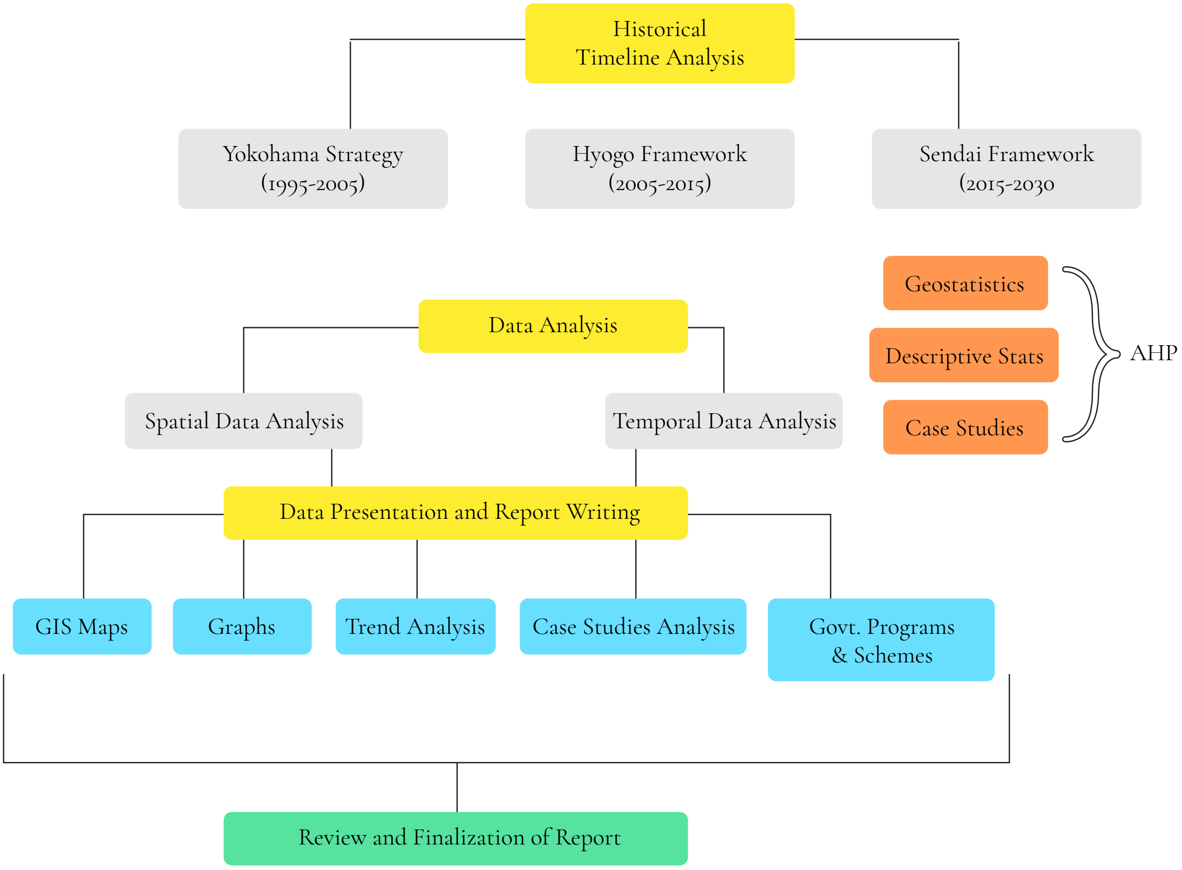


Figure 2: Detailed methodology used for the data analysis

In order to account for the variation in the occurrence of these events, spatio-temporal data analysis has been done so as to get a clear understanding of the occurrence pattern, and the frequency of events.

Multi-hazard assessment requires a comprehensive geospatial database to be used. Analytic Hierarchy Process (AHP) is a multi-criteria decision-making method which has been used in the study to evaluate the exposure due to these events (Saaty 1990; Saaty 2004, 1977). The analytic hierarchy process is a structured technique for organizing and analysing complex decisions, based on mathematics and psychology. Expert opinion and mathematical judgement help in arriving at the best possible solution. Geostatistics, descriptive data analysis and case studies are used for the multi-criteria decision-making purpose using AHP to understand the severity of the event and to quantify the exposure. Steps involved are shown in the Figure 3.

In order to account for the variation in the occurrence of these events, spatio-temporal data analysis has been done so as to get a clear understanding of the occurrence pattern, and the frequency and intensity of events

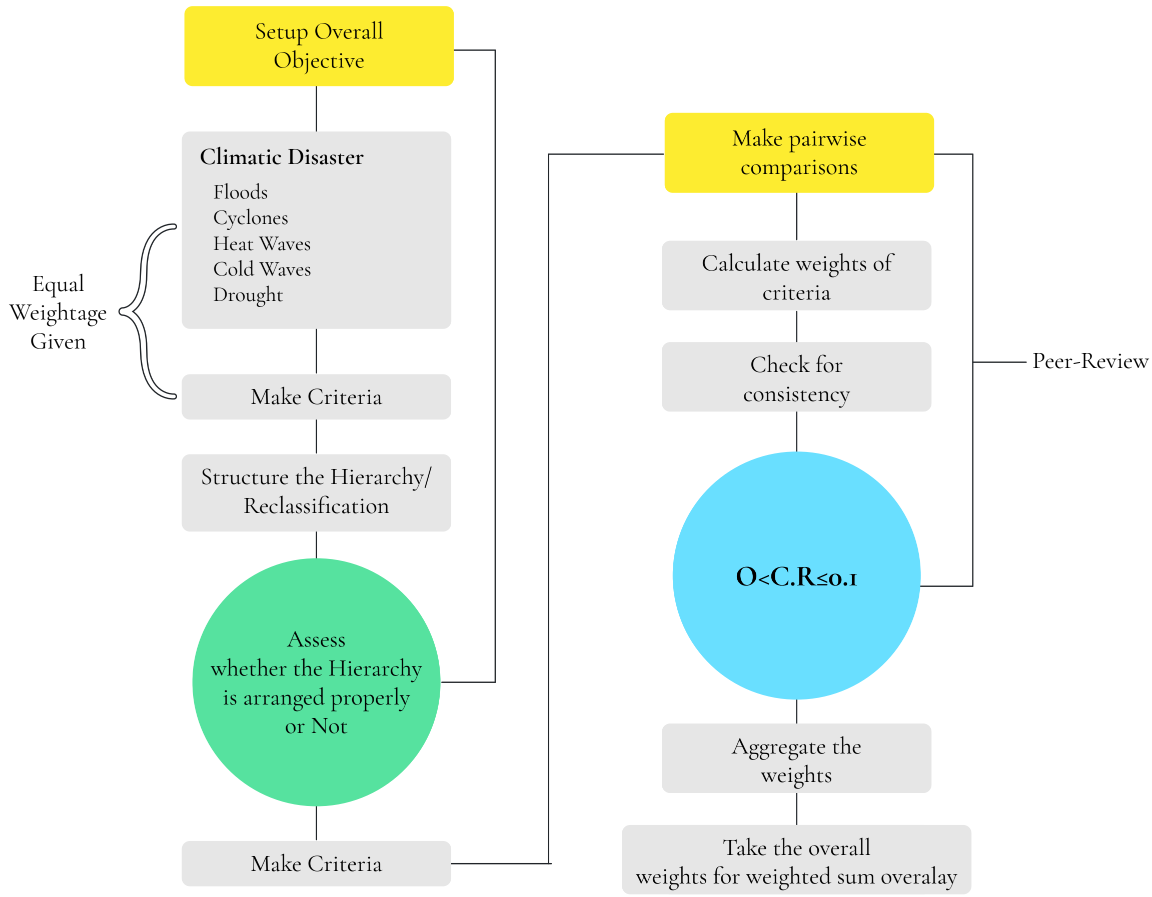


Figure 3: Steps involved in the Analytic Hierarchy Process (AHP) for the multi-hazard exposure assessment

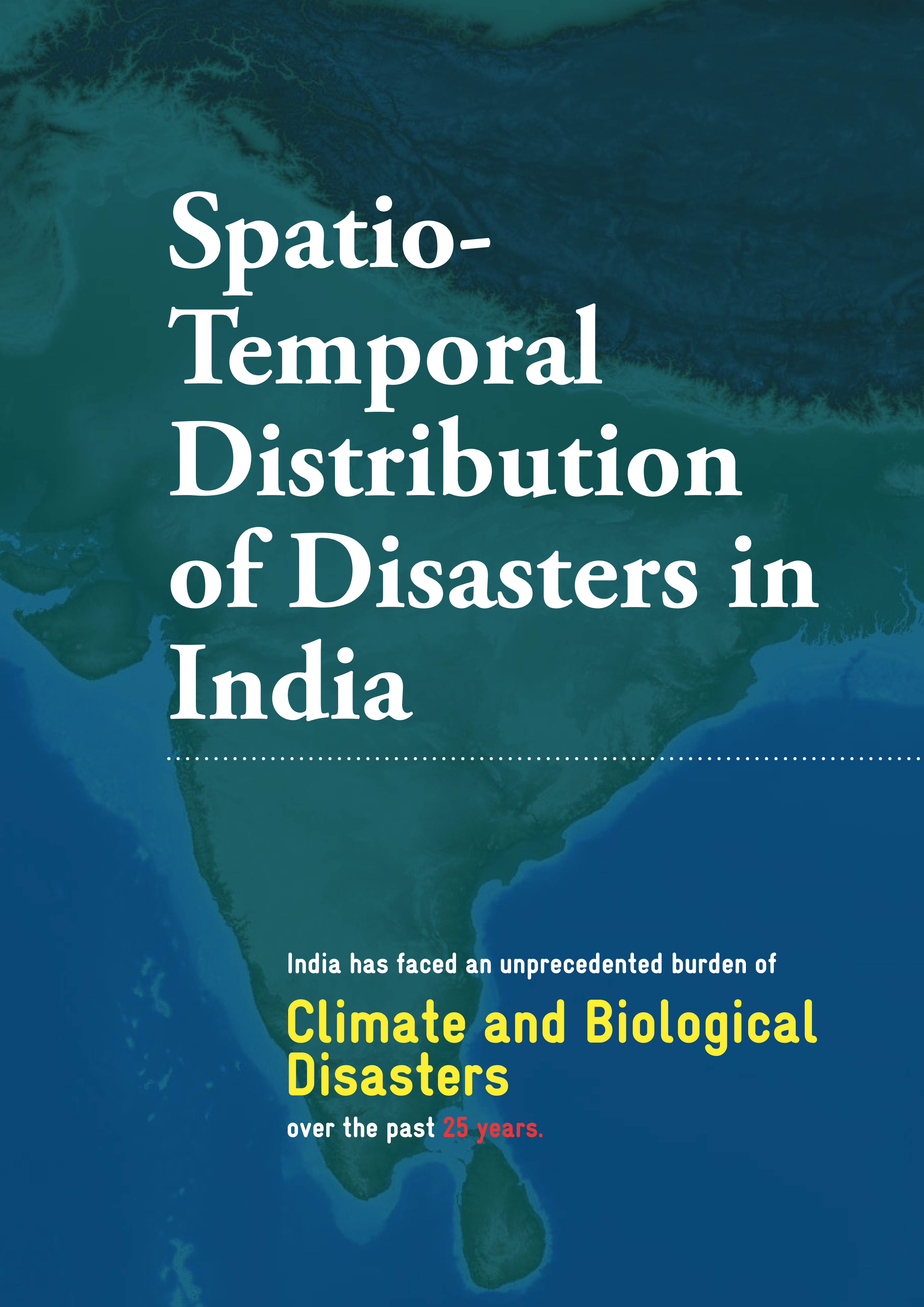
The final representation of the data includes the maps prepared using GIS technique, graphs using statistical tools and trend analysis using the wide-ranged data. Case studies related with these disasters have been included to showcase their impacts in reference to the disaster trends. Various schemes and programmes of government in the states as well as at central government level have been reviewed for their efficiency in dealing with these disasters. Based on outcome of the study, appropriate interventions can be included in the programs and schemes of government to address risk and impact of such disasters on people and environment. Proactive planning is important for effectively dealing with these climatic and biological disaster so that damages and losses could be minimised.

1.7. Limitations of the study

The present study is an innovative approach of risk assessment through mapping of past data on the key climatic and biological disasters and, thus, is first ever such attempt of spatial and temporal mapping-based analysis at sub-national levels. In the past, some studies have been undertaken by Centre for Research on Epidemiology of Disasters (CRED), Belgium. Despite the systematic approach and resources, present study also suffers with implicit challenges and limitations.

The key challenges that the study faces are the following:

- There is no prevailing mechanism for systematically capturing data of disaster damages and losses as well as overall impacts of disasters. Reports exists only on major disasters in the form of Memorandum submitted by State Governments.
- Unit of the risk analysis and mapping in the study is state-level. This makes addition to number of events. For example, if a cyclone affected more than two states, the number of records is two or more. 'Disastrous weather events report' by the Indian Meteorological Department only includes events with human, infrastructure, environmental or social impacts.
- Changes in administrative boundaries and resultant complexities with disaggregation of data posed unavoidable challenges. Number of districts in India as per census 1991 was 466, increasing to 593 in the year 2001. Four new states were formed after 1995, J&K is divided into two UTs in 2019 and UT of Dadra and Nagar Haveli and Daman Diu were merged as one UT in 2020.



Spatio-Temporal Distribution of Disasters in India

India has faced an unprecedented burden of

Climate and Biological Disasters

over the past 25 years.

As per the objectives of the study, this section presents changes in incidences of the select five climate-linked disasters (Floods, Droughts, Cyclones, Heat Waves and Cold Waves) and the three biological disasters (Dengue, JE and COVID-19) in India. Disaster incidence data is aggregated at the state level and changes in number of incidences/events has been compared across the three international policy regimes on disaster reduction–Yokohoma/ pre-Hyogo period 1995-2005, Hyogo period 2005-2015 and post Hyogo/ Sendai period 2015-2030. The latest data available till 2020 has been considered for the study.

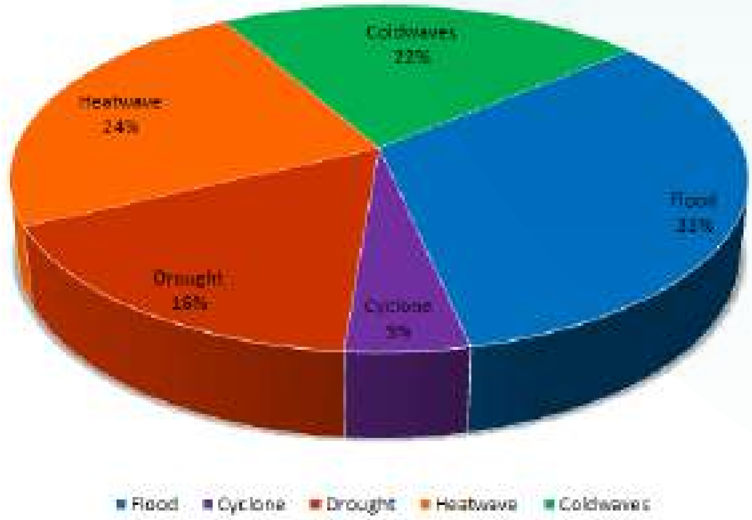


Figure 4: Occurrence by disaster type (number of events occurred) - Five climate related events during the period 1995-2020

During the period from 1995 to 2020 (Figure 4), a total of 1058 climate-related disaster events (floods, cyclones, droughts, cold waves and heat waves) were reported (reported till the end of October 2020). During the pre-HFA (1995-2005), HFA (2005-2015) and post-HFA (2015-2020) periods, a total of 420, 356 and 282 incidents were recorded. In India, floods accounted for 33 per cent of overall number of climate-related disaster incidents, followed by 24 per cent heat waves, 22 per cent drought, 16 per cent cold waves, and 5 per cent cyclones. In case of the biological outbreaks, dengue reported 63 per cent of cases, whereas JE reported 37 per cent of cases (Figure 5). It clearly manifests that India has faced an unprecedented burden of climate and biological disasters over the past 25 years. It is noticeable that almost two-third of total number of disasters recorded during the previous two periods occurred in only the first five years of the Sendai period.

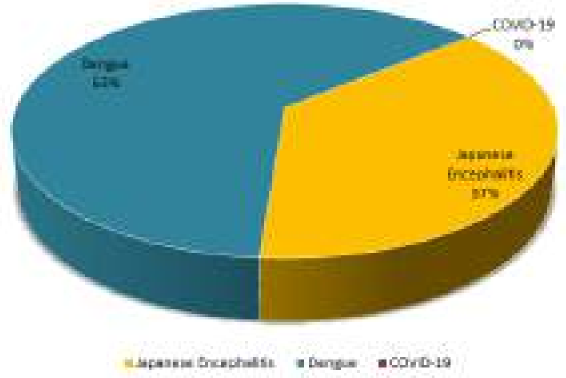
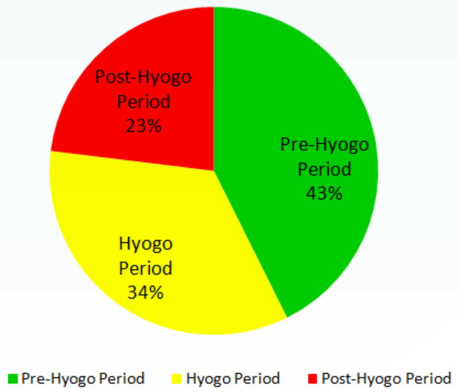


Figure 5: Occurrence by select three biological outbreaks during 1995-2020

2.1. Climatic disasters

2.1.1. Floods

Pattern of flood disasters reveals that during pre-HFA, HFA, and post-HFA, the cumulative number of total events were 148, 119, and 80, respectively. There was a slight decrease (1 per cent) during HFA as compared to the pre-HFA. However, the annual average number of events increased by 2 per cent during the Sendai period. Figure 6 (a and b) show the distribution of the total number of flood events and average annual occurrences during the pre-, during- and post-HFA eras.



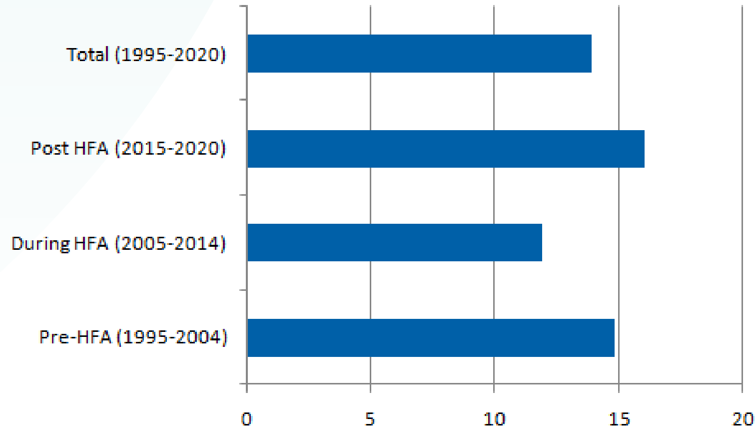


Figure 6 a & b: Distribution of total number of flood events and annual average number of flood events during the three periods

Although most parts of India are affected by floods, frequency and effects of floods vary significantly from one state to the other.

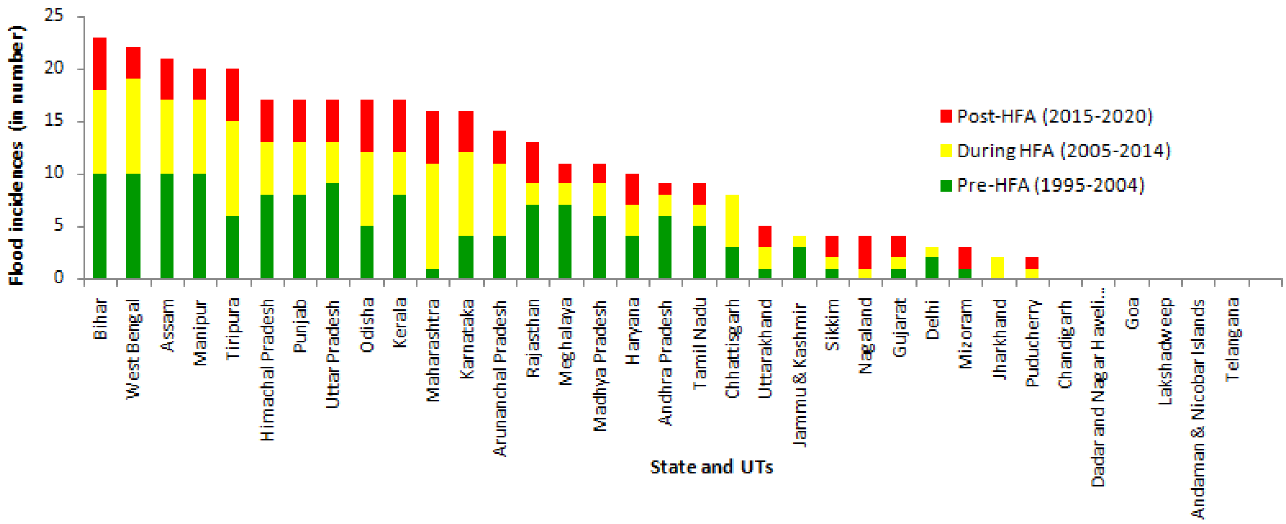
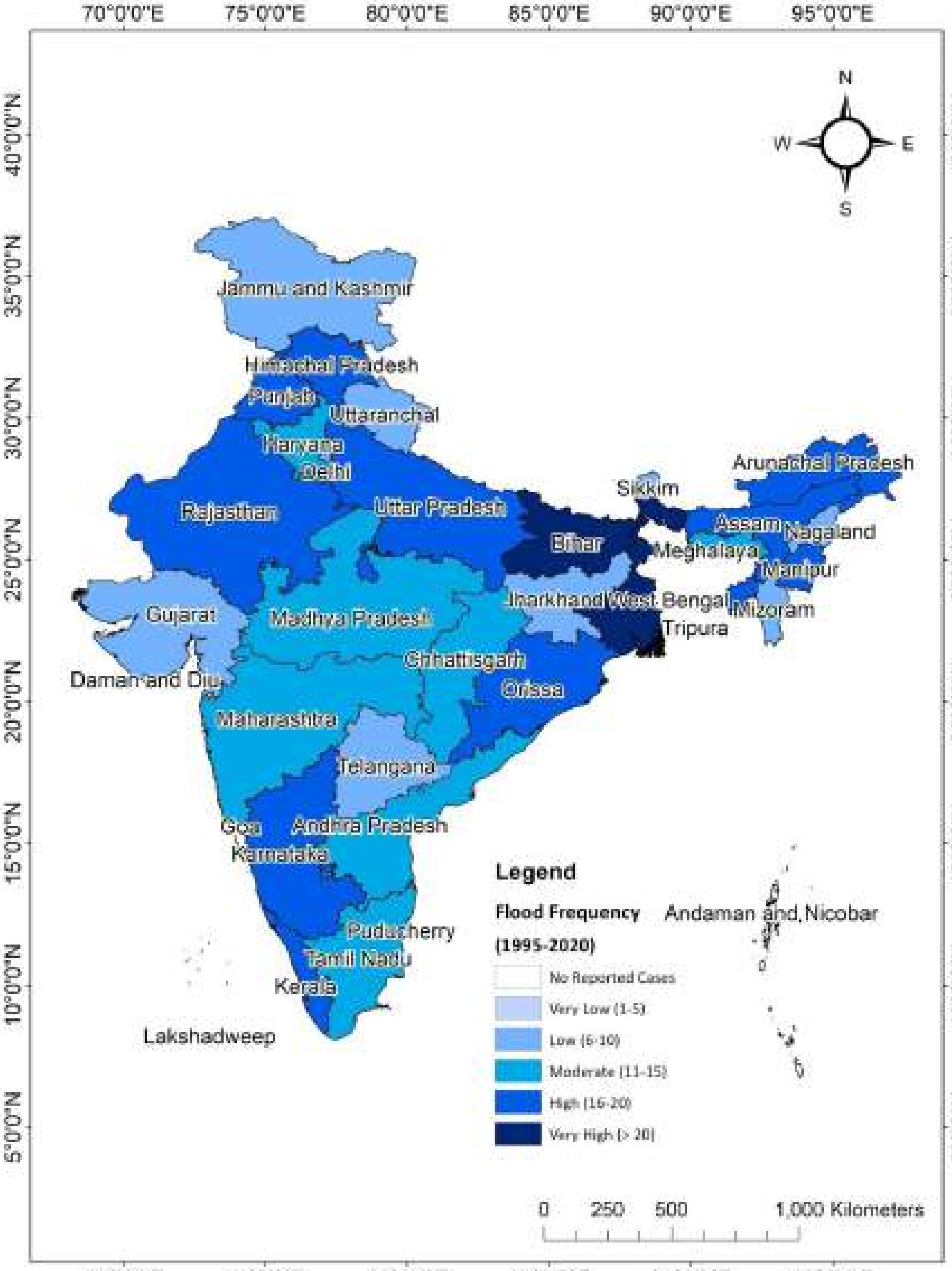


Figure 7: State-wise distribution of total number of flood events reported during Pre HFA, HFA and Post HFA Periods (Data source: IMD).

Data for the period 1995 to 2020 shows that floods are most frequent climate-related disaster events affecting almost the entire country, i.e., 29 out of the total of 36 states and UTs experienced floods during the period of study (Figure 7).

It is evident from the map (Figure 8) that Bihar, West Bengal, Assam, Manipur and Tripura experienced most frequent floods in 26 years i.e. more than 20 times.



Compiled by: Study Team

Data Source, Disasterous Weather Event Reports, IMD and MHA Reports

Figure 8: State-wise distribution of total number of flood events from 1995 to 2020.

(Note: The scale bar represents the incidences in 25 years. Very low, low, moderate, high and very high frequency representing the range 0- no flood events, 0-5, 6-10, 11-15, 16-20 and more than 20 incidents during the period covered in the study.)

It is evident from the map of the geographically distributed flood events (figure 8) that from 1995 till 2020, 29 of the 36 states and UTs in the country have been affected by floods. It is also observed that during the pre-HFA, HFA and Post-HFA phases, frequency of floods was not consistent.

Few states, for e.g., Maharashtra, rarely experienced floods during the pre-HFA period whereas during the HFA and post-HFA periods, the state experienced many incidences of destructive floods. Similarly, during HFA and post-HFA, Karnataka and Arunachal Pradesh recorded an increase in the frequency of floods, whereas Jharkhand and Puducherry recorded no flood events during pre-HFA phase. The frequency of flooding during the HFA period was higher in Tripura, Maharashtra, Karnataka and Arunachal Pradesh. There was also a rise in flood frequency in Kerala, Mizoram, Tripura, Gujarat, Sikkim, Nagaland, Rajasthan and Haryana during the post-HFA timeline.

It is perceptible from the map and chart depicting the spatial distribution that regular flood frequency was more prominent in the Indo-Gangetic Plains, north-eastern zone and eastern parts of India. The south-western regions also witnessed high levels of flooding. However, frequency of floods was moderate to very low in the Himalayan mountain regions (except for the state of Himachal Pradesh), western India and central India.

Data for the period 1995 to 2020 shows floodsare most frequent climate-related disaster events that have effected almost the entire country, i.e., 29 out of the total of 36 states and UTs.

2.1.2. Droughts

Trend analysis for drought has shown the overall number of events as 63, 51 and 51 during the pre-HFA, HFA and post-HFA periods, respectively. There was a decline of 1.2 per cent during HFA, relative to pre-HFA, considering the total annual number of events. During the Sendai period, however, annual average number of events increased by 2.6 per cent. Figure 9 (a and b), show the distribution of the total number of drought events and the average annual figure, respectively, during the pre-and post-HFA period.

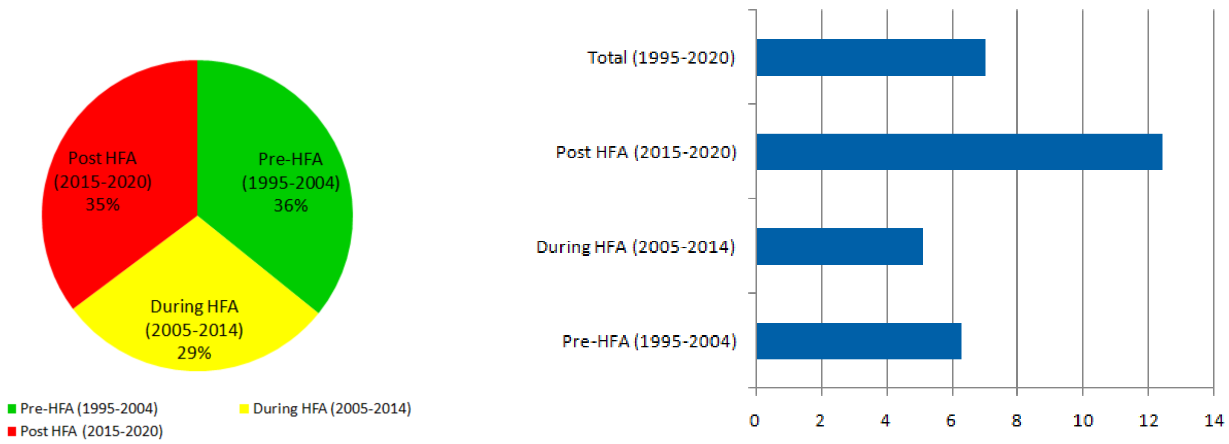


Figure 9 a & b: Percentage distribution of total number of drought events and annual average number of droughts events.

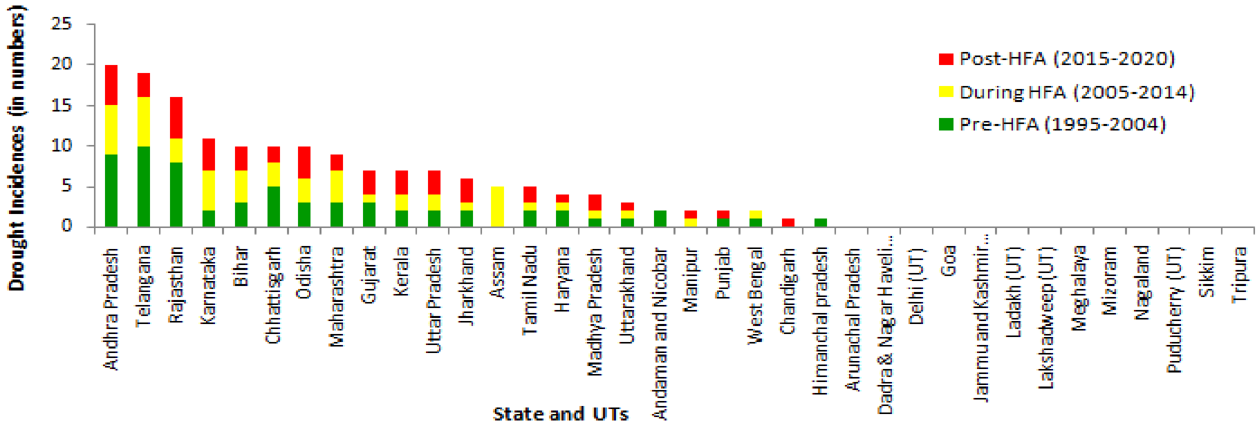
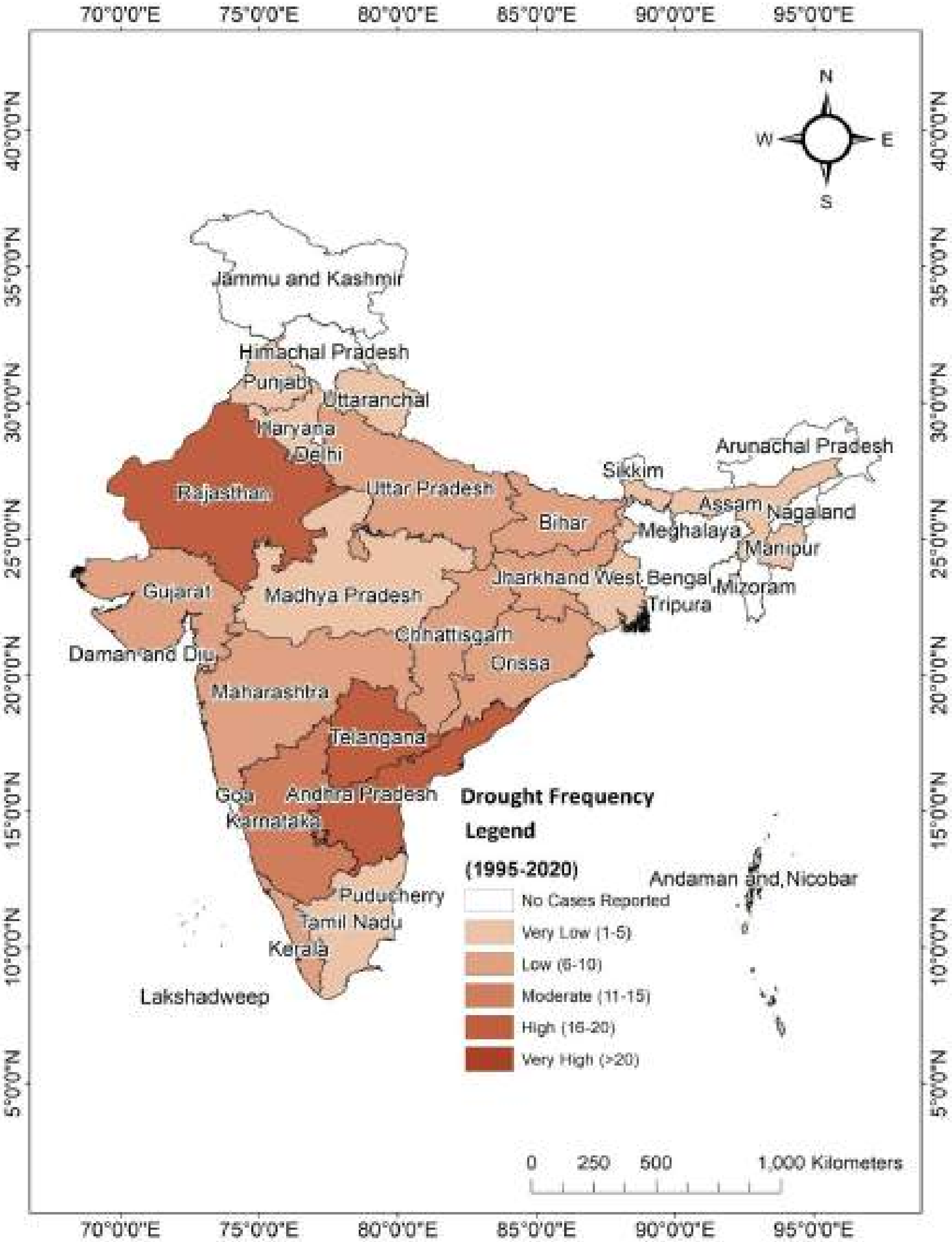


Figure 10: State-wise number of reported drought events during pre-HFA, HFA and post-HFA

During the period under the study, 23 out of 36 states and UTs of India experienced drought events with varying frequency and consequences. It is evident from the state-level analysis (Figure 10 and Figure 11) that in the past 25 years, AP, Telangana and Rajasthan witnessed drought more than 15 times, whereas states like Karnataka, Bihar, Chhattisgarh and Odisha have faced drought more than 10 times.



Compiled by: Study Team
Data Source, Disasterous Weather Event Reports, IMD and MHA Reports

Figure 11: Thematic map depicting the state-wise frequency of drought during 1995-2020

(Note: The scale bar represents the incidences in 25 years. Very low, low, moderate, high and very high frequency representing the range 0- no drought events, 0-5, 6-10, 11-15, 16-20 and more than 20 incidents during the analysis period)

Drought frequency also varied across all states over the three time periods but the overall increasing trend at the national-level is evident as shown in the previous section on temporal analysis. Number of drought incidences decreased slightly during HFA and again increased in the Post-HFA period in AP (Pre HFA -9, HFA- 6, Post HFA- 5) and Telangana (Pre HFA- 10, HFA- 6, Post HFA- 3) states. Rajasthan, Odisha, Chhattisgarh, Tamil Nadu, Gujarat and Kerala have seen a similar trend. During the HFA period, Manipur also had no recorded drought incidences. All instances of drought during the HFA period covered Assam. In Kerala, frequent droughts are reported during post HFA. Chandigarh (UT) also reported drought incidences during post HFA.

2.1.3. Cyclones

Trend for cyclones during pre-HFA, HFA and post-HFA reveal the cumulative number of recorded events as 67, 95 and 70, respectively. Occurrence of cyclones had an increasing trend, considering the average annual number of events, i.e., 19 events in pre-HFA to 17 during HFA and 12 events in post-HFA period of 5 years. Annual average number of events during the HFA period has shown marginal decrease and a further increase of 3 per cent during the Sendai period. Figure 12 depicts the distribution of the total number of cyclone events and average annual figure for pre- and post-HFA and total cyclone events.

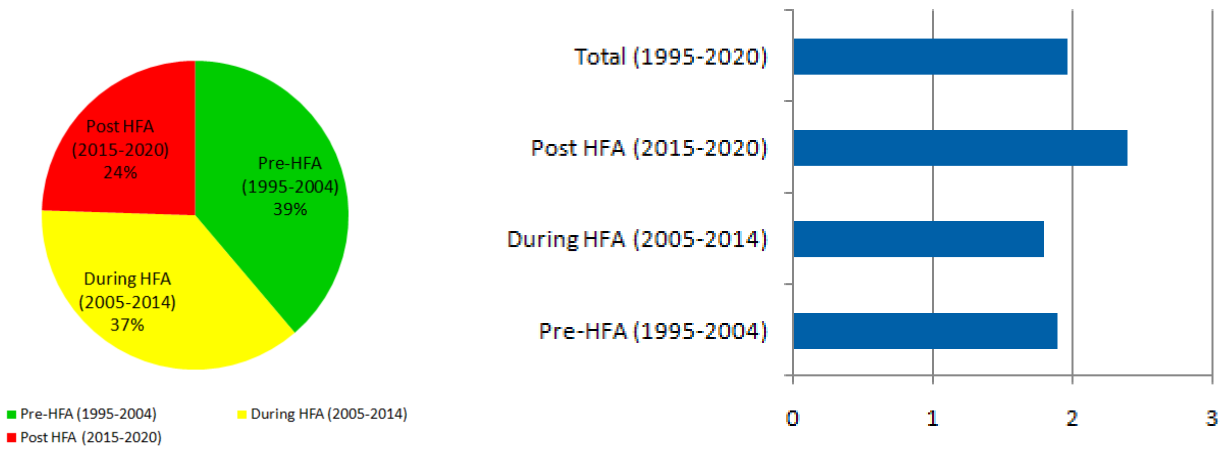


Figure 12: Percentage distribution of total number of cyclone events and annual average number of cyclone events during Pre HFA, HFA and post HFA Periods.

During the periods under study, 11 out of 36 states and UTs witnessed cyclones of varying frequency and effects.

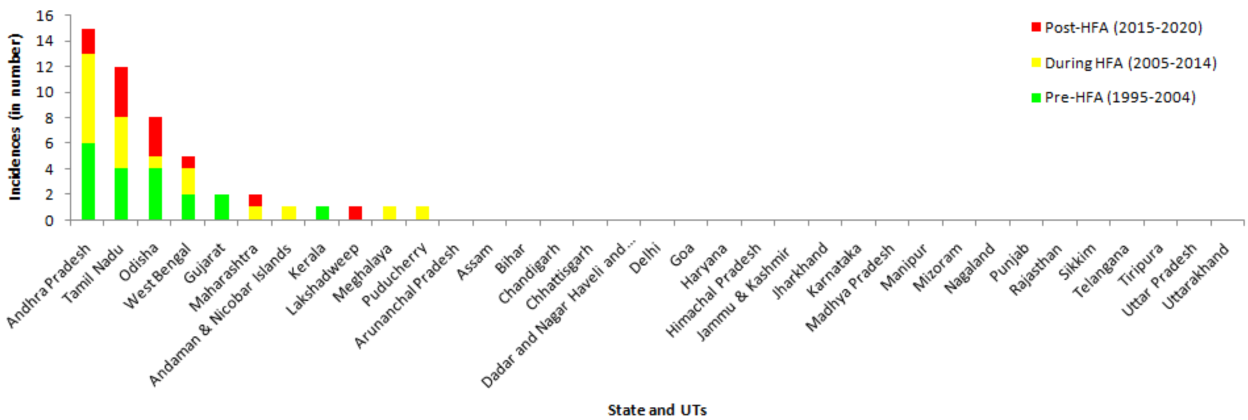
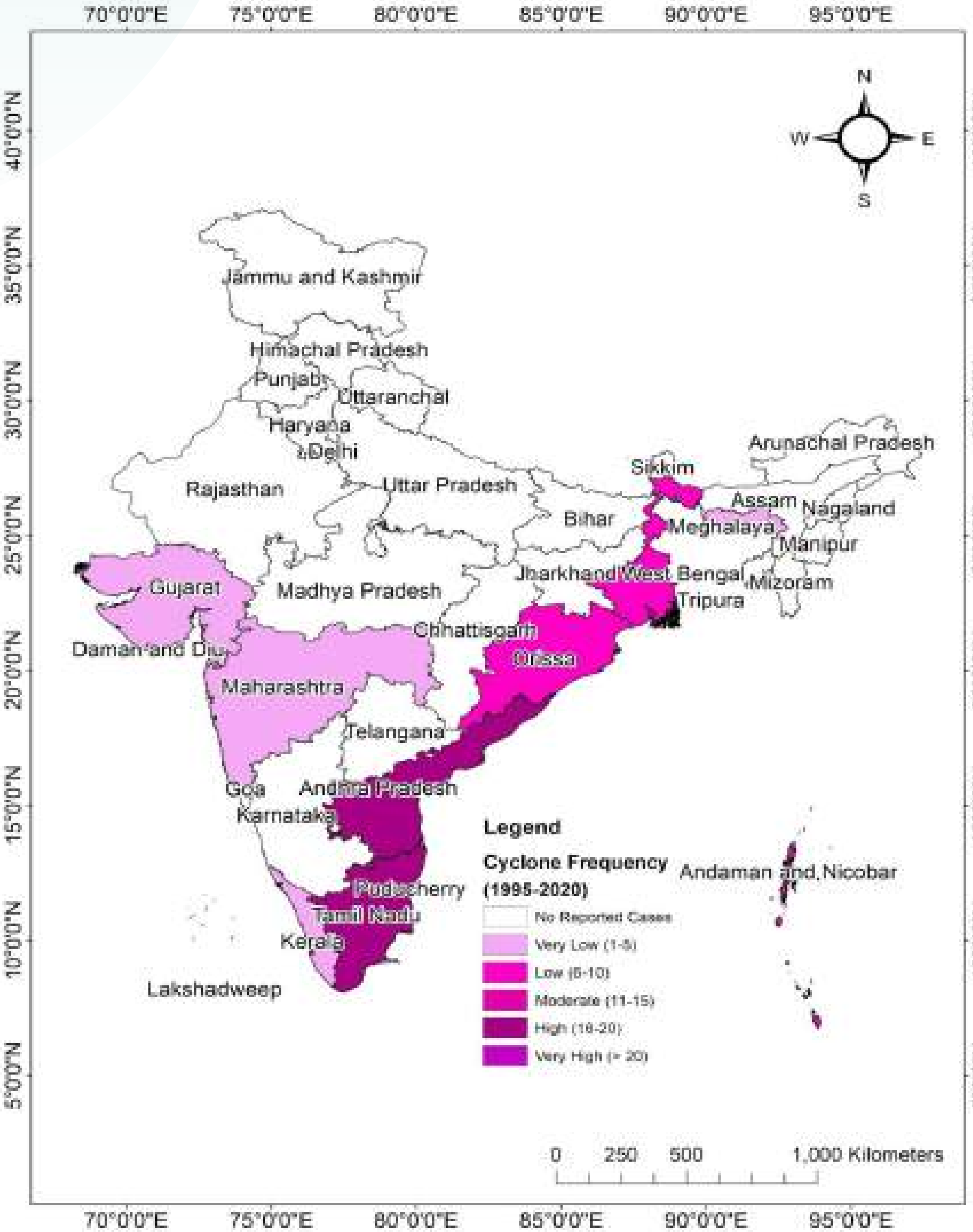


Figure 13: State-wise Cyclone occurrences reported in Pre HFA, during HFA and Post HFA period till 2020

As depicted in Figure 13, the frequency of cyclones has shown slightly increasing trend in Andhra Pradesh, i.e. during pre-HFA-6, HFA-6, and decreased during the post-HFA period. In Odisha and Tamil Nadu, an increase in the number of cyclone incidents has been recorded during the post-HFA period.



Compiled by: Study Team
Data Source, Disasterous Weather Event Reports, IMD and MHA Reports

Figure 14: Cyclone Frequency Map from 1995-2020 (Source: IMD)

(Note: The scale bar represents the incidences in 25 years. Very low, low, moderate, high and very high frequency representing the range 0- no cyclone events, 0-5, 6-10, 11-15, 16-20 and more than 20 incidents during the analysis period.)

A similar pattern was seen in the case of Maharashtra also. State-level analysis as shown in the map (Figure 14) revealed the highest number of cyclones in the Bay of Bengal area has been recorded and faced by Andhra Pradesh, Tamil Nadu, Odisha and West Bengal.

2.1.4. Heat Waves

Trend analysis for heat waves (Figure 15) revealed the total number of events recorded during pre-HFA, HFA and post-HFA as 90, 95 and 68, respectively. Incidences of heat waves have shown an increasing trend in view of the average annual number of events, i.e. from pre-HFA to HFA and post-HFA. During the post-HFA (Sendai period), the yearly average number of events increased by about 20 per cent.

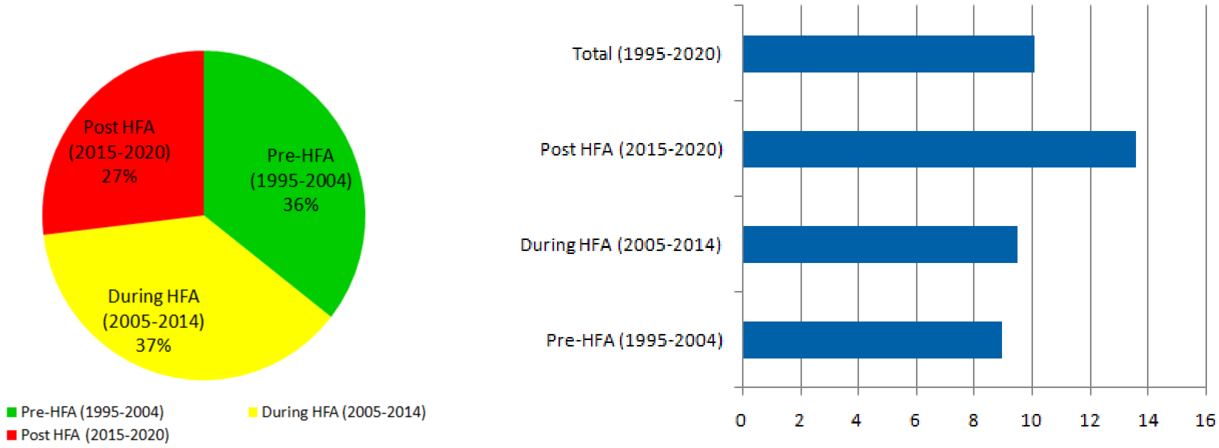


Figure 15: Percentage distribution of total number of heatwave events & annual average number of heatwave events during pre-HFA, HFA and post-HFA Periods

During the Sendai period, the average number of annual events increased by about 20 per cent. As high as 27 out of 36 states and UTs endured heat waves of varying frequency and effects during the period under the study. Odisha (24) had the largest number of cases, followed by Maharashtra (22), West Bengal (21) and Rajasthan (20).

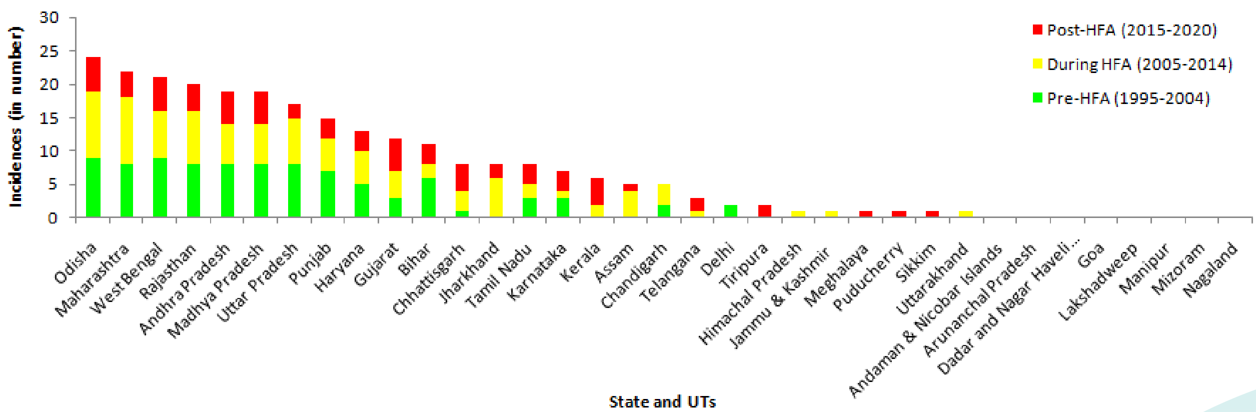
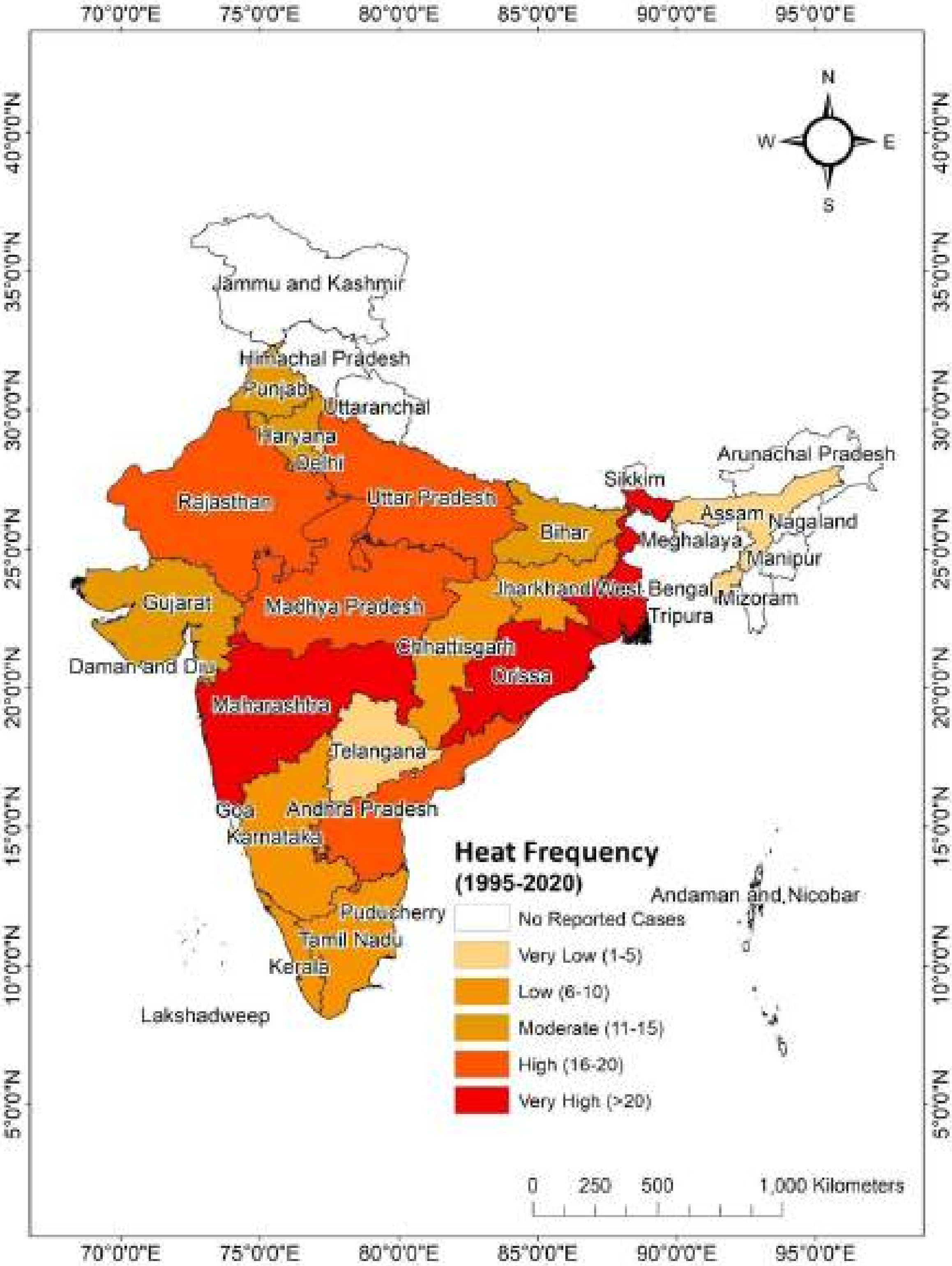


Figure 16: State-wise heatwave Incidents reported in Pre HFA, during HFA and Post HFA Period from 1995-2020

As evident from Figure 16, in the states, viz. Odisha, Maharashtra, Jharkhand and Gujarat, the frequency of heat waves increased during the HFA period. Six states, namely Odisha, West Bengal, Madhya Pradesh, Andhra Pradesh, Gujarat and Telangana experienced five heat wave events during the post-HFA period. Kerala, Jharkhand, and Assam also have no pre-HFA heatwave episodes recorded. In Kerala, the number of heat wave incidences increased and Sikkim, Meghalaya, Tripura and Puducherry experienced heat waves only during the post-Hyogo period.



Compiled by: Study Team
Data Source, Disasterous Weather Event Reports, IMD and MHA Reports

Figure 17: State-wise heatwave frequency map for 1995-2020 (Source: IMD)

(Note: The scale bar represents the incidences in 25 years. Very low, low, moderate, high and very high frequency representing the range 0- no heat wave cases, 0-5, 6-10, 11-15, 16-20 and more than 20 incidents during the analysis period.)

Heatwave events were found to be doubled in post-HFA compared to the HFA time. During the HFA period, the frequency of heat waves increased in a few states, such as Haryana, Chhattisgarh, Jharkhand and Arunachal Pradesh. After 2005, Goa and Nagaland never reported a heat wave. After 2005, heatwave incidents were recorded in Mizoram and Dadra and Nagar Haveli, and there are no records post-Hyogo in these states.

At the regional level, the number of incidences in the north-east and eastern regions indicate an increasing trend in the post-Hyogo period. Similarly, in the post-Hyogo period, the southern regions have also shown an increasing trend (Figure 17).

2.1.5. Cold Waves

Trend analysis for cold waves indicated total number of reported events as 10,074 and 60 during the pre-HFA, HFA and post-HFA periods, respectively. Considering the average annual number of events, cold waves have shown decreasing trend in the Hyogo period and again an increase during the Sendai Period. Distribution of total number of coldwave events and the average annual number of incidences during pre-HFA, during HFA and post-HFA periods are shown in Figure 18.

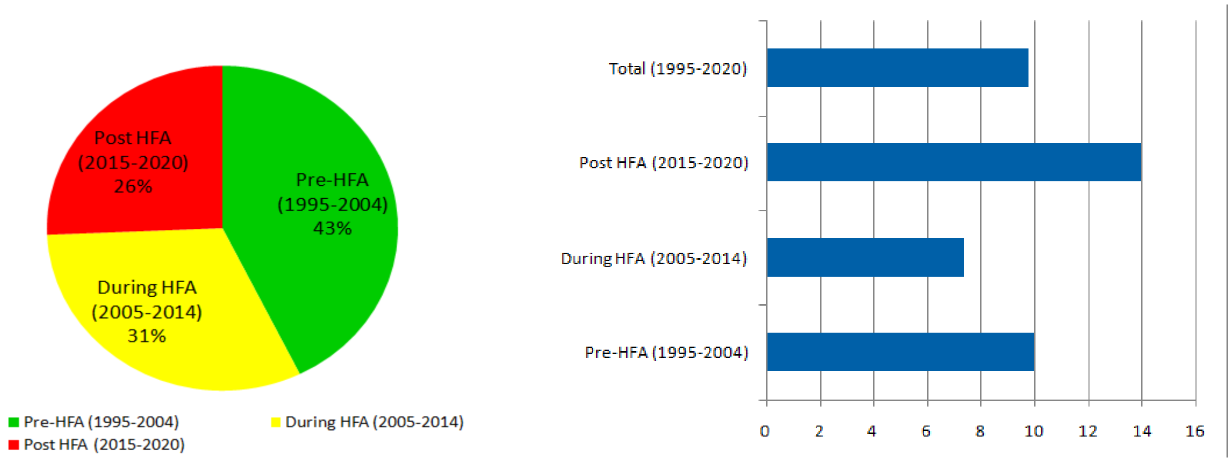


Figure 18: Percentage distribution of total number of cold wave events and annual average number of cold wave events during pre-HFA, HFA and post-HFA periods

During the pre-Hyogo period, total number of reported climate-related disaster events was 420, and during the Hyogo period it was 357. However, in the Sendai period, until 2020, the recorded events for the initial six years were 282.

During the period under study, 24 out of 36 states and UTs experienced cold waves of varying frequency and effects. The state-level analysis for 25 years has shown that three states/UTs have experienced more than 20 cold wave incidences. Cold waves were reported more than 10 times in seven states. The highest number of cold wave events was recorded in Uttar Pradesh (25), followed by Rajasthan and Bihar. The state-wise distribution of cold wave events is shown in Figure 19.

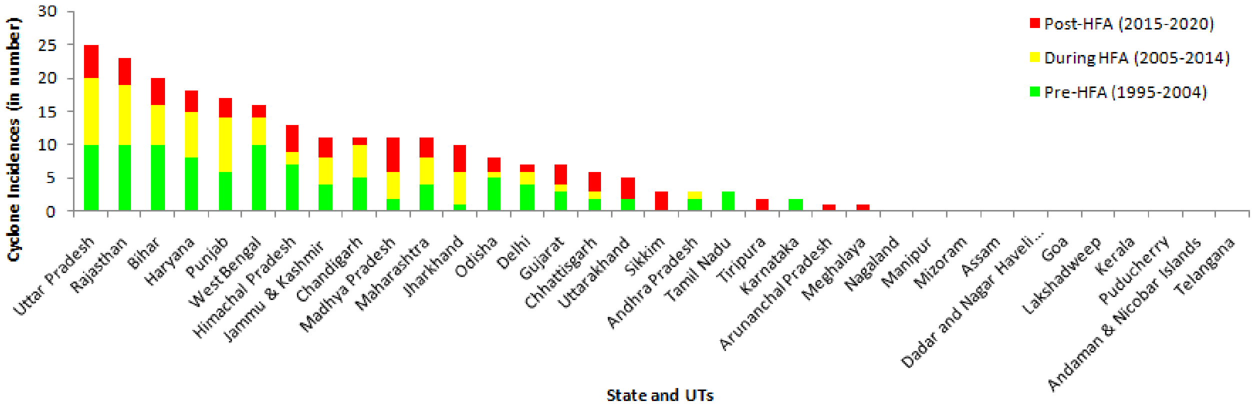
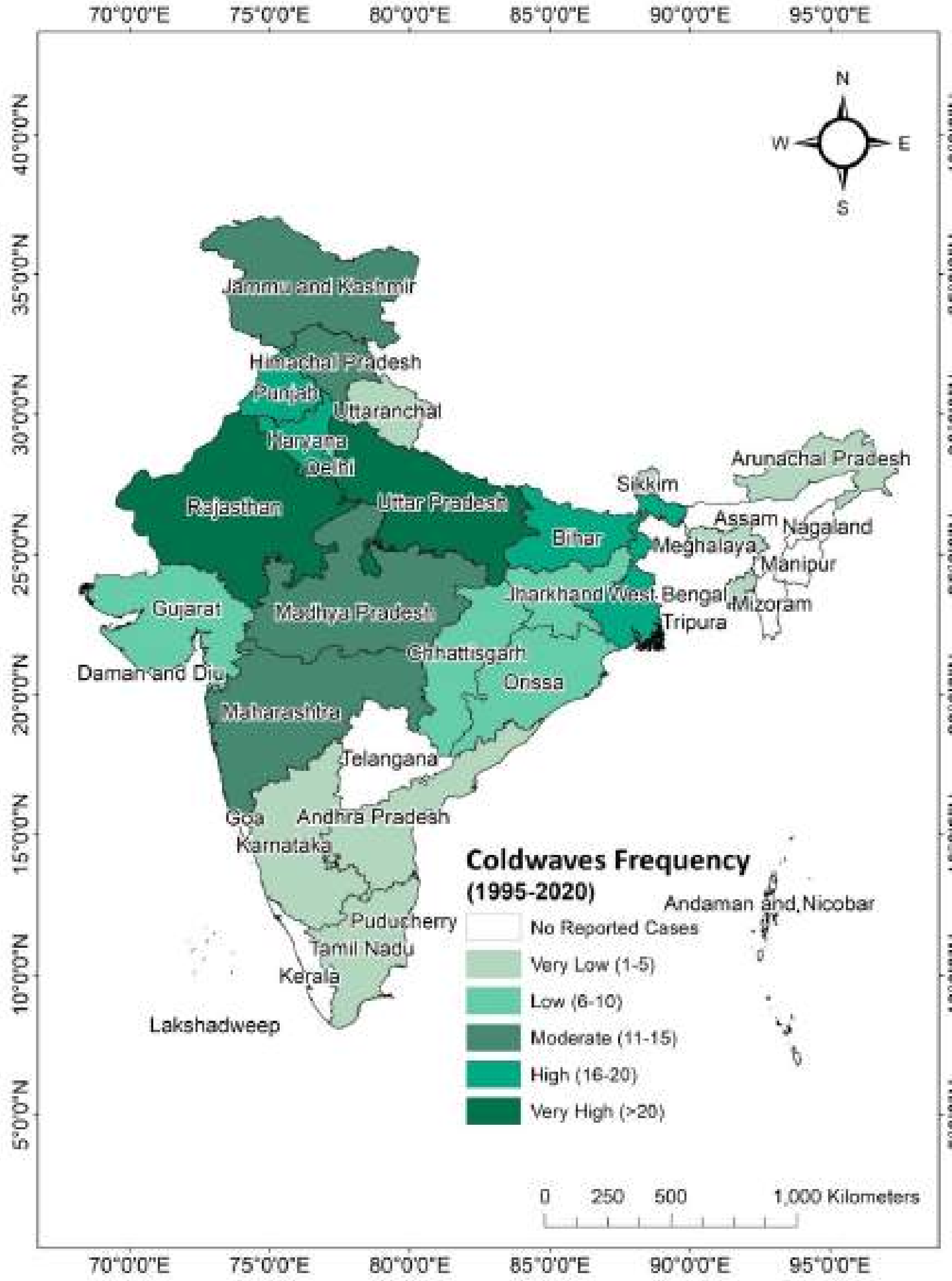


Figure 19: State-wise cold wave Incidents reported in pre-HFA, during HFA and post-HFA Period from 1995-2020

The incidences of cold waves and average number of incidents in most states remained unchanged. However, during the post-HFA period, states such as Madhya Pradesh, Jharkhand, Gujarat, Chhattisgarh and Uttarakhand as well as Himachal Pradesh, cold wave events indicated rising trend. Cold waves in the four states of Tripura, Arunachal Pradesh, Sikkim and Meghalaya were reported only in the post-HFA period. Number of cold wave events in Delhi and Chandigarh has decreased during post-HFA.



Compiled by: Study Team

Data Source, Disasterous Weather Event Reports, IMD and MHA Reports

Figure 20: State-wise cold wave frequency map for 1995-2020 period (Source: IMD)

(Note: The scale bar represents the incidences in 25 years. Very low, low, moderate, high and very high frequency representing the range 0- no cold wave cases, 0-5, 6-10, 11-15, 16-20 and more than 20 incidents during the analysis period.)

2.2. Biological disasters

Biological outbreak disaster is characterised as the devastating effects caused by a huge spread of a certain type of living organism or virus that can cause an epidemic or pandemic disease, infestation of plant, animal or insect life (Noji, 2001). Epidemic level demonstrates a disaster that affects several individuals in a given region or group. The level of a pandemic implies a disaster that affects a much wider area, often the whole continent or even the entire earth. In this study, the two key biological outbreak disasters in India, i.e., Japanese Encephalitis (JE), Dengue and COVID-19 have been covered.

2.2.1. Japanese Encephalitis (JE)

Trend analysis for JE has shown the total number of recorded events during the pre-HFA, HFA and post-HFA period as 87, 125 and 91, respectively. JE incidences shown a growing pattern, i.e., 87 in pre-HFA to 125 during HFA and 91 in less than 5 years during post-HFA, given the average annual number of events. Figure 21 shows the distribution of the total number of JE events and the average annual figure for pre-, during and post-HFA.

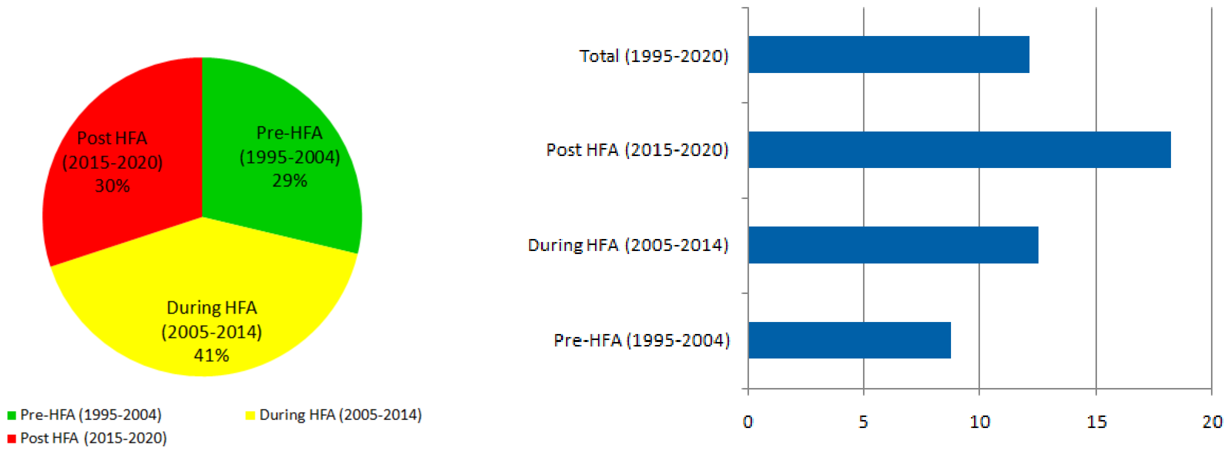


Figure 21: Percentage distribution of total number of JE events & annual average number of JE events during pre-HFA, HFA and post-HFA Periods

Tamil Nadu in India reported the first case of JE in 1955 and since then, major outbreaks have been reported from different parts of the country, in particular rural areas (Kumari et al. 2013). The disease caught the attention of the Indian Government after a major outbreak in Bankura district of West Bengal in the year 1973, where the fatality rate of approximately 43 per cent was reported (Tiwari, et al. 2012). Another major outbreak was reported in 2005 in the states of Uttar Pradesh and Bihar that claimed 1500 lives. Recent outbreak was reported in 2019 from the states of Assam and Bihar. Children under 15 years of age are more susceptible to this vector-borne disease that causes long-term neurologic abnormalities and serious disabilities (WHO, 2016).

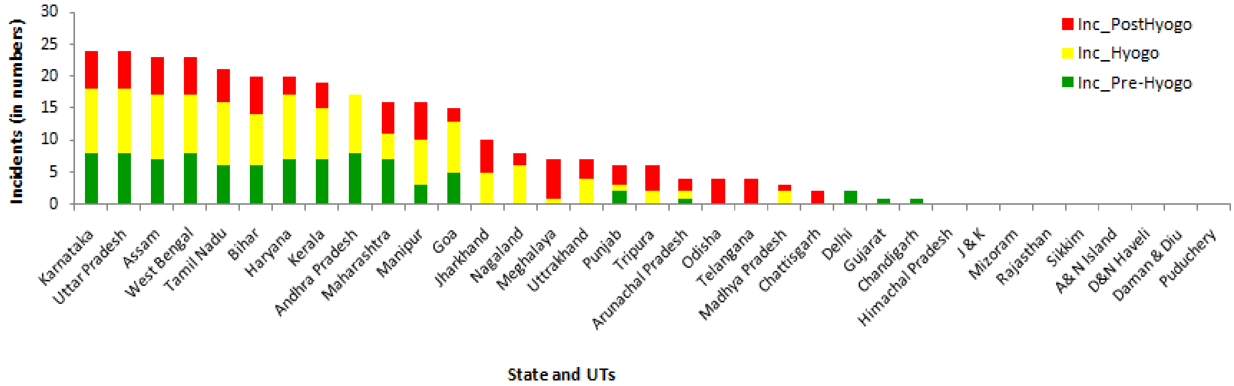
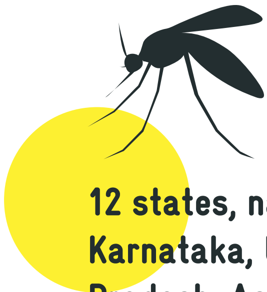


Figure 22: State-wise Japanese Encephalitis incidents reported in Pre-HFA, during HFA and Post-HFA Period from 1995-2020.

As shown in the graph (Figure 22), 12 states, namely, Karnataka, Uttar Pradesh, Assam, West Bengal, Tamil Nadu, Bihar, Haryana, Kerala, Andhra Pradesh, Maharashtra, Manipur and Goa have shown high incidences of JE. These states experienced more than 20 outbreaks during the period under analysis. Consequently, the health risk burden is very high in these states. States of Jammu and Kashmir, Mizoram, Rajasthan, Sikkim, Andaman and Nicobar and Union Territories of Dadar and Haveli, Daman and Diu and Puducherry have never reported JE incidences in the last 25 years.

JE is a vector-borne disease which spreads through mosquito Culex and needs standing water and moderate temperature to breed. Change in global climate, coupled with intensive rice cultivation and pig rearing, has been reported as some of the reasons for rise in the incidences (Hsu, et al. 2008; Sakamoto et al, 2019). As shown in Figure 22, JE incidences have increased in the post HFA periods tremendously in comparison to HFA and Pre-HFA periods. After 2015, JE spread to non-endemic regions of the country and regular cases have been reported from North-East regions, Odisha, Telangana and Chhattisgarh. In 2016, severe outbreak of JE was reported in Odisha that affected 336 children and caused 103 deaths (Sahu, et al. 2018).

Figure 23 shows the patterns of JE incidences across the country. The states of Andhra Pradesh, Assam, Bihar, Haryana, Karnataka, Kerala, Maharashtra, Manipur, Tamil Nadu, Uttar Pradesh and West Bengal are the most affected states where outbreaks have been reported regularly. Among these states, Karnataka and Andhra Pradesh have reported two outbreaks of JE every year (Singh et al. 2012) and Uttar Pradesh and Assam have been under constant surveillance due to large numbers of deaths reported recently. Today, JE has emerged as a leading paediatric health issue in our country. The disease can be prevented through early diagnosis and immunization programs.



12 states, namely, Karnataka, Uttar Pradesh, Assam, West Bengal, Tamil Nadu, Bihar, Haryana, Kerala, Andhra Pradesh, Maharashtra, Manipur and Goa have shown high incidences of JE. These states experienced more than 20 outbreaks during 1995-2020 substantially increasing the health risk burden.

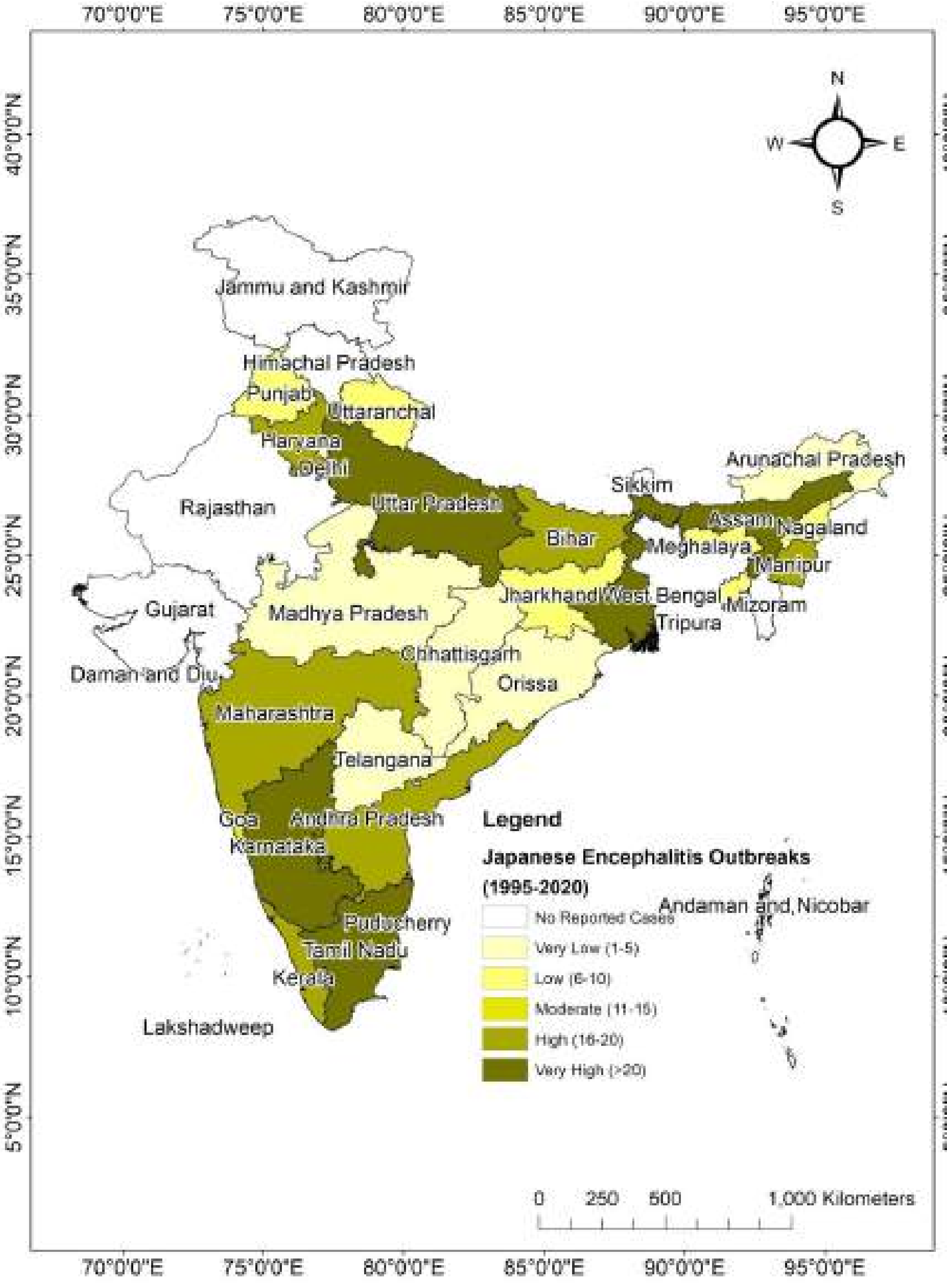


Figure 23: Japanese Encephalitis Outbreak Map with reported Incidents from 1995-2020

(Note: The scale bar represents the incidences in 25 years. Very low, low, moderate, high and very high frequency representing the range 0- no JE cases reported, 0-5, 6-10, 11-15, 16-20 and more than 20 incidents during the analysis period.)

Data source: Ministry of Health and Family Welfare

2.2.2. Dengue

Dengue epidemics in India have become more frequent since mid-1990s, particularly in urban areas, and have spread rapidly to new regions, such as Orissa, Arunachal Pradesh and Mizoram, where dengue has traditionally been non-existent (Mutheneni et al, 2017). The dengue trend review has shown the total number of recorded incidents during the pre-HFA, HFA and post-HFA periods as 87, 231 and 201, respectively. Incidences of dengue cases had an increasing trend given the total annual number of incidents, i.e. 8.7 in pre-HFA to 23.1 during HFA and 33.5 during post-HFA periods, respectively. In the post-HFA period, the average number of cases per year of dengue increased nearly four times from pre-HFA. Figure 24 shows the distribution of the total number of dengue cases and the average annual figure for pre-HFA, during HFA and post-HFA periods.

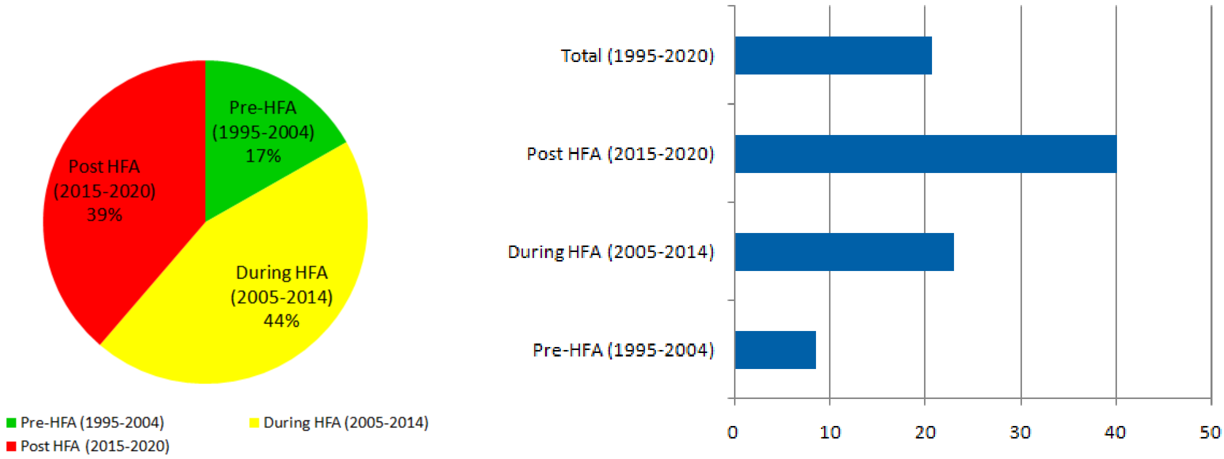


Figure 24: Percentage distribution of total number of dengue events and annual average number of dengue events during Pre HFA, HFA and post HFA Periods

With 12 states reporting more than 20 outbreaks during the period under the study, the health risk burden of dengue remained very high. Karnataka and Tamil Nadu, followed by Delhi, Gujarat, Haryana and Maharashtra, have reported the highest number of cases. Lesser incidences of dengue have been recorded in the north-eastern states (Figure 25).

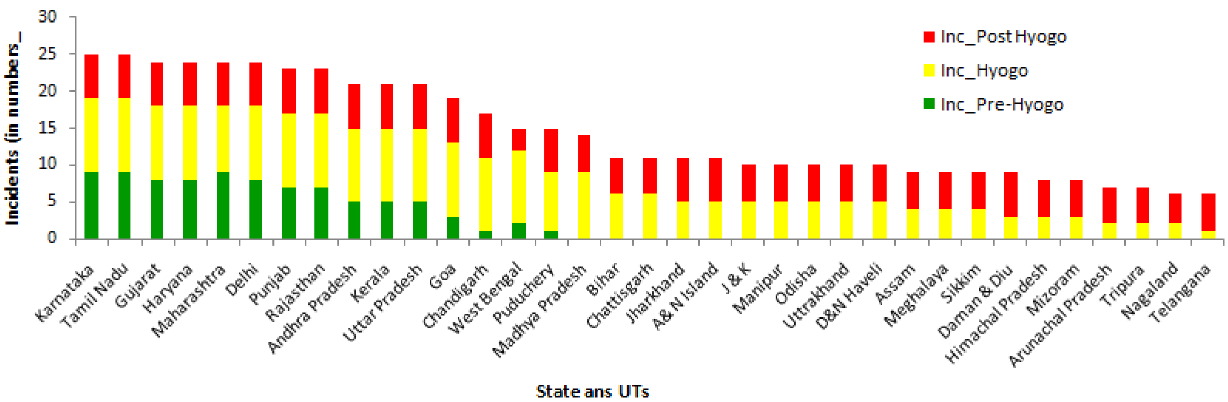


Figure 25: State-wise Dengue Incidents reported in pre-HFA, during HFA and post-HFA Period from 1995-2020.

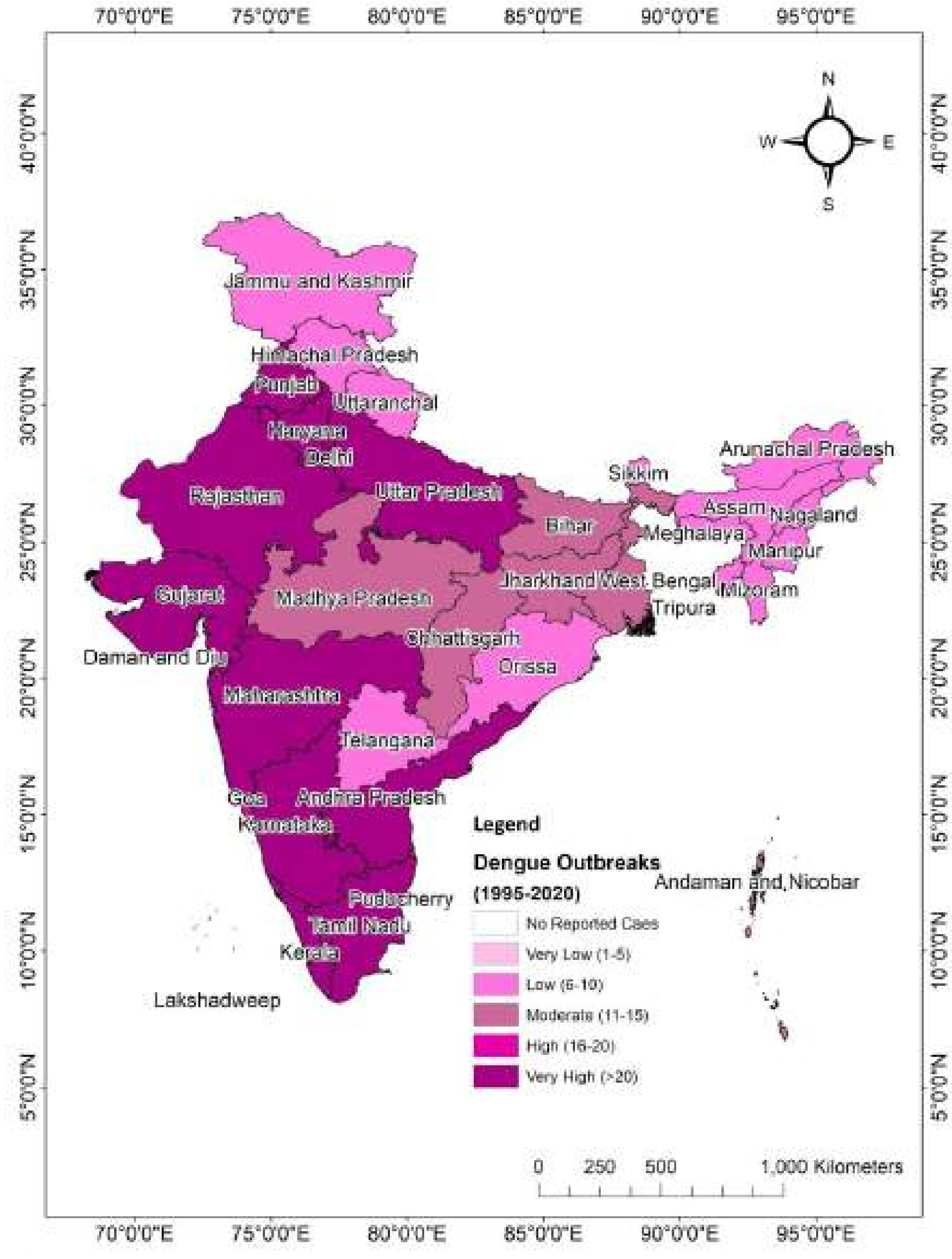


Figure 26: Dengue Outbreak Map with reported Incidents from 1995-2020

(Note: The scale bar represents the incidences in 25 years. Very low, low, moderate, high and very high frequency representing the range 0- no dengue cases reported, 0-5, 6-10, 11-15, 16-20 and more than 20 incidents during the analysis period.)

Data source: Ministry of Health and Family Welfare

As shown in the Figure 25 and Figure 26, 17 per cent of the overall pre-HFA outbreaks cases were reported from 15 states. A maximum number of dengue outbreaks were recorded during the HFA period, with 231 (46 per cent) reported in different states of India. Geographical locations and the prevalence of disease have changed over time. Changes in the weather cycle and weakened immune systems are attributed to an increase in the number of dengue cases (Gupta et al, 2012).

2.2.3. COVID-19

The case wise distribution of COVID-19 indicates that 97 per cent (10,533,330) persons have been cured, about 1 per cent (1,46,091) active cases exist and only 2 per cent (1,54,996) persons died as of 30 November 2020 (Figure 27).

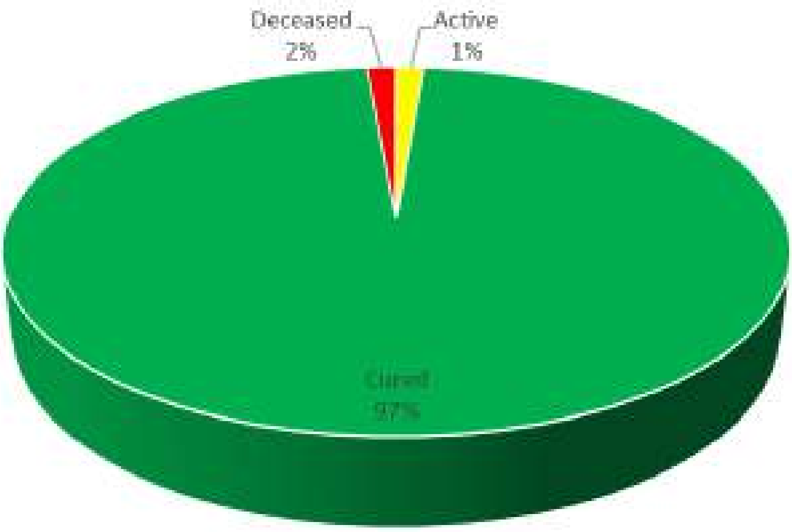


Figure 27: COVID-19 reported, cured and deceased persons as on 7 February 2021

COVID-19 is a highly infectious disease caused by a newly discovered strain of the virus. The world as a whole is under the influence of this pandemic. Active cases have been reported in almost all states of India. With the highest number of cases registered and still increasing every day, Maharashtra is the worst affected state in India as shown in Figure 28.

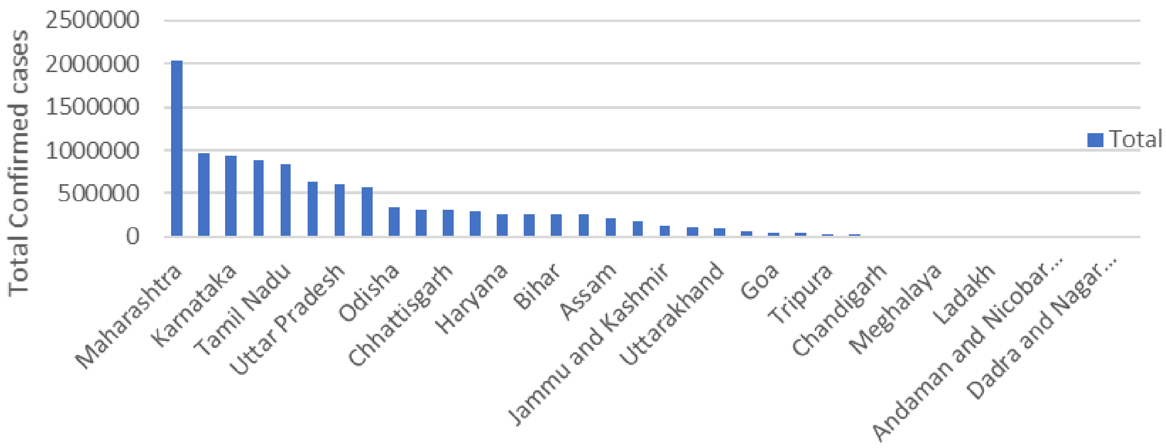


Figure 28: State-wise COVID-19 total cases confirmed as on 7 February 2021 (https://www.mohfw.gov.in)

In India, Maharashtra has witnessed the highest number of cases followed by Karnataka, Tamil Nadu, Andhra Pradesh, Delhi, Uttar Pradesh, Punjab and Gujarat (Figure 29). However, reported cases per 100,000 population is highest in Punjab and Delhi, followed by Maharashtra, Karnataka, Kerala, Tamil Nadu, Chhattisgarh and Arunachal Pradesh.

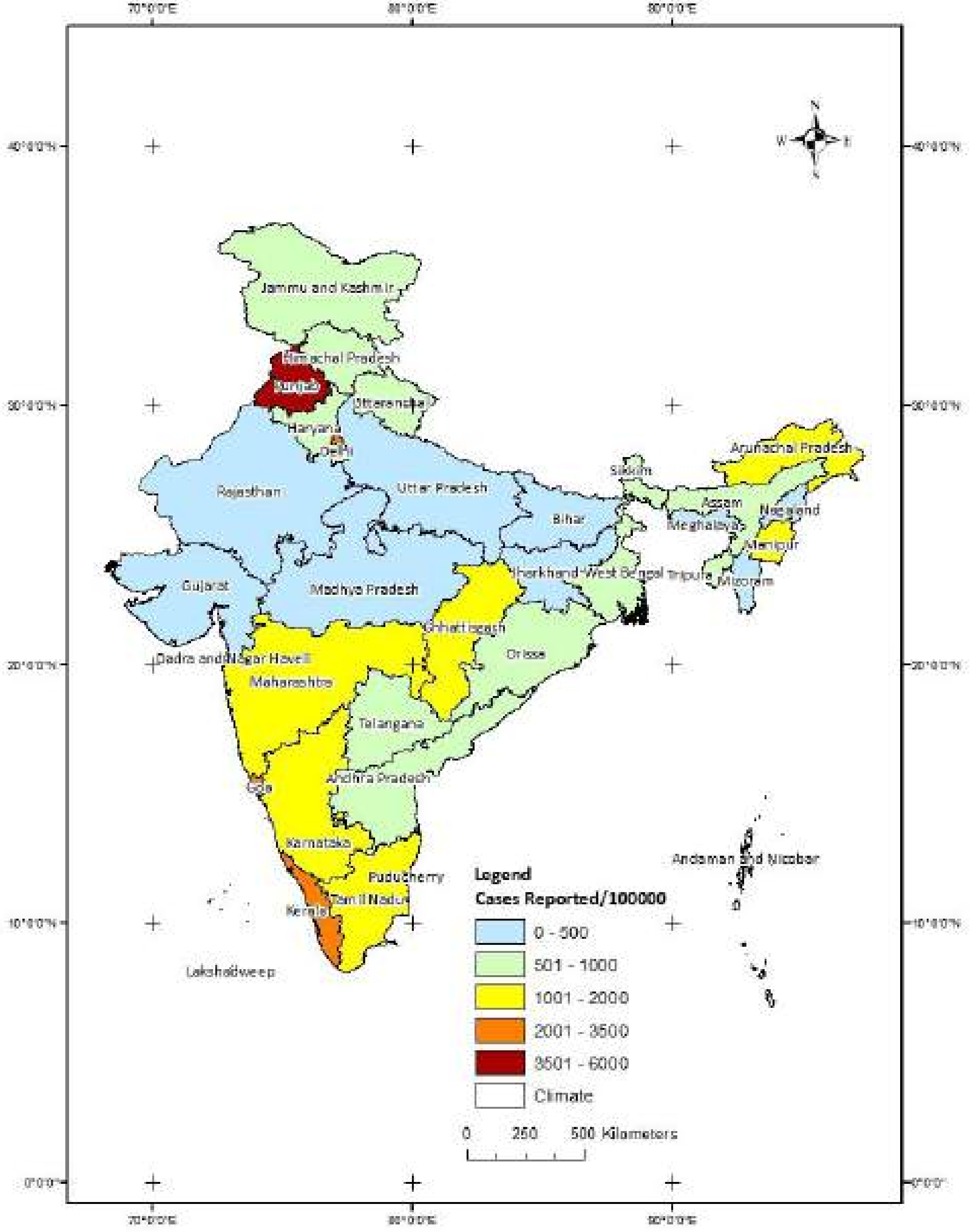


Figure 29: Map depicting the number of confirmed cases per 100,000 population as on 7 February 2020 (data source: https://www.mohfw.gov.in/)

Data source: Ministry of Health and Family Welfare

It is noteworthy that the total number of cases in the north-eastern states is relatively low, as compared to other states of India, although Arunachal Pradesh and Manipur have more than 1,000 cases per 100,000 population.

2.3. Composite Analysis for Climatic and Biological disasters

2.3.1. Climatic disasters

State-level composite analysis of the total number of events reported during the period and disaggregated for pre-HFA, HFA and post-HFA period has been carried out to understand the changing trends spatially during the three periods (Figure 30). State-level composite spatial analysis shows that eight out of 36 states have experienced more than 50 disasters during 1995-2020. The highest number of climatic events is recorded in Rajasthan (n=72), followed by Odisha (n=67), Uttar Pradesh (n=66), West Bengal (n=66), Bihar (n=64), Maharashtra (n=60), Andhra Pradesh (n=52). Goa, Dadar and Nagar Haveli and Daman & Diu did not have any reported events (IMD).

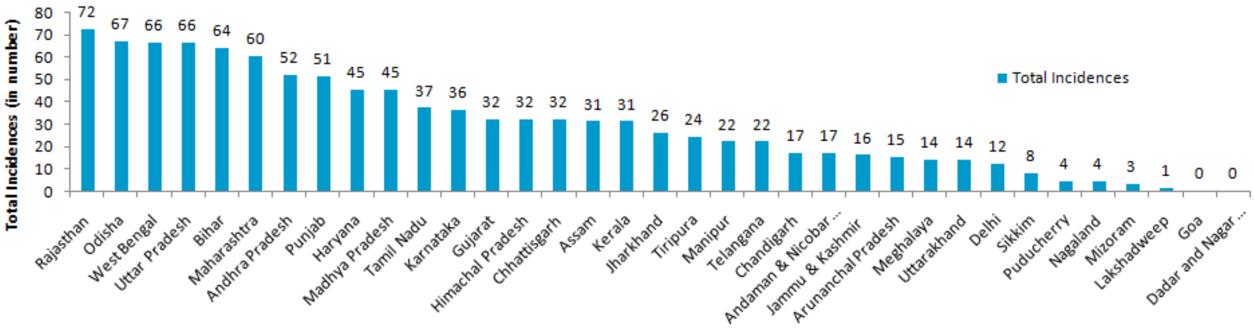


Figure 30: State-wise overall climatic disasters from 1995-2020

Multi-hazard spatial analysis has shown that six states viz. Odisha, West Bengal, Maharashtra, Andhra Pradesh, Gujarat, and Tamil Nadu witnessed all five of the selected disasters (Figure 31). In a number of North Indian states viz. Rajasthan, UP, Punjab, Haryana, Himachal Pradesh, Bihar, four out of five climatic disasters were reported. Similar profile can also be seen in the case of central Indian states such as Madhya Pradesh, as well as in South Indian states such as Karnataka and Kerala.

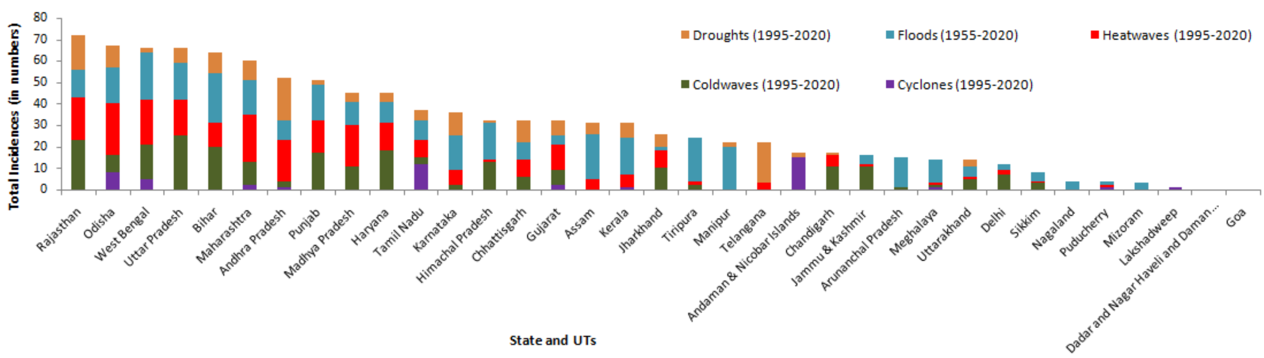
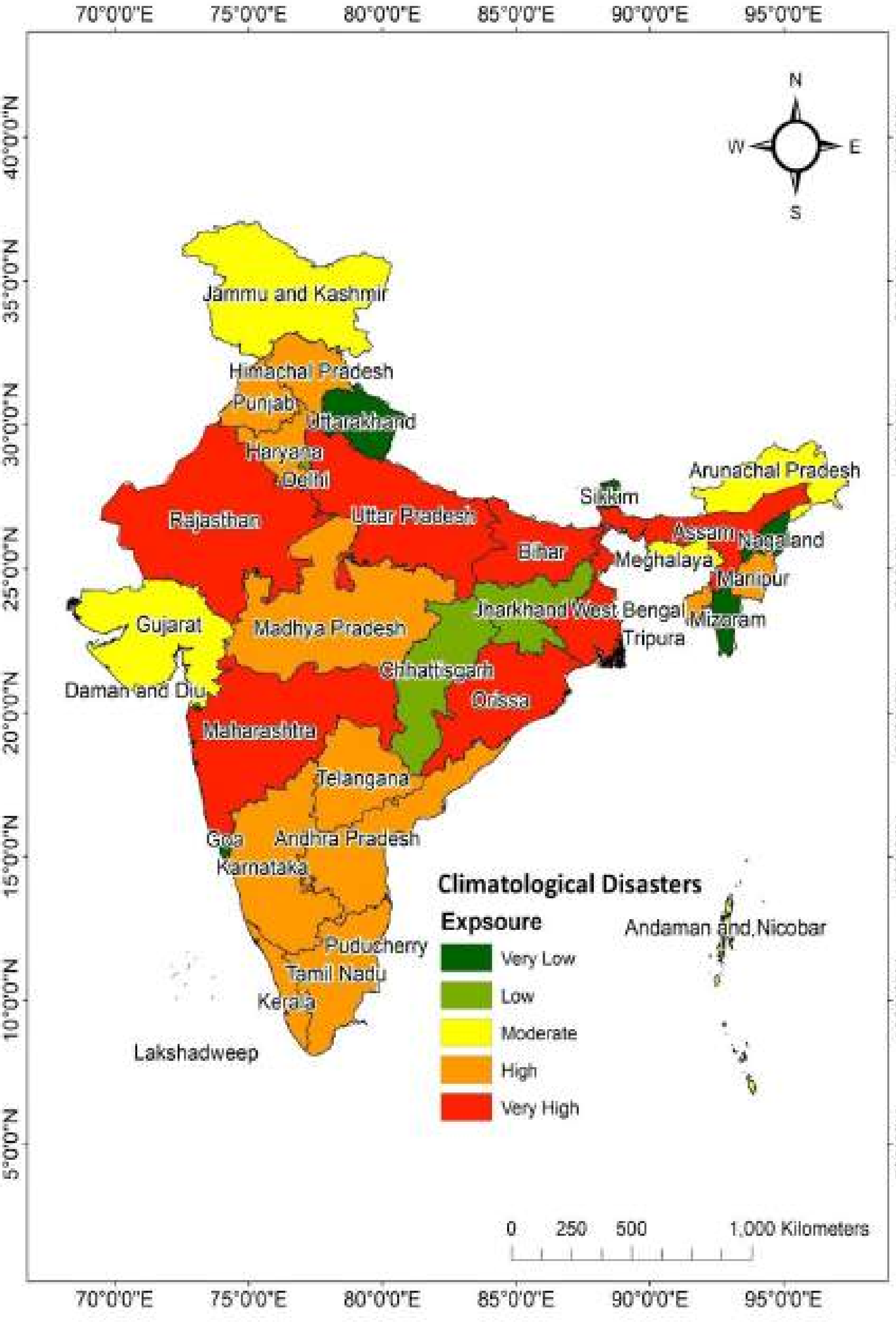


Figure 31: State-wise breakup of climatic disasters reported during 1995-2020

The weighted overlay method has been applied for geo-spatial analysis of disaster events by frequency of occurrences. Equal weight has been given to all the five selected disasters and ranks from 1 to 5 are assigned to each for the five climatic disasters in ascending order. Rank 5 means more than 20 events in the reporting period and 1 means less than 5 events. Composite overlay map depicting the total number of events is given in Figure 32.



Compiled by: Study Team

Data Source, Disasterous Weather Event Reports, IMD and MHA Reports

Figure 32: Composite Climatic Disaster frequency map for the period 1995-2020.

2.3.2. Biological disasters

As per the analysis, there has been an overall increase in the number of biological outbreaks from 1995 to 2020. Figure 33 shows state-wise distribution of biological outbreaks, i.e., Dengue and Japanese Encephalitis as per the latest research for the period 1995-2020.

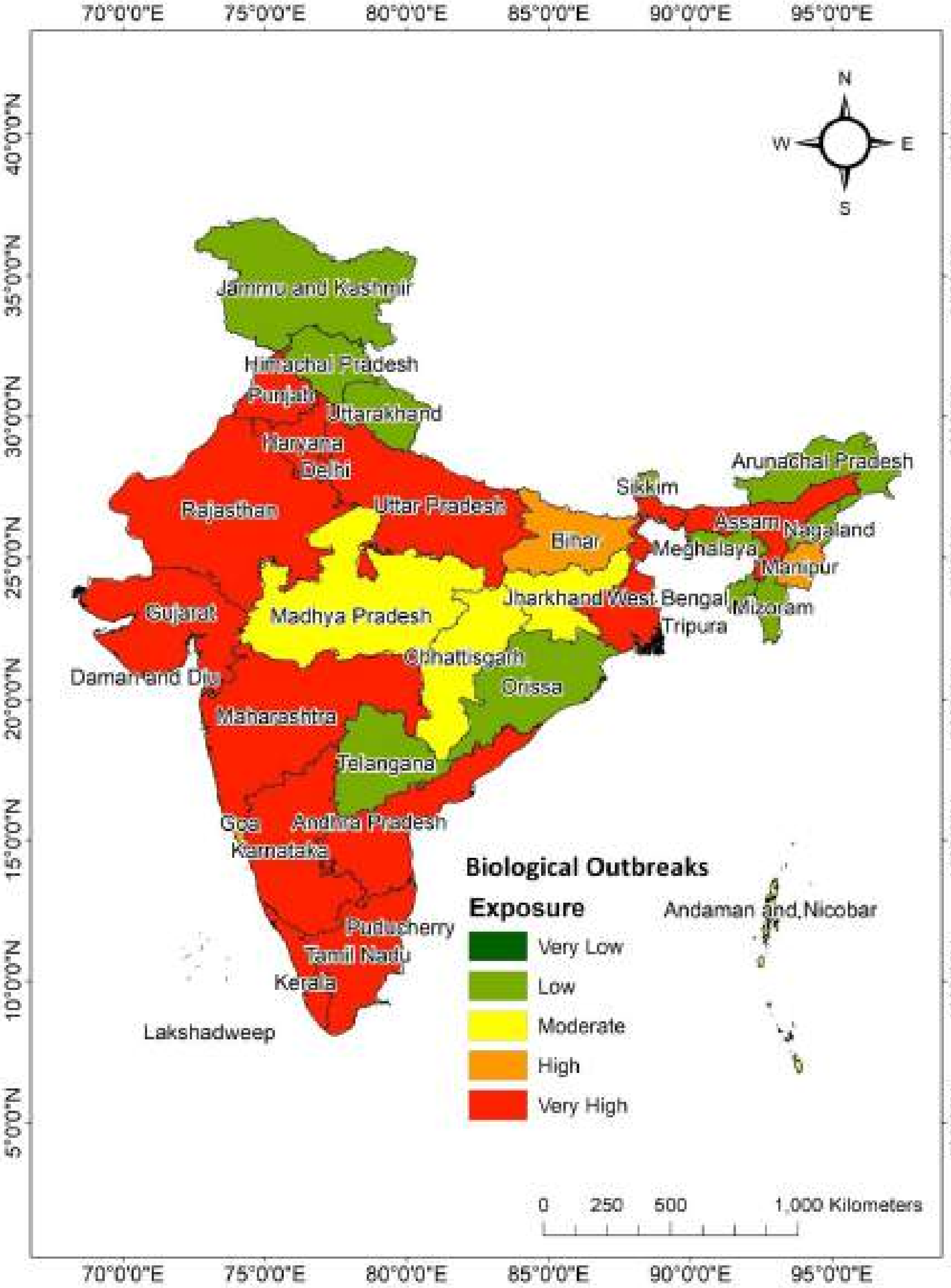


Figure 33: Comparative state-wise analysis of overall numbers of incidents for Dengue and Japanese Encephalitis during 1995-2020.

Data source: Ministry of Health and Family Welfare

COVID-19 has not been taken for comparative analysis here as it was not reported in any of the previous years. It has been used as one event for each state while performing the overlay analysis for deriving the composite map. The spatial distribution of COVID-19 is much higher than JE and dengue as the infections have spread to every part of India.

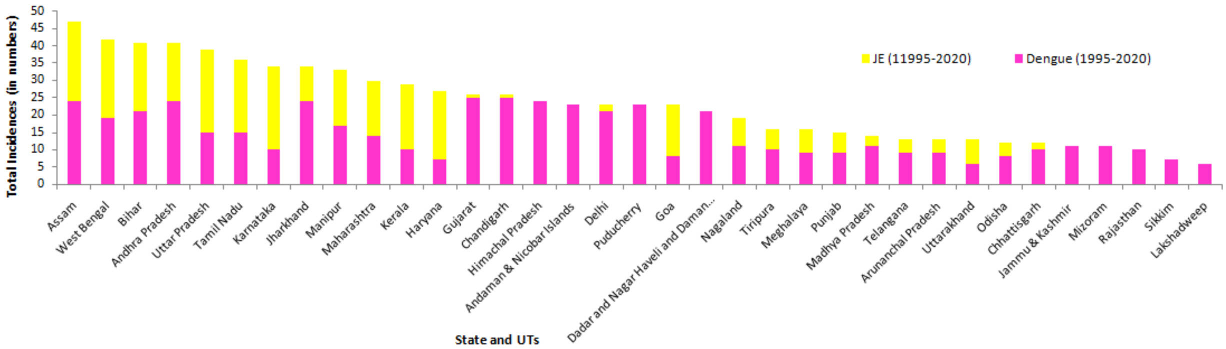


Figure 34: Comparative state-wise analysis of overall numbers of incidents for Dengue and Japanese Encephalitis during 1995-2020.

As evident from Figure 33 and Figure 34, the spatial coverage of dengue is more than JE. As per the official data, total 507 incidences of dengue and 303 incidences of JE have been reported in the last 25 years. Dengue cases have been reported from all States and Union Territories, most of the cases coming from urban and peri-urban regions of India. Sporadic cases have also been reported from rural India. In the case of JE, maximum cases have been reported from rural India and are strongly linked with states where rice cultivation is a major agricultural practice.

2.3.3. Combined climatic and biological disasters

To understand the frequency of selected disaster events at the state level for all the eight events, a composite map has been prepared. Similar to the composite map of climatic and biological events, weighted overlay method was applied with equal weightage and ranks in descending order of frequency. Figure 35 shows the state-wise comparative spatial distribution of both biological and climate related disasters, i.e., JE, Dengue, Drought, Floods, Heat Waves, Cold Waves and Cyclones as per the current study for the period 1995-2020.

From Figure 36, it is evident that West Bengal, Uttar Pradesh and Bihar are the 3 states that have experienced more than 100 events combining both climatic and biological outbreak events, and 15 states and UTs have experienced more than 50 events in the same period.

Composite frequency map of climatic and biological outbreak disasters clearly shows that no state or UT of India is free of disasters. UTs such as Dadra & Nagar Haveli and Daman & Diu were not affected by climatic events. However, the UTs reported several events of dengue during the period.

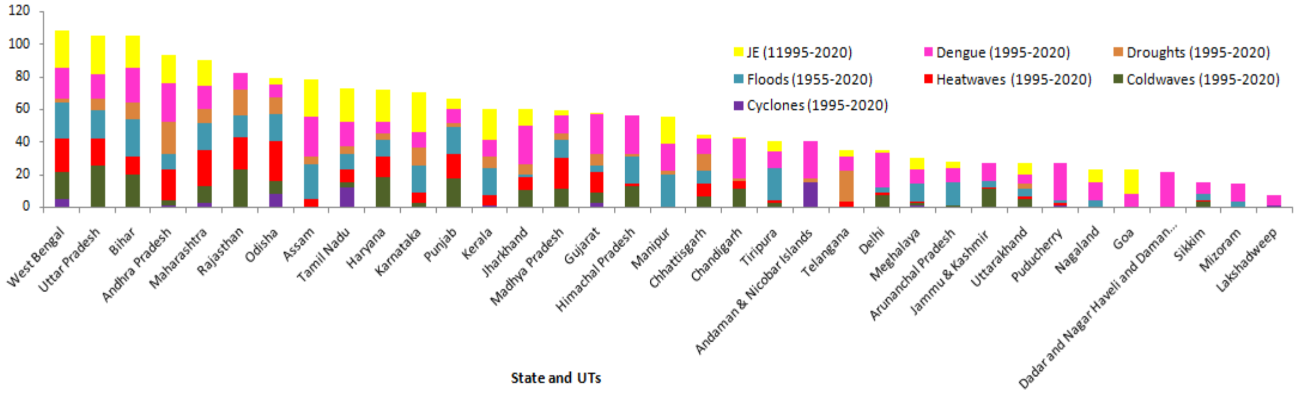


Figure 35: Comparative state-wise analysis for overall numbers of Incidences for JE, Dengue, Drought, Floods, Heat waves, Cold waves and Cyclone during 1995-2020.

As seen in the bar diagram, total number of disaster events year wise (disaggregated at state level except COVID-19) indicates an increasing pattern for both hydro-meteorological and biological disasters (Figure 36). The overall number of recorded incidents were highest in 2016 and lowest in 1996 (no reported outbreaks), respectively.

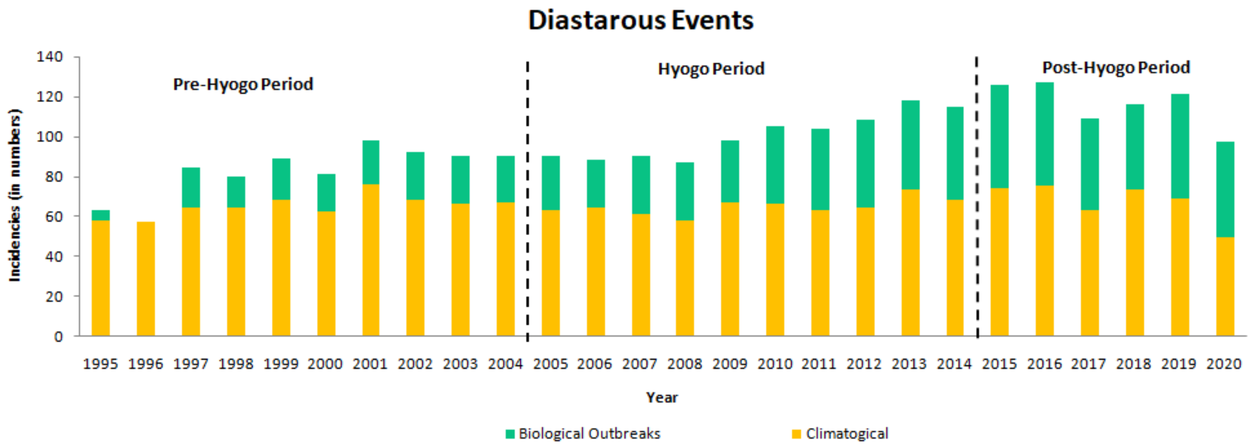
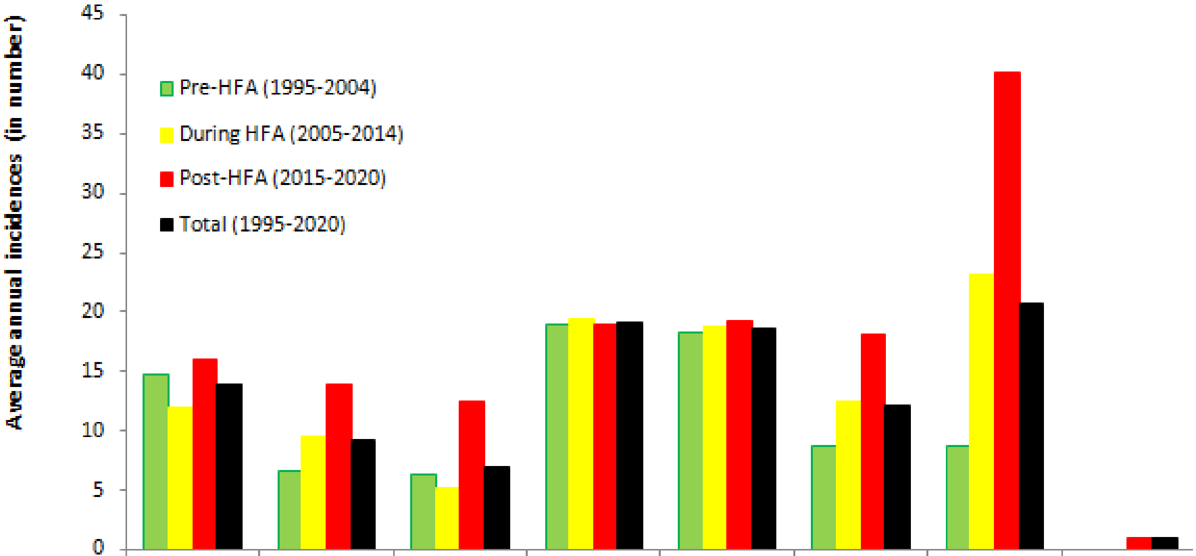


Figure 36: Yearly Trend for all disasters (climatic + biological) represented as stacked bars.

During the pre-HFA, HFA and post-HFA period, the total number of events recorded were 594, 712 and 575, respectively. The stacked bar diagram indicating annual average number of events disaster wise for all the eight disasters studied for the pre-HFA, HFA and post-HFA period is shown in Figure 37.



	Flood	Cyclone	Drought	Heatwave	Coldwaves	Japanese Encephalitis	Dengue	COVID-19
Pre-HFA (1995-2004)	15	7	6	19	18	9	9	0
During HFA (2005-2014)	12	10	5	20	19	13	23	0
Post-HFA (2015-2020)	16	14	12	19	19	18	40	1
Total (1995-2020)	14	9	7	19	19	12	21	1

Figure 37: Average annual number of disaster events recorded for Pre, during, post HFA and total number.

From Figure 37 and Table 1, it is evident that both the biological and climatic disasters have shown an increasing trend in the post-HFA period. Among the climatic disasters, drought and cyclone have shown significantly increasing trend in the post-HFA period. None of the disasters show any decreasing trend in post-HFA.

Table 1: Total number of reported disaster events during 1995-2020

Disaster	Pre-HFA (1995-2004)	During HFA (2005-2014)	Post-HFA (2015-2020)	Total (1995-2020)	Av. Annual (Pre-HFA)	Av. Annual (HFA)	Av. Annual (Post HFA)	Av. Annual -Total
Flood	148	119	80	347	14.80	11.90	13.33	13.35
Cyclone	19	17	12	48	1.90	1.70	2.00	1.85
Drought	63	51	62	176	6.30	5.10	10.33	6.77
Heat Waves	90	95	68	253	9.00	9.50	11.33	9.73
Cold Waves	100	74	60	234	10.00	7.40	10.00	9.00
Sub Total	**420**	**356**	**282**	**1058**	**42.00**	**35.60**	**47.00**	**40.69**
Biological					0.00	0.00	0.00	0.00
JE	87	125	91	303	8.70	12.50	15.17	11.65
Dengue	87	231	201	519	8.70	23.10	33.50	19.96
COVID-19	0	0	1	1	0.00	0.00	0.17	0.04
Sub Total	**174**	**356**	**293**	**823**	**17.40**	**35.60**	**48.83**	**31.65**
Total	**594**	**712**	**575**	**1881**	**59.40**	**71.20**	**95.83**	**72.35**

The average annual number of events during the Sendai period was calculated by dividing the total number of events by the number of years. For e.g., for pre-HFA total number of events is divided by 10, for post-HFA the total number is divided by 6 since the data collected is for six years period.

Geospatial study, such as a composite analysis of climatic parameters, helps in determining the trend of climate-related disasters and associated risks. State-level composite spatial analysis has shown (Figure 38) that 8 out of 36 states experienced more than 50 disasters during the analysis period. The highest number of climate-related adverse events is recorded in Rajasthan (n=72), followed by Odisha (n=67), Uttar Pradesh (n=66), West Bengal (n=66), Bihar (n=64), Maharashtra (n=60), Andhra Pradesh (n=52). Goa, Dadar & Nagar Haveli and Daman & Diu did not have any reported events during that period.

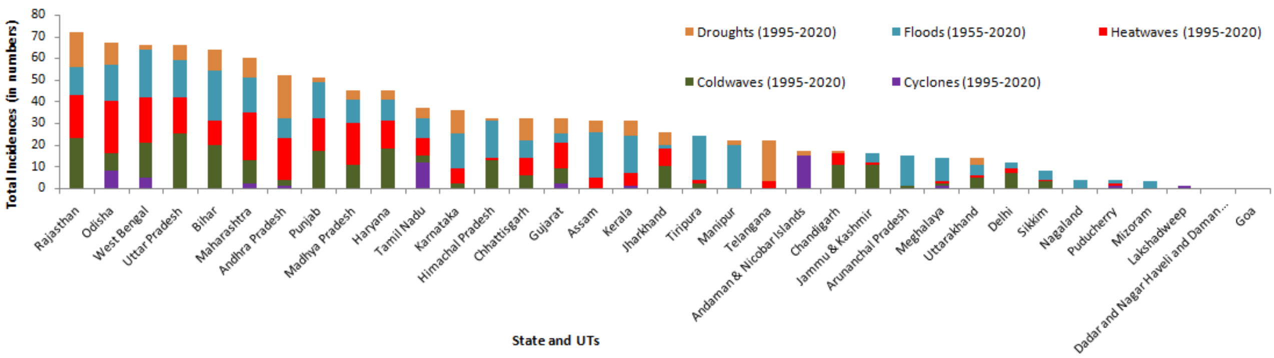


Figure 38: State-wise overall Incidents reported from 1995-2020

Multi-hazard spatial analysis shows that all five of the studied climatic disasters were witnessed by Odisha, West Bengal, Maharashtra, Andhra Pradesh, Gujarat and Tamil Nadu. Four out of five climate related disasters were reported in a number of the North-Indian states, viz. Rajasthan, UP, Punjab, Haryana, Himachal Pradesh and Bihar. Similar profile can also be seen in the case of central Indian states such as Madhya Pradesh, as well as in South Indian states such as Karnataka and Kerala. In the case of JE, maximum cases have been reported from rural India and are strongly linked with states where rice cultivation is the major agricultural practice.

Scale of Implications of Disasters

Cyclones accounted for

48% of India's

overall human life loss due to climate-related disasters, followed by heat waves (26 per cent), 18 per cent due to floods and 8 per cent due to cold waves

In this section, we delve into impacts of the select climatic and biological disasters in India. As mentioned in the foregoing, there is a lack of systematic data on economic loss and damage due to disasters in general, for both types of disasters: frequent but widespread and low impact—extensive ones, and infrequent but high impact in small areas—intensive disasters. The only data on impacts that is available and systematic is regarding population and area affected. In these categories, population affecting the data on mortality was useful for the purpose of the study. Hence, this section looks into mortality, especially for biological disasters, and additionally, also analyses the statistics on affected population. In addition, the overall impacts across social, economic and environmental sectors are presented towards the end as case studies.

3.1. Climatic Disasters

3.1.1. Floods

India has consistently faced many flood events that claimed huge loss of economy and lives. In the present study, state and UT wise temporal and spatial analysis of the total number of deaths due to floods, i.e., loss to human life has been carried out. Besides deaths, the total area affected and total economic loss has also been used to assess the impact of the floods.

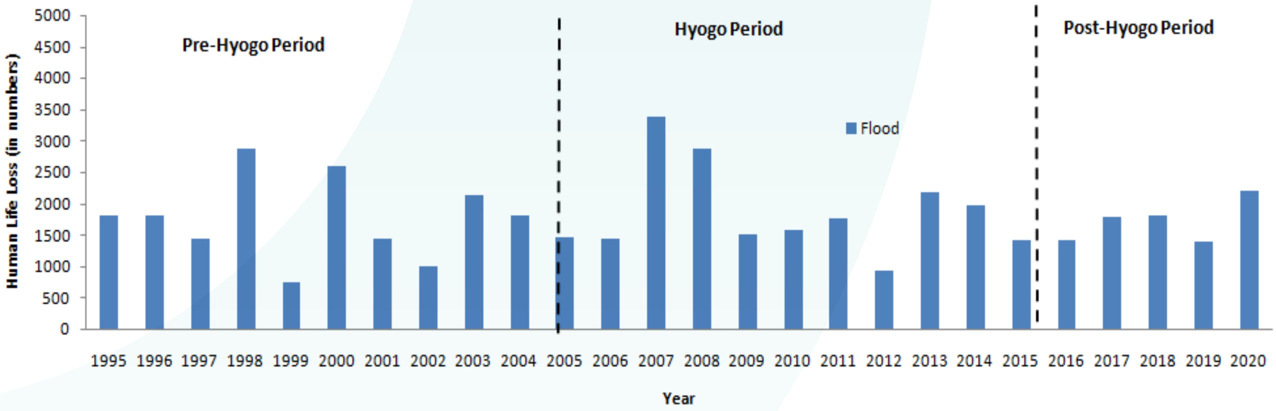


Figure 39: Year wise trend for flood related death during 1995 to 2020

Total human lives lost due to flood during the period of analysis was 45,065. Number of deaths reported during pre-HFA, HFA and post-HFA (SFDRR) were 17,944, 19,088 and 8033, respectively (Figure 39). Year wise distribution of human lives lost by flood events reveals no significant change over the three periods. Peak in number of deaths were reported in the years 1998, 2000, 2007 and 2008. The percentage of human lives lost were 34 per cent, 35 per cent, and 31 per cent of the total deaths reported during pre-HFA, HFA and post-HFA Periods (Figure 40). There was a slight increase (1 per cent) during the HFA period in comparison to Pre-HFA, and further decrease in mortality during post-HFA (i.e. SFDRR).

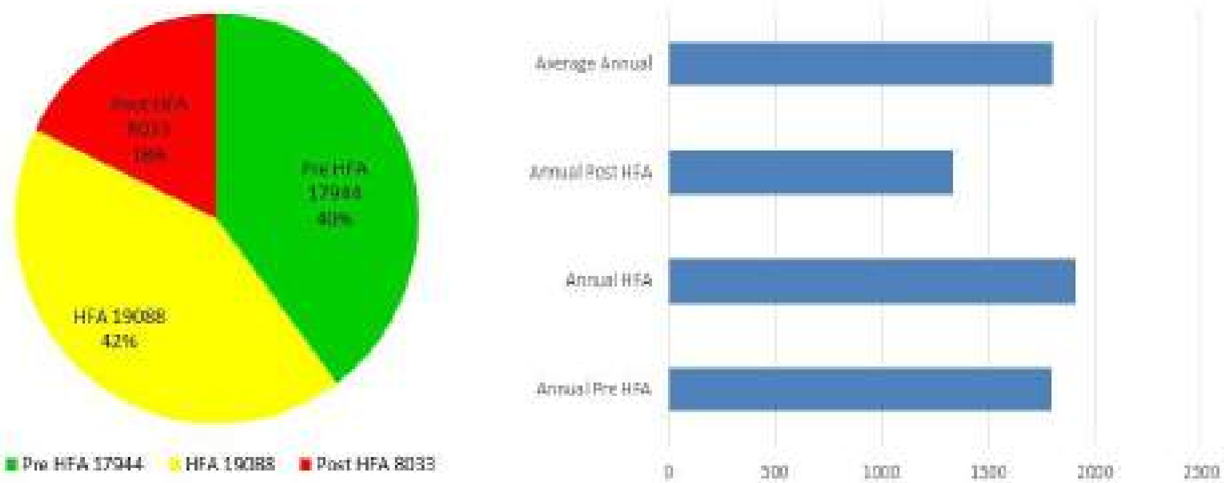


Figure 40: Percentage distribution of human lives loss due to flood & the total number of human lives lost per year due to flood incidents during pre-HFA, HFA and post-HFA periods.

Figure 41 shows state-wise distribution of human lives lost due to floods during 1995 to 2020. Analysis indicated the mortality due to floods as very high (>4000) in the states of West Bengal, Uttar Pradesh and Bihar, whereas it was high (3000-4000) in the states of Gujarat, Andhra Pradesh, Karnataka and Kerala. The mortality was moderate (2000-3000) in Uttarakhand, Chhattisgarh, and Himachal Pradesh, while it was low (1000-2000) in Tamil Nadu, Assam, Madhya Pradesh, Rajasthan and Maharashtra. This was further reported very low (0-1000) in the remaining states of Jammu and Kashmir, Punjab, Haryana, Odisha, Sikkim, Arunachal Pradesh, Nagaland, Mizoram, Meghalaya and Tripura. These remaining states had no reported deaths.

Death varied from state to state with 25 of the 36 states and UTs reported flood-related deaths. The states of Uttar Pradesh and Bihar were the most affected in terms of annual average death count (Figure 41).

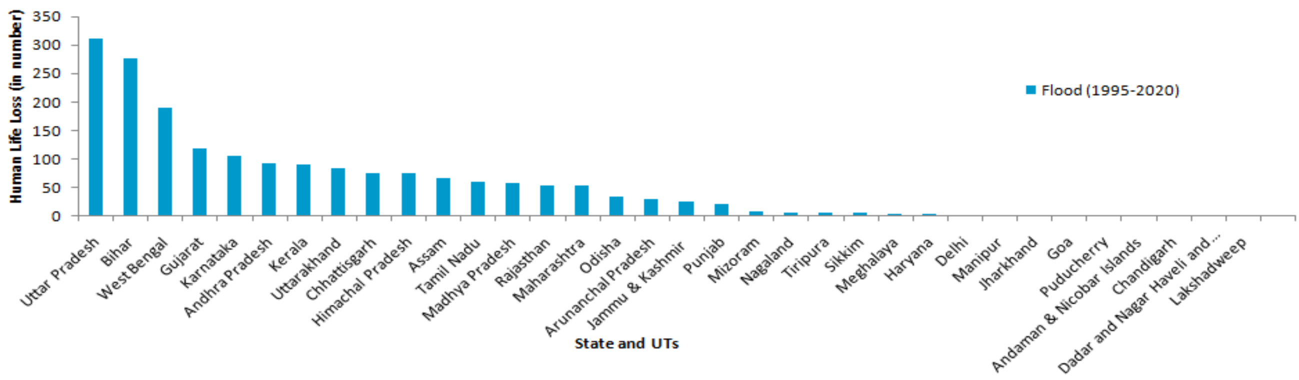
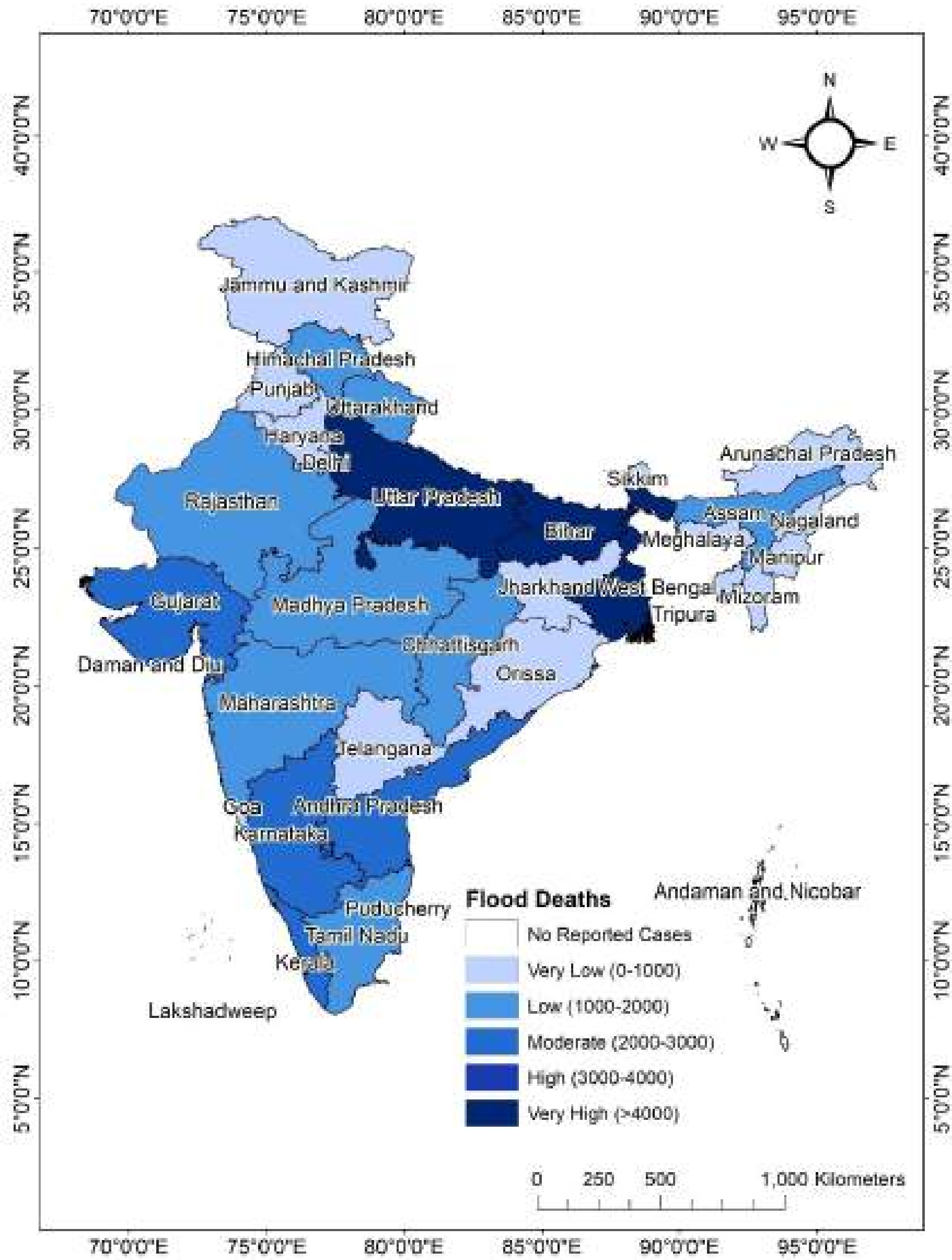


Figure 41: Annual average number of deaths due to flood incidents at the state level



Compiled by: Study Team
Data Source, Disasterous Weather Event Reports, IMD and MHA Reports

Figure 42: Thematic map depicting the loss of human lives due to floods at state level

In the states such as Uttar Pradesh, Bihar, West Bengal, Gujarat, Karnataka, Andhra Pradesh, Kerala and Uttarakhand, more than 100 people lost their lives on an annual basis due to floods (Figure 42).

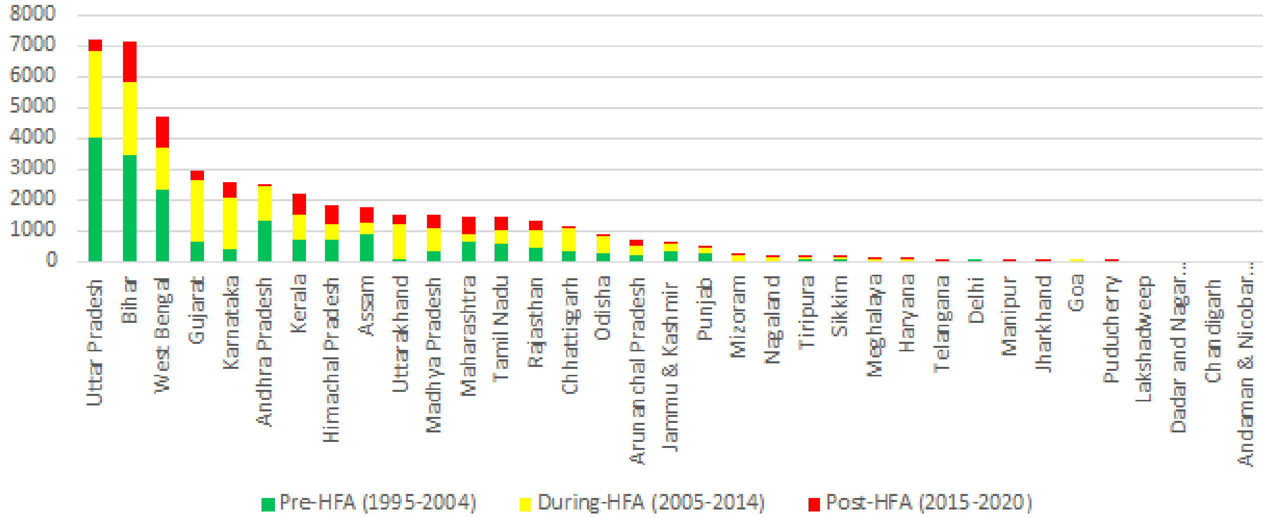


Figure 43: State-wise distribution of human lives loss due to flood incidents during pre-HFA, HFA and post-HFA.

It is also observed that during the pre-HFA, HFA and post-HFA, mortality due to floods was not consistent (Figure 43). In Bihar, Kerala, West Bengal, Himachal Pradesh, Assam, Tamil Nadu, Madhya Pradesh, Maharashtra and Rajasthan, the flood related deaths increased during the post-HFA period. Although flood-related deaths were highest in Uttar Pradesh, and the number of deaths decreased from pre-HFA to HFA period and further in post-HFA period. Manipur recorded flood related deaths only in post-HFA. Since Telangana was formed in 2015, flood related deaths were reported only during the post-HFA. In Gujarat, Delhi, Punjab, Chhattisgarh, Odisha and Andhra Pradesh, the flood related mortality reduced substantially during the post HFA period.

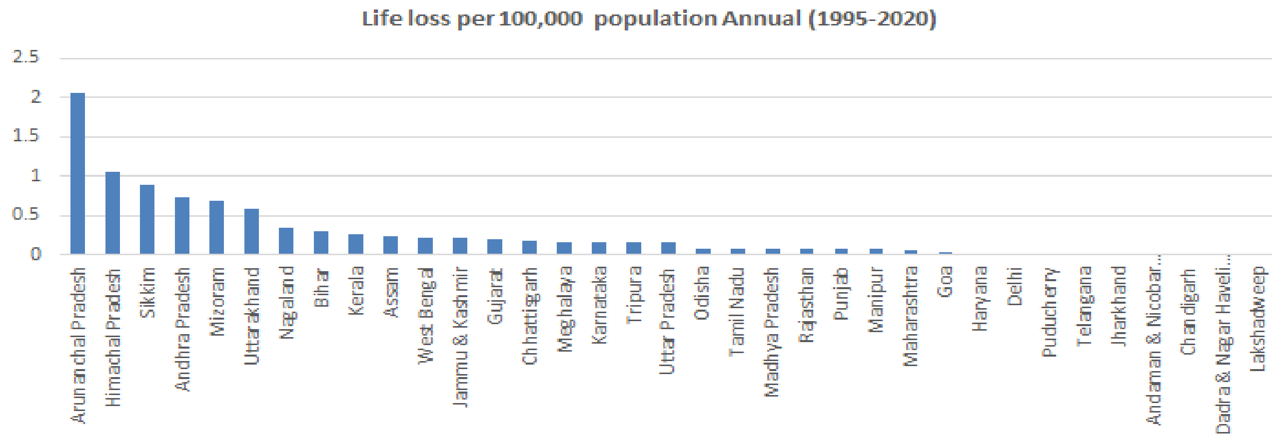


Figure 44: State-wise human lives lost per 100,000 population due to Flood

Deaths per 100,000 population is highest in Arunachal Pradesh (Figure 44), which is followed by Himachal Pradesh, Sikkim and Andhra Pradesh. Although Uttar Pradesh ranks first in the total number of fatalities, it ranks 18th in mortality per 100,000.

3.1.2. Droughts

Though the famine situation is fully averted and droughts have become less intense in the recent years as compared to the previous century, droughts still ravage one or the other parts of the country almost every year, following deficiency in rainfall or its erratic spatial and temporal distribution. In recent years, the impact of drought has been widespread and has became a national concern during 1987-88, 2002-03, 2009-10 and 2015-16 continuing until 2018.

During the analysis period, major droughts were reported during 2002, 2009 and 2015. Number of districts declared drought affected was 383, 338 and 273 respectively during 2002, 2009 and 2015. More than 25 per cent of the districts in the country were affected by drought during 2001, 2004, 2012, 2014, 2016 and 2018. During the Sendai Framework period, there was an increase in the frequency of drought, as evident from drought declared districts (Figure 45).

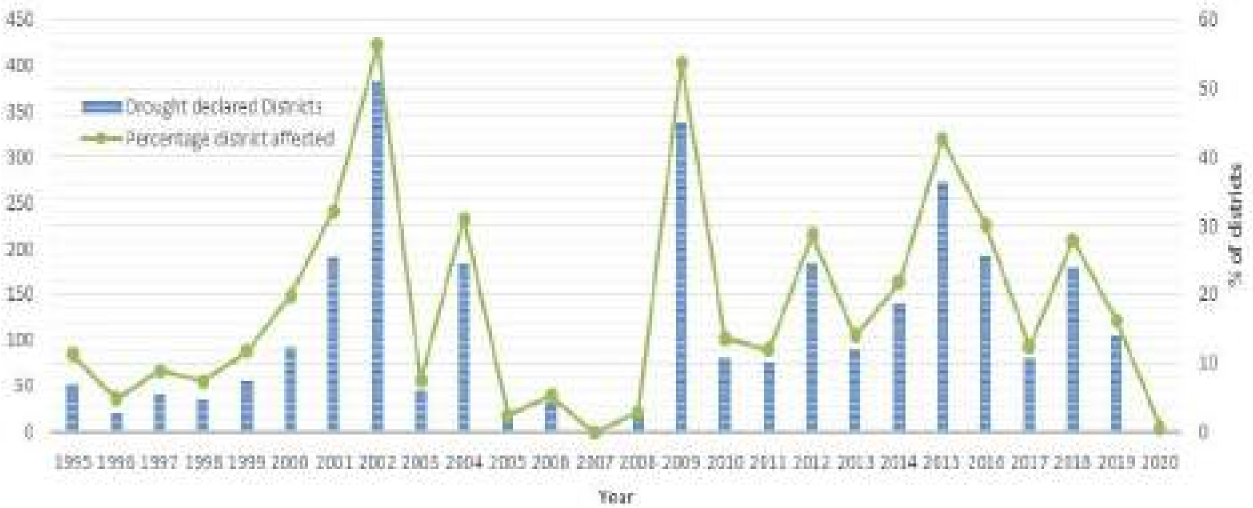


Figure 45: Total number of districts and percentage of districts declared as drought affected during 1995-2020 period.

The major drought during the pre-HFA period was in 2002. A total of 390 districts received deficient rainfall, out of which 177 districts received scanty rainfall i.e. less than 60 per cent of normal. 18 states were hit by drought and affected more than 300 million people. 56 per cent land received low monsoon rains, affecting nearly 300 million people. The loss was phenomenal. Agricultural contributions to the Gross Domestic Product (GDP) dipped by 3.1 per cent and agricultural income losses were estimated at Rs 39,000 crore. There was a steep fall in food grain production to the extent of 29 million tons in 2002. Due to deficit rainfall during the Kharif season, about 18.53 million hectare land was left unsown. The most affected states in terms of the cultivable land area unsown were Rajasthan (41 per cent). Tamil Nadu (27 per cent), Uttar Pradesh (19.4 per cent), Karnataka (17.6 per cent), Madhya Pradesh (13 per cent). Around 150 million cattle were affected due to lack of water and fodder.

Total of 390 districts received deficient rainfall, out of which 177 districts received scanty rainfall i.e. less than 60 per cent of normal during the major drought of 2002.

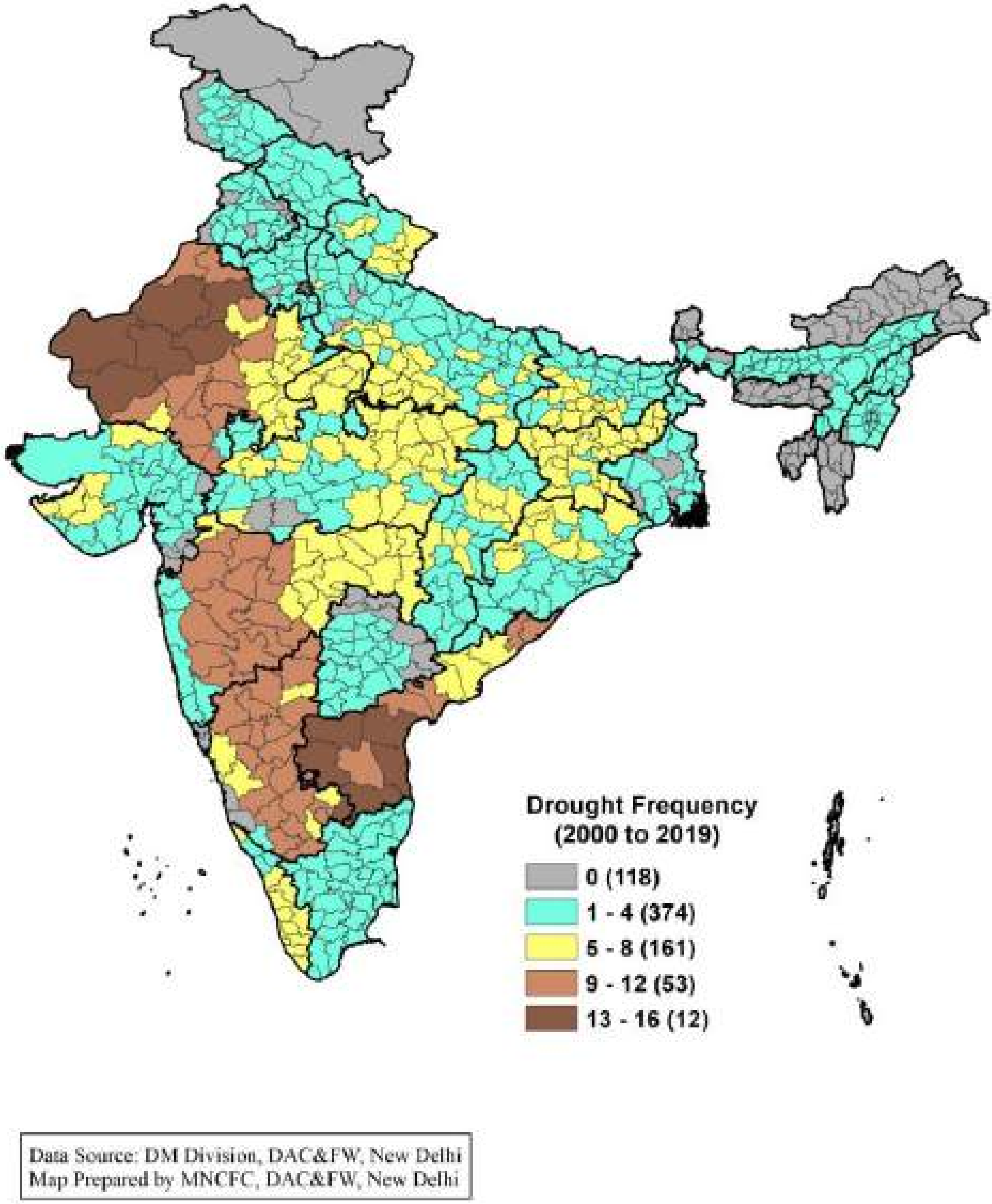


Figure 46: District level Agricultural drought occurrences

Major drought during the HFA period was in 2009, due to deficient and erratic rainfall of South-West monsoon. 338 districts from 14 states were declared as drought affected. Out of 511 meteorological districts for which data was available, 217 districts (42 per cent) of the meteorological districts received excess/normal rainfall and the remaining 294 districts (58 per cent) received deficient/scanty rainfall during the season. The total food grain production was estimated at 218.2 million tons against estimated production of 234.47 million tons. Overall, the agricultural contributions to the Gross Domestic Product (GDP) dipped by 0.2 per cent only. In seven states, namely Assam, Bihar, Karnataka, Maharashtra, Manipur and Nagaland around 120 million people were affected and in five states namely Bihar, Jharkhand, and Karnataka and UP, approximately 48 million animals were affected.

Table 2: Summary of major drought episodes

Year	2002	2009	2015
No of states affected	18	14	11
Number of districts Affected	383	338	273
People affected	300 million	400 million	330 million
Cattle Affected	150 million	48.03 million	
Crop Area Affected	NA	30 million hectare	29.89 million hectare
Un-sown Area	18.53 million hectare	47 million hectares	NA
Economic Loss	39000 crore	NA	NA
Economic Loss as percentage of GDP	3.10%	0.20%	NA

Source: Ministry of Agriculture and Farmer's Welfare, Govt of India

In the year 2015-16, India faced one of the most severe drought conditions that it had seen in the last 150 years. About 39 per cent of the country's area remained dry and received scanty rainfall. The monsoon rainfall in 2015 was the tenth driest year on record (1906–2015) across India, with a deficit of 14.5 per cent, and the Indo-Gangetic Plain witnessed a rainfall deficit of 25.8 per cent (third rank event) (Mishra et al., 2016), with overall 24 per cent area under severe drought situation. The year 2015 was a major EL NINO year that resulted in failure of monsoon. The prolonged dry period extended throughout winter and due to moisture stress, crops were impacted both in Kharif and Rabi season. Drought in 2015 affected 11 states and 273 districts. A total of 29.89 million hectare of cropped area was affected due to drought. Total population affected was 330 million. The 2015-18 drought was the longest drought seen in the last 150 years, i.e. 41 months.

3.1.3. Cyclones

On an average, two to three tropical cyclones occur per year in India, with around one being a severe tropical cyclone or more. The 1999 Odisha Cyclone was the deadliest cyclone during the given analysis period. Temporal distribution of deaths during the period 1995-2020 is shown in Figure 47. From the Figure 48 it can be inferred that mortality due to cyclonic storms was highest during the pre-HFA period with 89 per cent of loss of life during the period due to the deadliest 1999 Odisha Super Cyclone with more than 11,000 deaths.

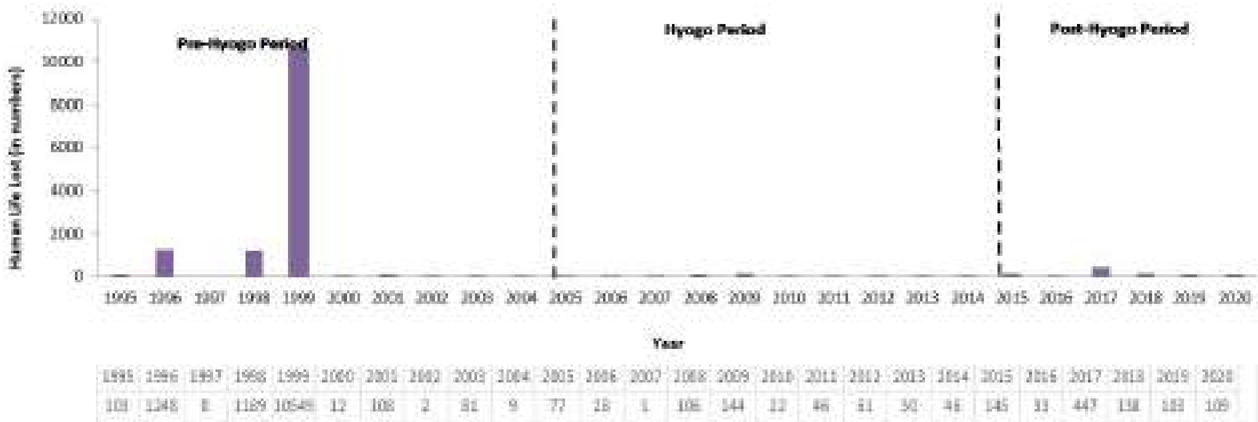


Figure 47: Year wise trend for cyclone related death during 1995 to 2020.

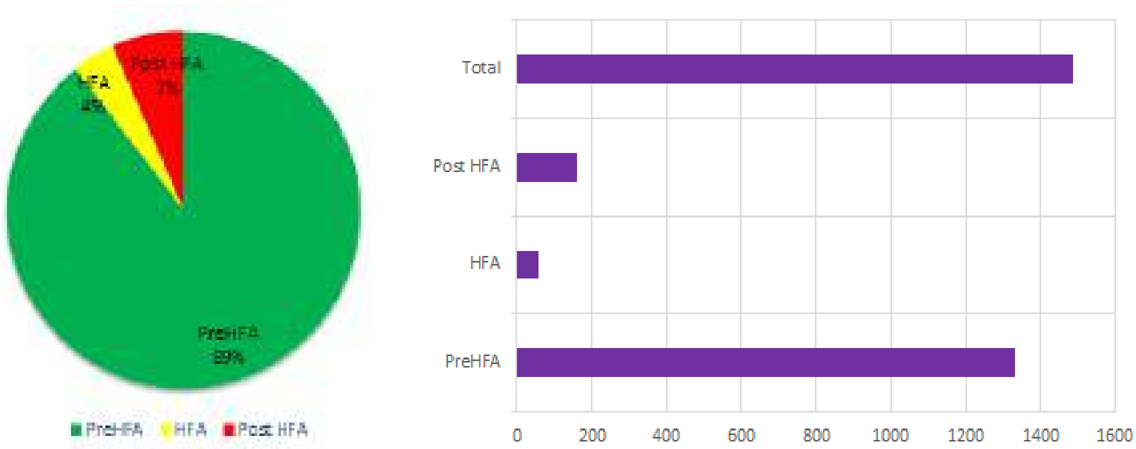


Figure 48: Percentage distribution of loss to human life due to Cyclone & average annual human life loss due to Cyclone incidences during pre-HFA, HFA and post-HFA.

The temporal distribution of human life loss due to cyclonic storms shows that the total number of human life losses during the pre-HFA, HFA and post-HFA phases was 89 per cent, 4 per cent and 7 per cent, respectively, as shown in Figure 48. It was noted that the number of human-lives loss due to cyclonic events has shown a declining trend in HFA, considering the overall annual number of human life lost. Although the frequency of cyclones in Odisha is less than Andhra Pradesh and Tamil Nadu, human life loss is very high relative to the other states and UTs.

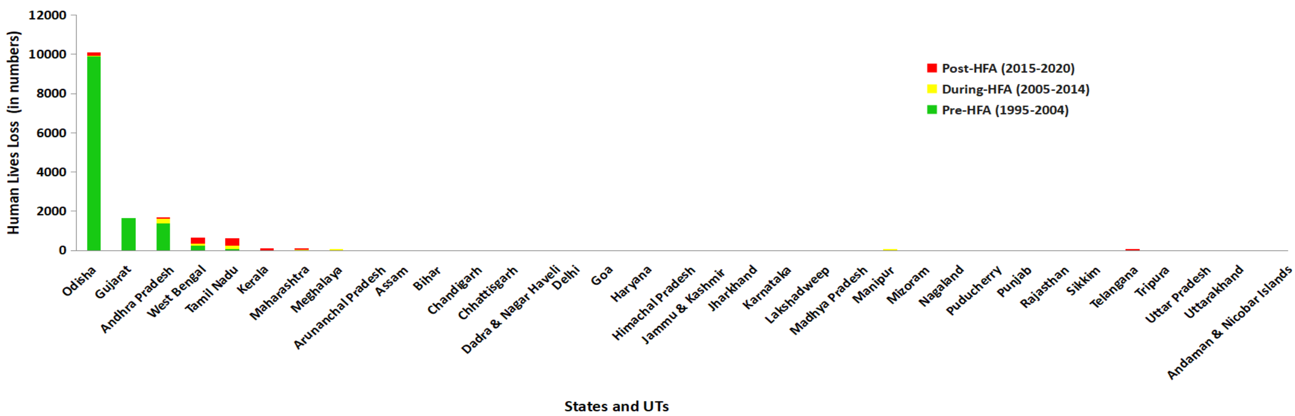


Figure 49: State-wise distribution loss of human lives due to cyclone events during pre-HFA, HFA and post-HFA periods

From Figure 49, the same can be inferred with respect to the three periods, i.e., highest mortality rate in Odisha during pre-HFA. Mortality due to cyclones is showing an increasing trend in Tamil Nadu and Maharashtra during post-HFA. Figure 50 and Figure 51 depicts the total number of human life loss at the state-level during the entire period and disaggregated during Pre-HFA, HFA and Post-HFA period, respectively.

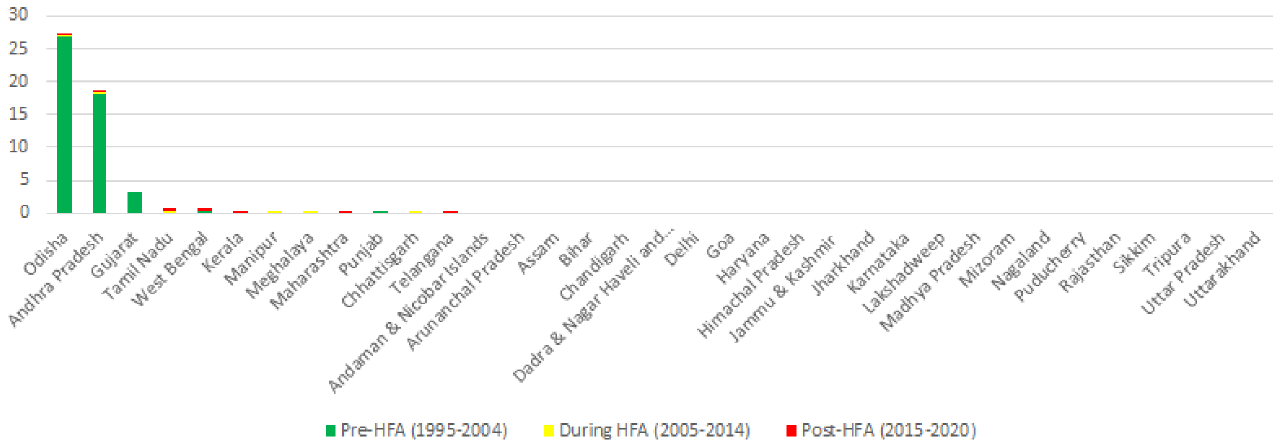
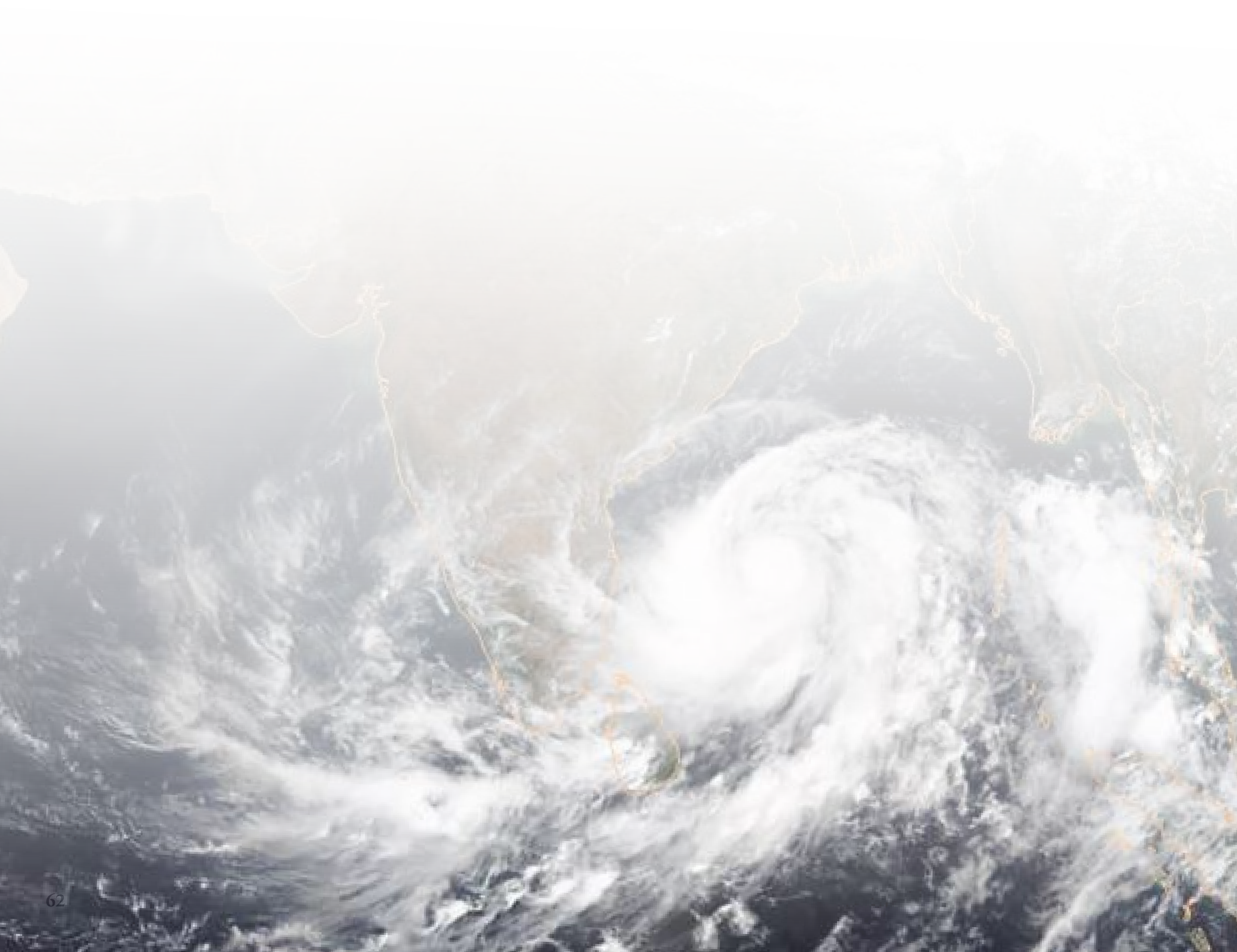
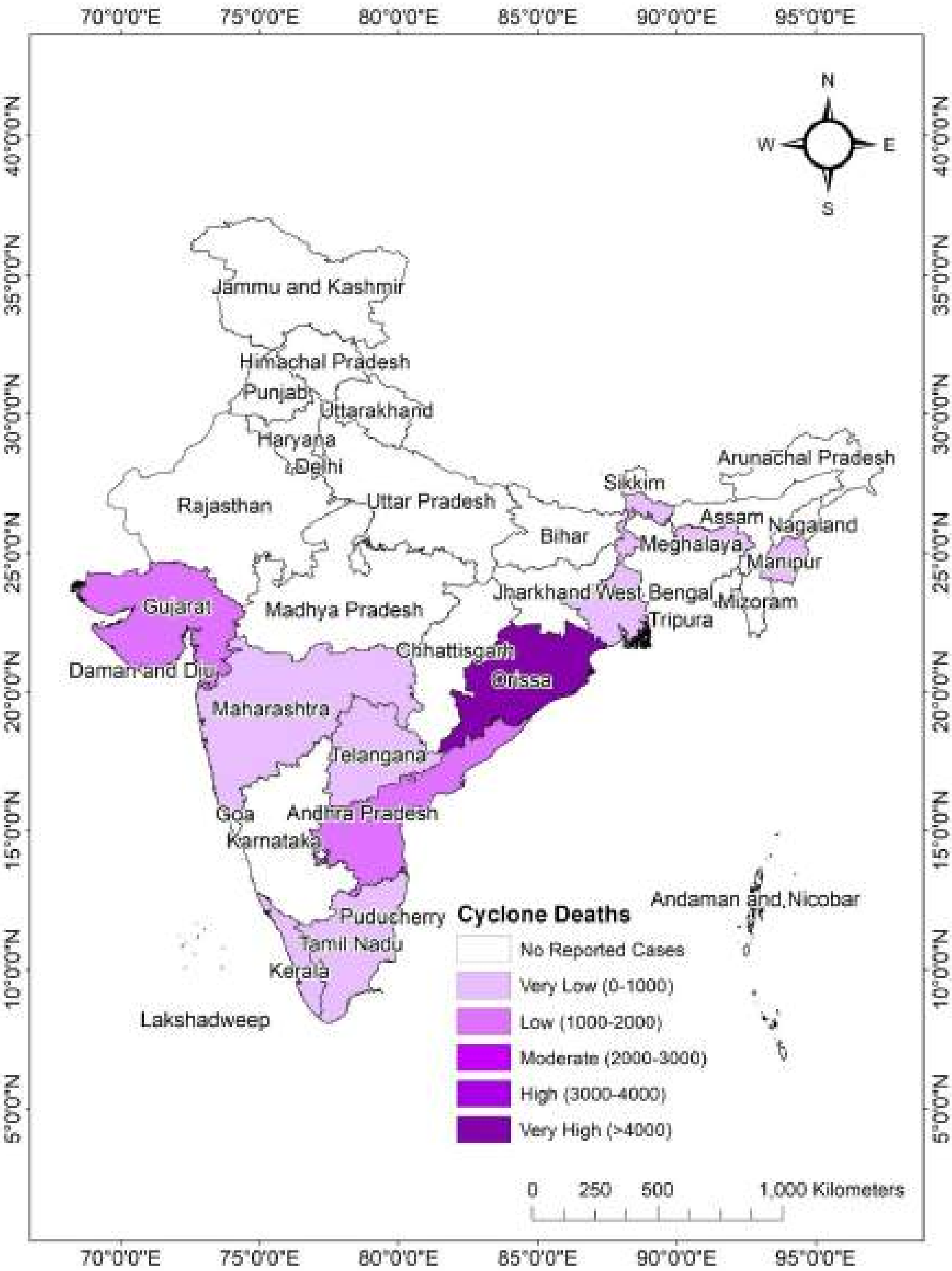


Figure 50: State-wise distribution of human lives loss due to cyclone events per 100,000 during pre-HFA, HFA and post-HFA.

Mortality per 100,000 population and loss of human life comparisons slightly vary for a few states. For example, Gujarat has the second highest number of loss of human life, followed by Andhra Pradesh. However, in terms of mortality per 100,000, Andhra Pradesh has the second highest . Similar case is observed in the case of Maharashtra.





Compiled by: Study Team
Data Source, Disasterous Weather Event Reports, IMD and MHA Reports

Figure 51: Thematic map depicting the loss of human lives due to cyclones at the state-level

3.1.4. Heatwaves

Spatial-temporal analysis of heatwave related deaths for the period 1995-2020 has been carried out using the data obtained from disastrous weather events reports developed by IMD and state government reports.

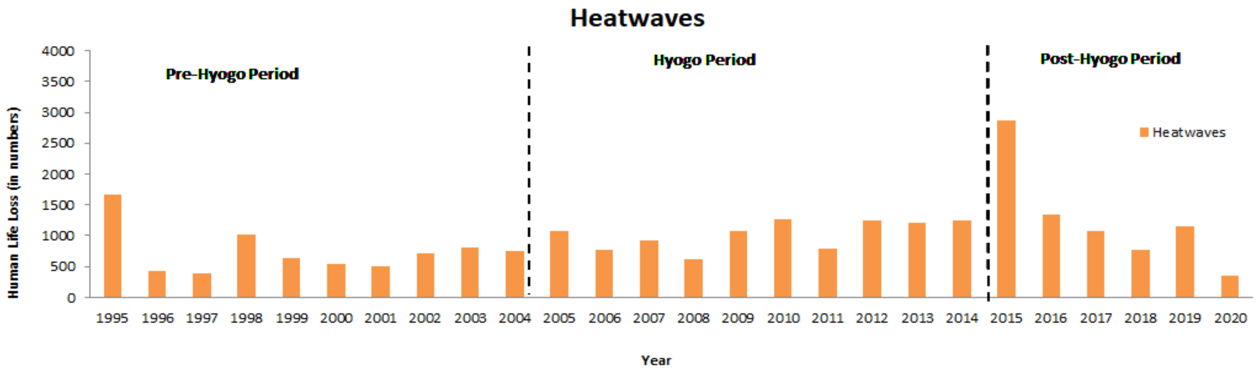


Figure 52: Year wise trend for Heat Wave related deaths during 1995-2020

A total of 23,578 human lives, i.e., an average of 972 lives were lost due to heatwaves during 1995-2020 (Figure 52). The temporal distribution of loss of human life due to heatwaves shows that the total number of human life loss during the pre-HFA (7463), HFA (10230) and post-HFA (7570) phases were 30 per cent, 40 per cent and 30 per cent, respectively, as shown in Figure 53. Figure 52 depicts a year wise trend of heatwave related death during 1995 to 2020 across the three periods. It shows that 2015 (post Hyogo) was the year with devastating heat wave in terms of number of lives lost. It can also be noted that the number of human lives lost due to heatwave incidents was highest during the post-HFA, taking into account the overall annual number of deaths.

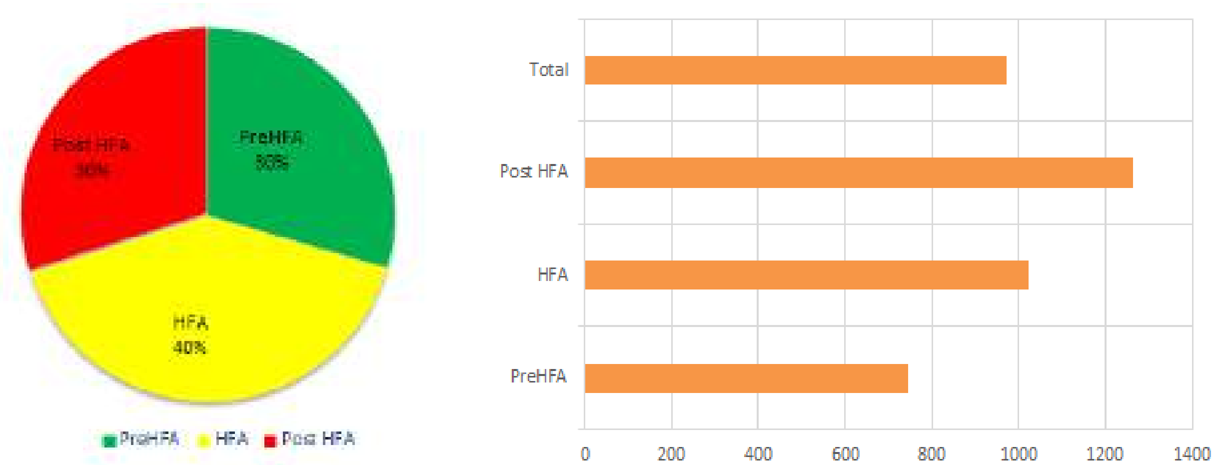


Figure 53: Percentage distribution of human life loss & the average annual number of human lives loss due to Heat Wave incidences during pre-HFA, HFA and post-HFA.

Heat Wave related deaths show an increasing trend in most of the states including Andhra Pradesh, Uttar Pradesh, Bihar, Maharashtra, Telangana and Jharkhand in the post-HFA period (Figure 54, Figure 55 and Figure 56). In Delhi and Tamil Nadu, heat wave deaths reduced substantially. Punjab, Odisha, Madhya Pradesh and West Bengal are also showing a decreasing trend in post-HFA. Telangana was formed in the year 2015 and hence most of the reports appear in post-HFA only. However, it is important note that many districts of Telangana were also affected by drought during pre- and during HFA when the state was part of united Andhra Pradesh.

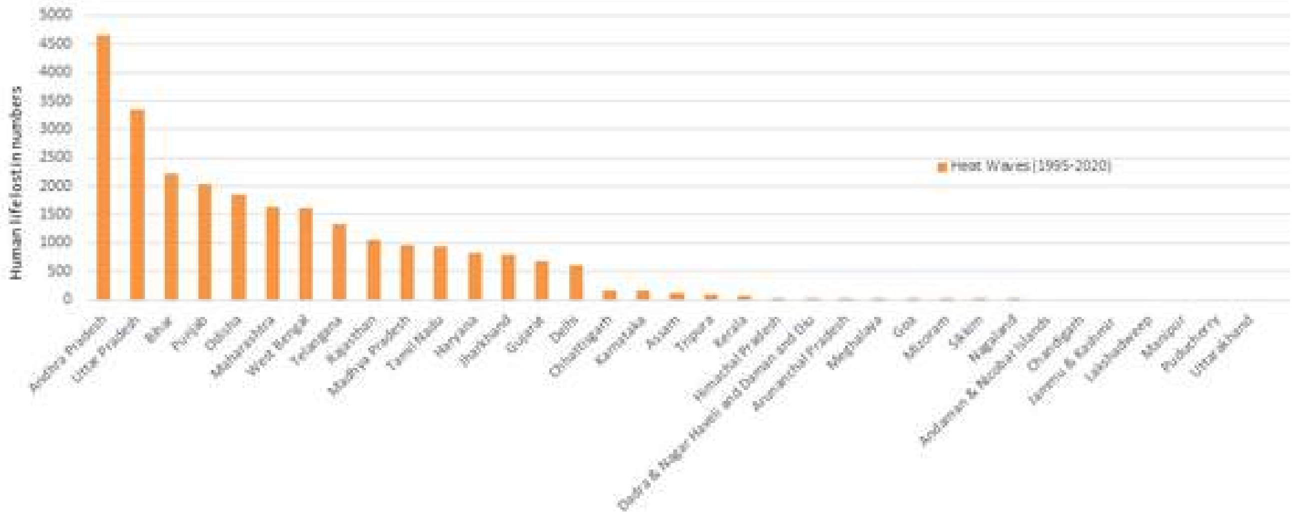


Figure 54: Number of deaths per year due to Heat Wave incidents at the state- and UT-level

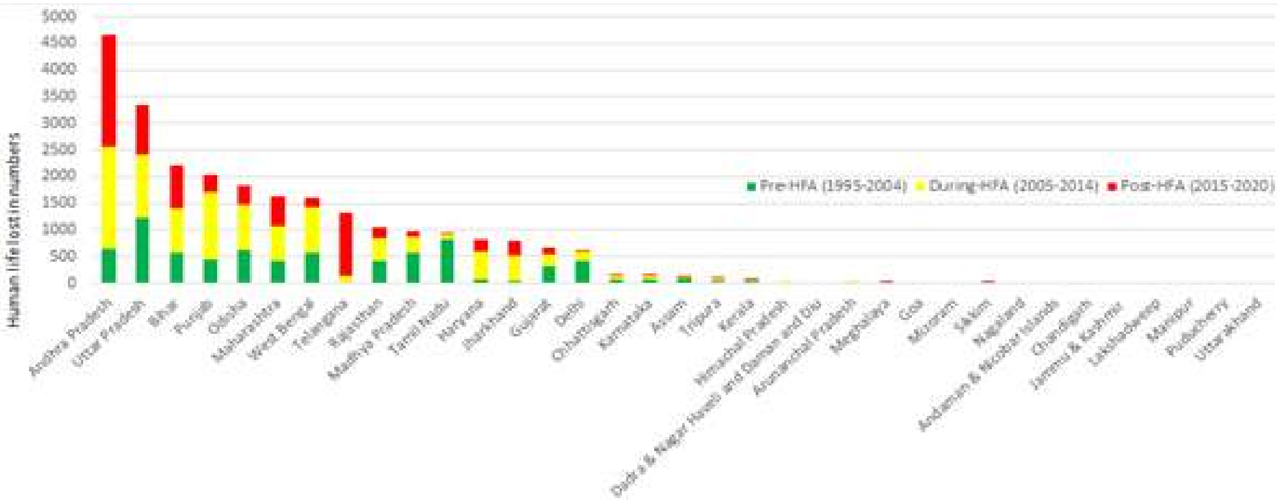
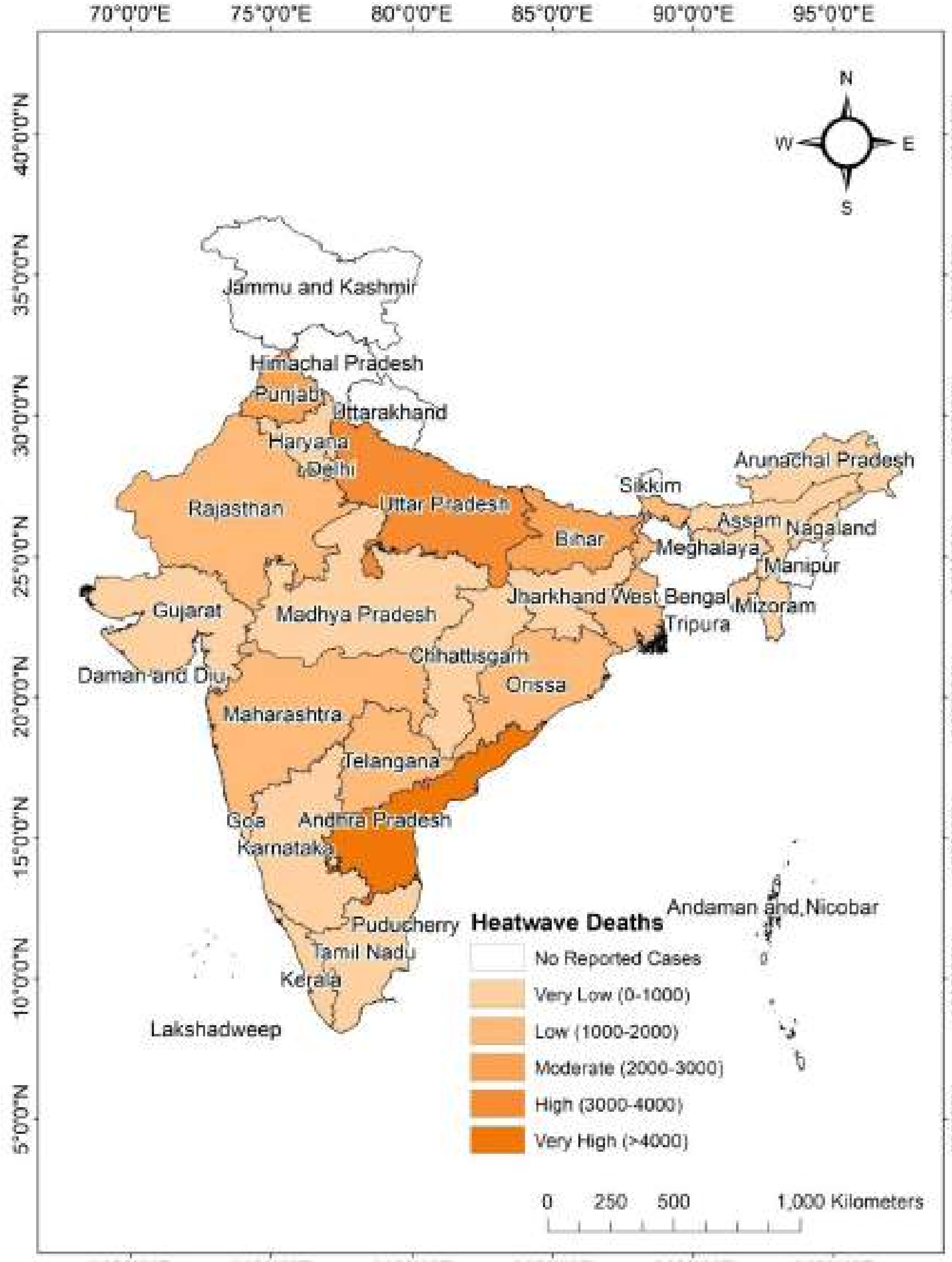


Figure 55: State-wise distribution of human lives loss due to Heat Wave incidents during pre-HFA, HFA and post-HFA periods



Compiled by: Study Team
Data Source, Disasterous Weather Event Reports, IMD and MHA Reports

Figure 56: Thematic map depicting the loss of human lives due to Heat Wave at the state-level

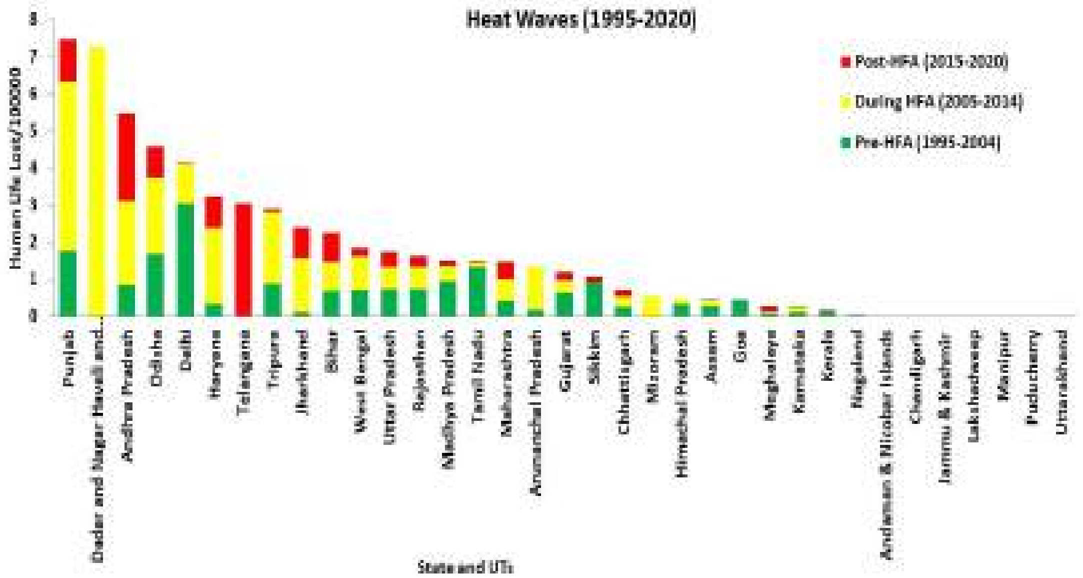


Figure 57: State-wise distribution of human lives loss per 100,000 population due to Heat Waves during pre-HFA, HFA and post-HFA.

Punjab has the highest number of human life loss per 100,000 population (Figure 57), followed by Dadra and Nagar Haveli (this is due to the low population and not due to large number of heat-wave deaths). The state of Telengana is formed in 2015 and hence the reports are only available for post-HFA Period. Both Andhra Pradesh and Telangana have large number of life loss in post-HFA.

3.1.5. Cold Waves

The analysis shows that the total loss of human lives due to cold wave during the 1995-2020 period is 19,126. The temporal distribution of human life lost due to Cold Waves depicts that (Figure 58), the total number of human life loss during the pre-HFA (6645), HFA (8357) and post-HFA (4123) phases was 35 per cent, 44 per cent and 21 per cent, respectively (Figure 59).

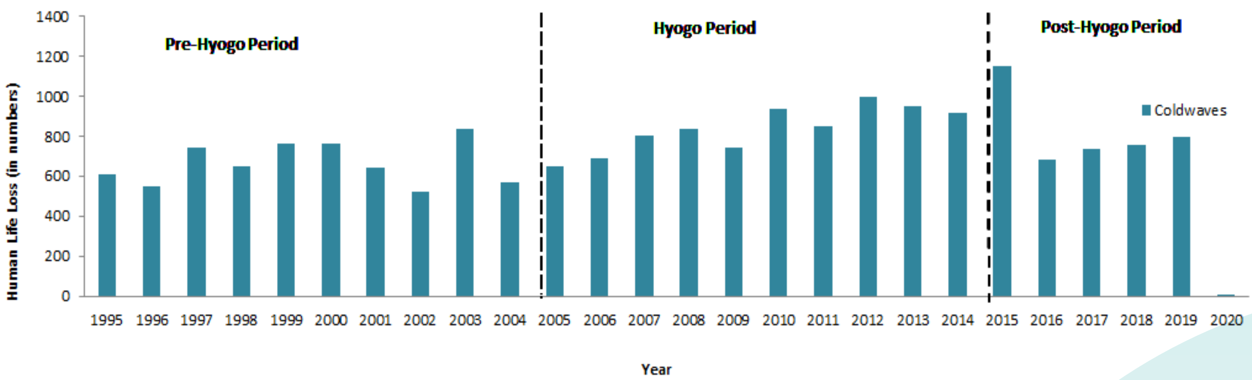


Figure 58: Year-wise trend of Cold Wave related death during 1995-2020.

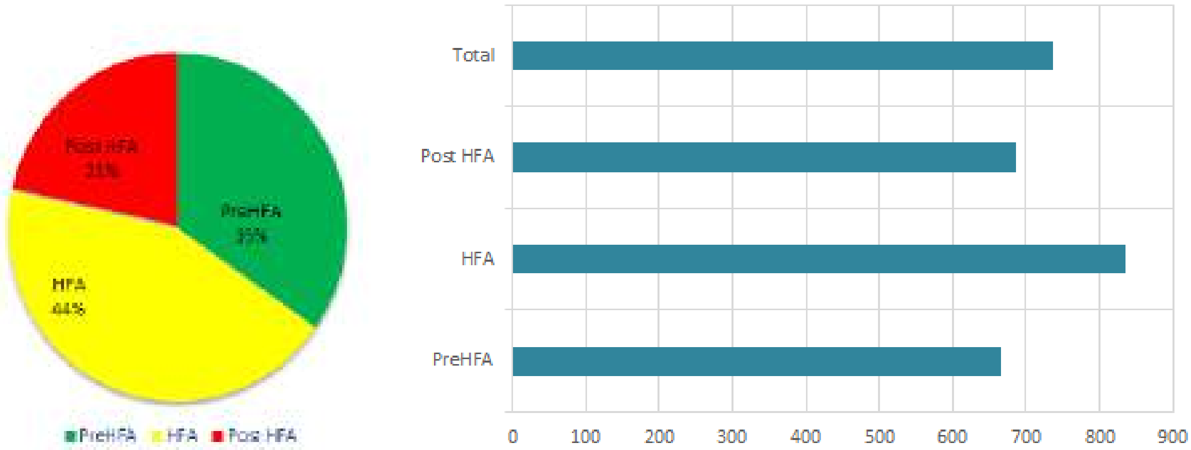


Figure 59: Percentage distribution of human lives loss due to Cold Wave & the average annual number of human life loss due to Cold wave incidences during Pre-HFA, HFA and post-HFA.

The analysis depicts that the highest number of human deaths reported during 2015 (during post-HFA) was the deadliest Cold Wave. It can also be noted that during the HFA, the number of human-lives loss due to Cold Wave incidents were maximum and decreased in the post-HFA period, taking into account the total annual number of incidents. Highest number of Cold Wave related deaths (5023) were reported in Uttar Pradesh, which accounts for 26 per cent of the total deaths in India. Bihar and Punjab followed UP in terms of mortality (Figure 60).

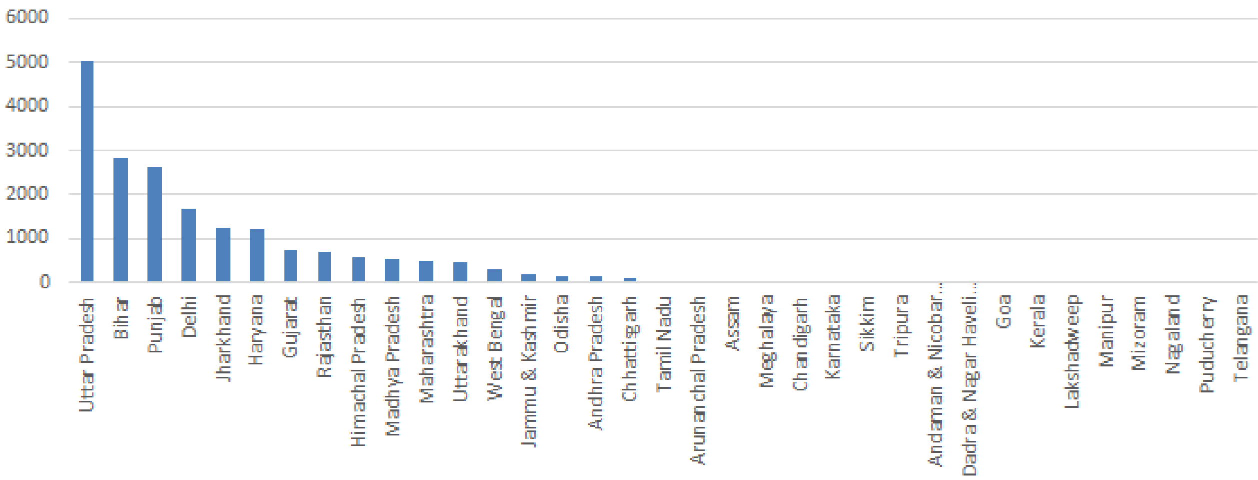
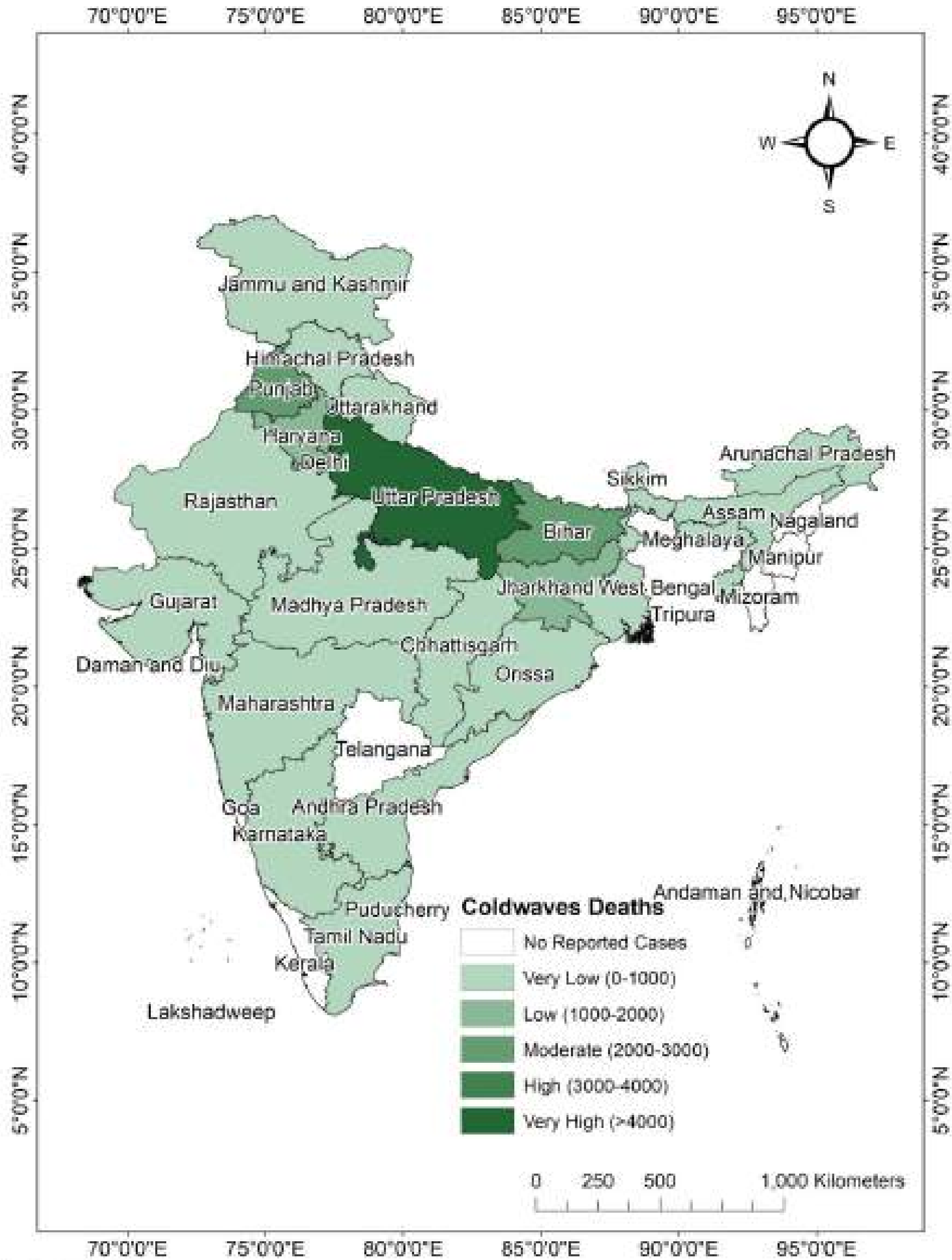


Figure 60: Number of deaths per year due to Cold Wave incidents at the state- and UT-level

Cold Wave related deaths are also showing an increasing trend in several states including, UP, Jharkhand, Uttarakhand, Jammu & Kashmir, Assam, Meghalaya, Chandigarh and Tripura in the post-HFA period. In contrast, Delhi, Punjab, Haryana, Himachal Pradesh and West Bengal show a decreasing trend in post-HFA. Telangana was formed in the year 2015 and hence most of the deaths reported in HFA and pre-HFA are appearing in Andhra Pradesh. However, it is important to note that districts of Telangana were also affected by the Cold Wave during pre-HFA and HFA while the state was part of united Andhra Pradesh (Figure 61).



Compiled by: Study Team
Data Source, Disasterous Weather Event Reports, IMD and MHA Reports

Figure 61: Map showing state-wise distribution of Cold Wave deaths

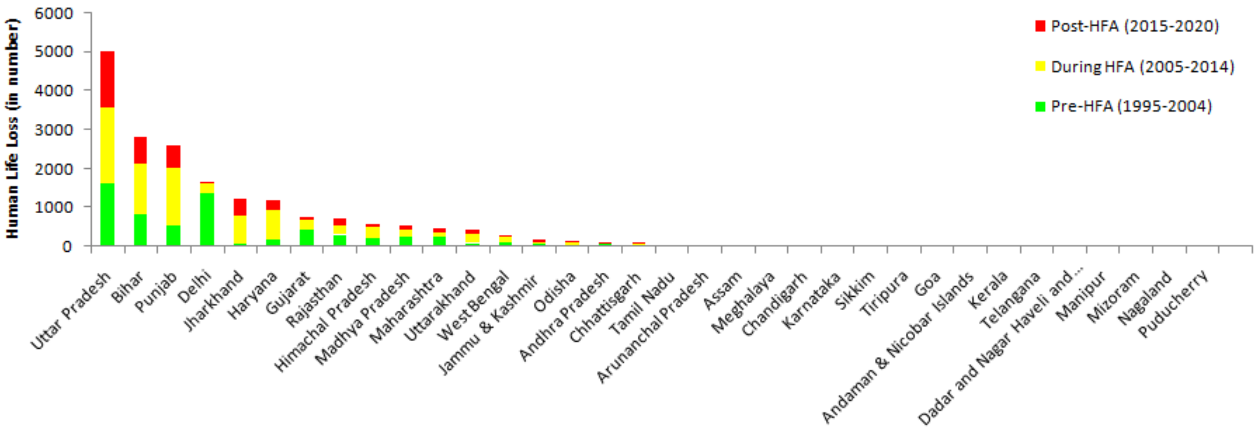


Figure 62: State-wise distribution of human lives loss due to Cold Waves incidents during pre-HFA, HFA and post-HFA.

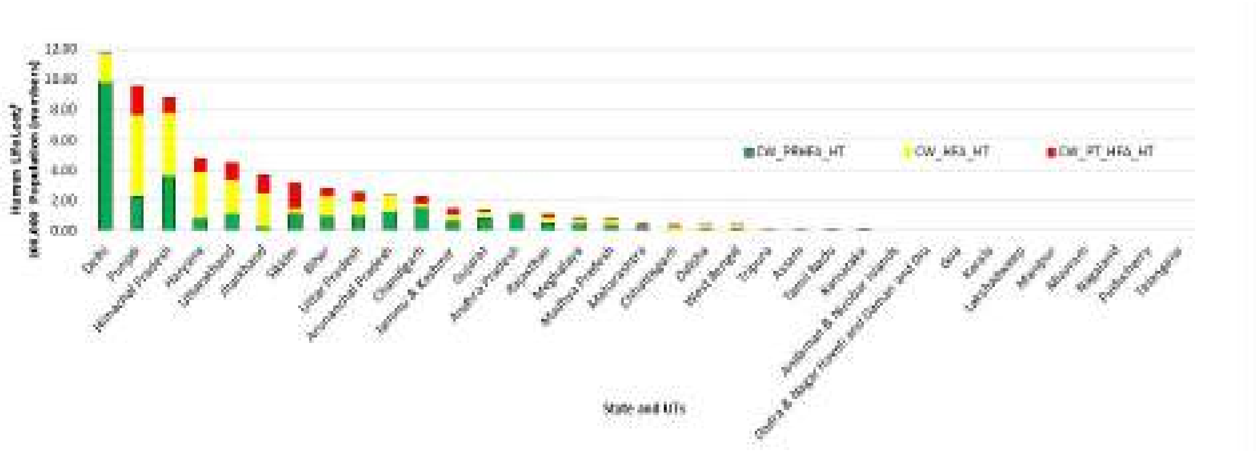


Figure 63: Comparative state-wise analysis for overall numbers of human lives lost due to Cold Wave per 100,000 population.

Delhi witnessed the highest number of human life loss per 100,000 population with 11.71 persons (Figure 63). It is worthwhile to note that cold wave related deaths decreased considerably in Delhi where it was highest in pre-HFA period. Uttar Pradesh is the 9th most impacted state in terms of the loss of life per 100,000. Jharkhand and Sikkim also show increasing trend in term of life loss.

3.2. Biological Disasters

3.2.1. Dengue

Dengue is a vector borne disease transmitted through mosquitoes bites during daytime from Aedes mosquitoes. It is common in tropical and subtropical areas and has been a very common illness in India for the last two decades. Regardless of their age and gender, dengue can affect everyone. In more than 100 countries in the WHO regions of Africa, America, the Eastern Mediterranean, South-East Asia and the Western Pacific, the disease is an endemic (Dengue fever).

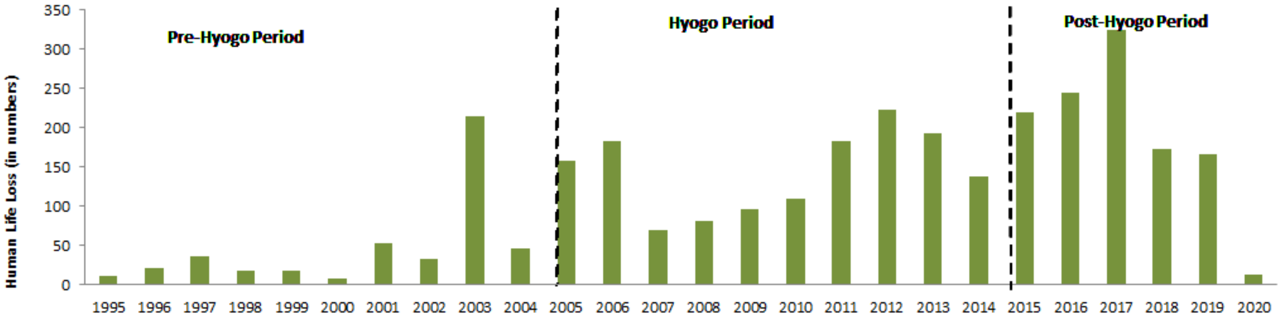


Figure 64: Year-wise trend for dengue related death during 1995 to 2020.

Dengue outbreaks have been reported from many states of India leading to different kinds of implications such as economic losses, life losses especially children and infants and loss of working days. In the current study, State/ UT based temporal and spatial analysis of the total number of deaths due to dengue i.e. the human lives loss has been carried out.

The analysis shows that the total loss of human lives during the 1995-2020 period is 3,025 (Figure 64). The temporal distribution of human life lost due to dengue depicts (Figure 65) that the total number of human lives lost during the pre-HFA (455), HFA (1430) and post-HFA (1140) phases was 16 per cent, 51 per cent and 32 per cent, respectively. Whereas figure 75 indicates a year-wise dengue associated mortality pattern between 1995 and 2020 compared to the three periods for all the states and UTs.

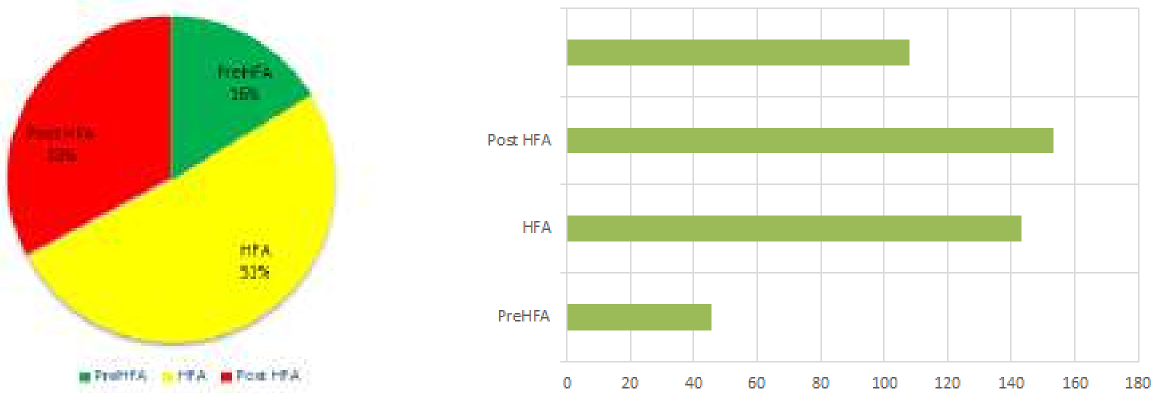


Figure 65: Percentage distribution of human life loss due to dengue and the annual average human life loss due to dengue incidences during Pre-HFA, HFA and post-HFA.

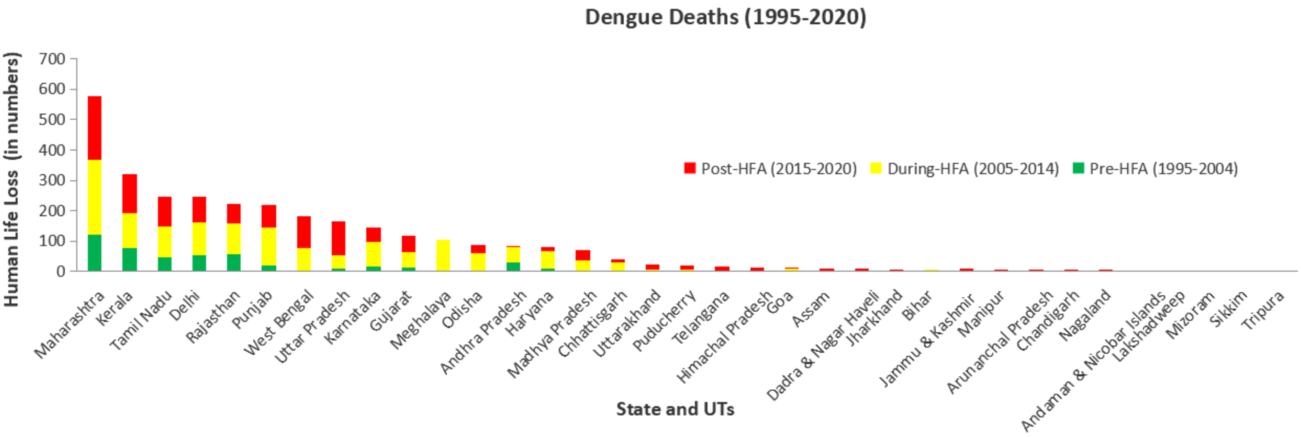


Figure 66: State-wise distribution of human lives loss due to dengue during Pre HFA, HFA and post HFA.

Dengue associated human deaths are showing an increasing trend in most of the states including Maharashtra, Kerala, Tamil Naidu, Delhi, Rajasthan, Punjab, West Bengal, Uttar Pradesh, Karnataka and Gujarat in the post-HFA period. In Meghalaya and Andhra Pradesh, dengue deaths reduced substantially. Decreasing trend is observed in the post-HFA period (Figure 66). Telangana was formed in the year 2015 and hence most of the reports are appearing in post-HFA only. However, it is important to make note that many districts of Telangana were also affected by dengue during pre and during HFA while the state was part of united AP.

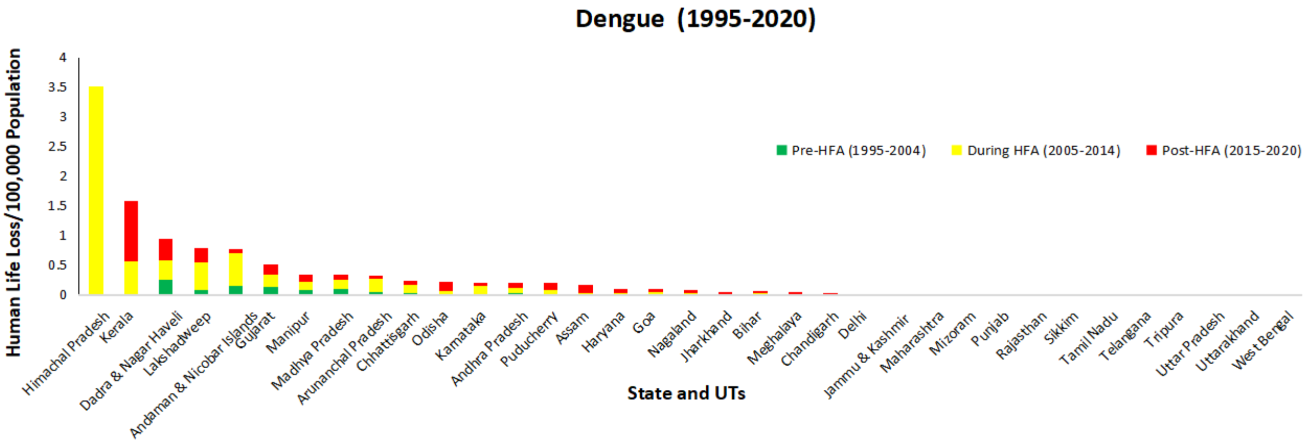


Figure 67: State-wise distribution of human lives loss per 100,000 population due to dengue outbreaks during pre-HFA, HFA and post-HFA Periods

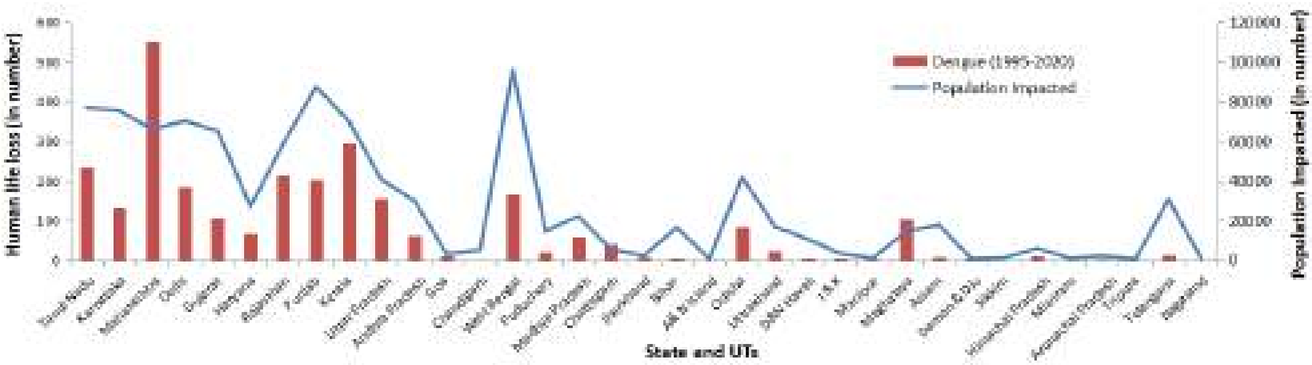


Figure 68: State-wise distribution of human lives loss along with population impacted due to dengue outbreaks

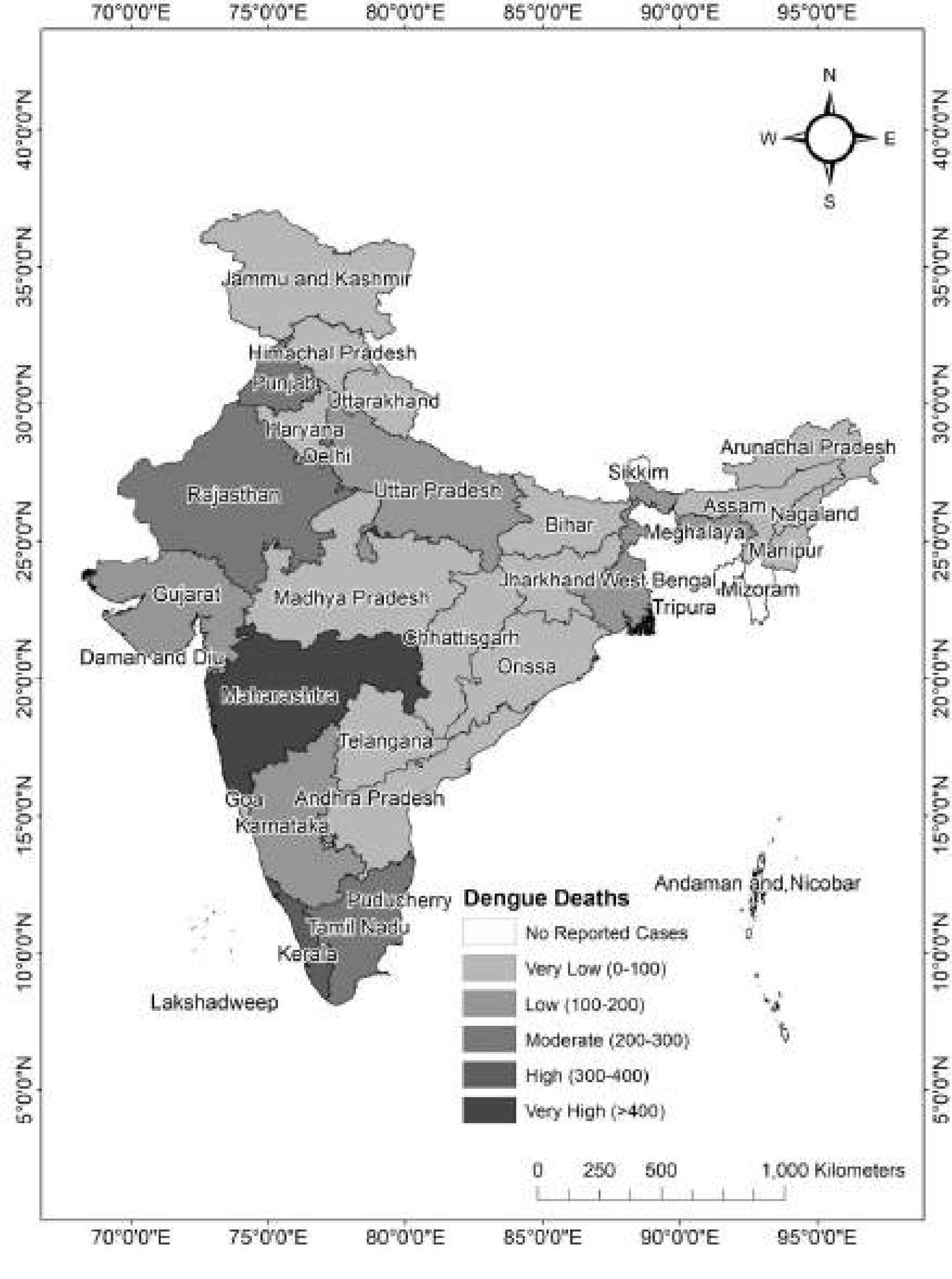


Figure 69: Thematic map depicting the loss of human lives due to dengue at state-level

Data source: Ministry of Health and Family Welfare

Figure 69 shows the map of the state-wise distribution of dengue deaths from 1995 till 2020 and the analysis indicates that the mortality due to dengue is very high (greater than 400) in the states of Maharashtra and Tripura, high (300 to 400) in the states of Kerala, Punjab and Rajasthan. The mortality is moderate (200-300) in the states of Tamil Nadu, Gujarat, Uttar Pradesh, West Bengal and Assam.

3.2.2. Japanese Encephalitis

Japanese encephalitis (JE) is another endemic caused by a mosquito-borne virus besides dengue. It was first recognised in India in 1955 and several major outbreaks have been recorded from various parts of the world since then, primarily in rural areas. With the exception of Dadra and Nagar Haveli, Daman and Diu, Gujarat, Himachal Pradesh, Jammu and Kashmir, Lakshadweep, Meghalaya, Punjab, Rajasthan, and Sikkim, infection is present throughout the country. Transmission occurs from May to October in northern India, and generally over the whole year in southern India.

The analysis shows that the total loss of human lives during the 1995-2020 period is 12,401. The temporal distribution of loss of human life due to JE (Figure 70) depicts that the total number of human lives lost during the pre-HFA (6049), HFA (5012) and post-HFA (1340) phases was 49 per cent, 40 per cent and 11 per cent, respectively. In addition, the figure reveals year-wise pattern of the dengue associated mortality between 1995 and 2020 across the three periods for all the states and UT (Figure 70).

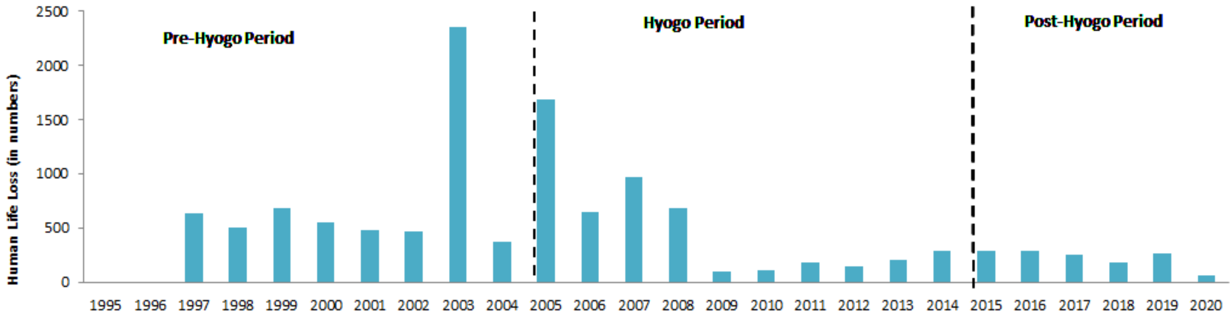


Figure 70: Year-wise trend for JE related death during 1995-2020

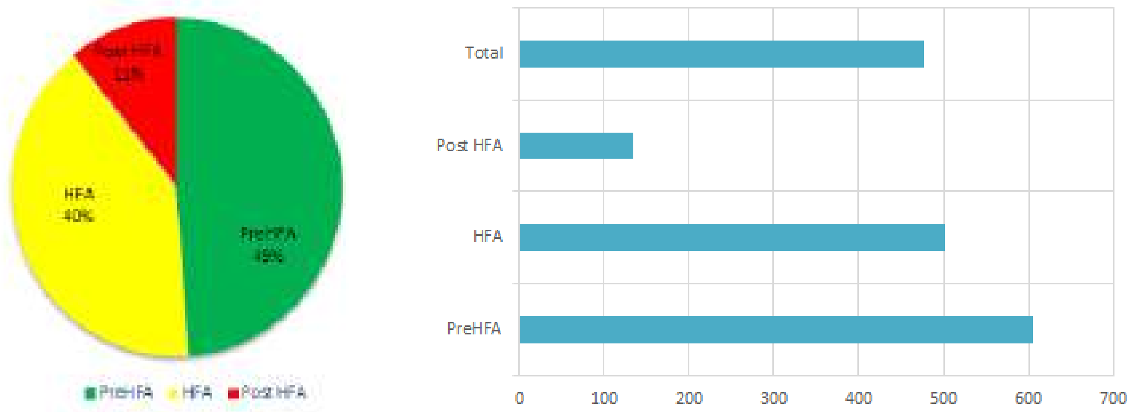


Figure 71: Percentage distribution of human life loss due to JE & the average annual number of human life loss due to JE outbreaks during pre-HFA, HFA and post-HFA

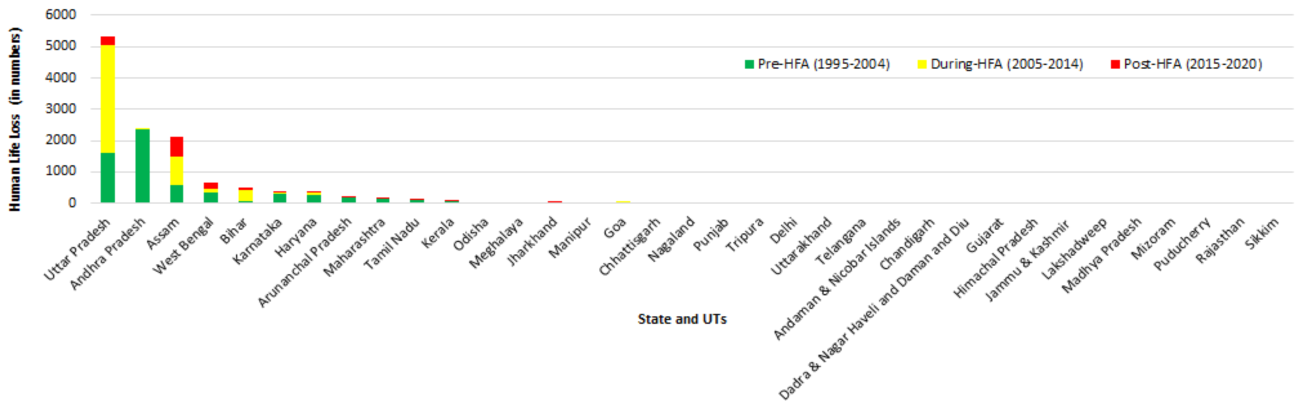


Figure 72: State-wise distribution of human lives loss due to JE events during pre-HFA, HFA and post-HFA periods

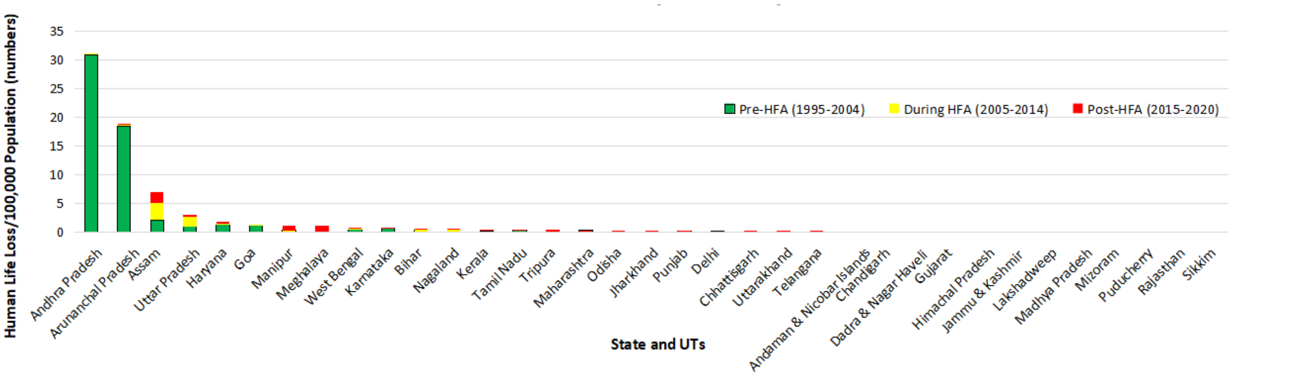


Figure 73: State-wise human lives loss per 100,000 population due to JE

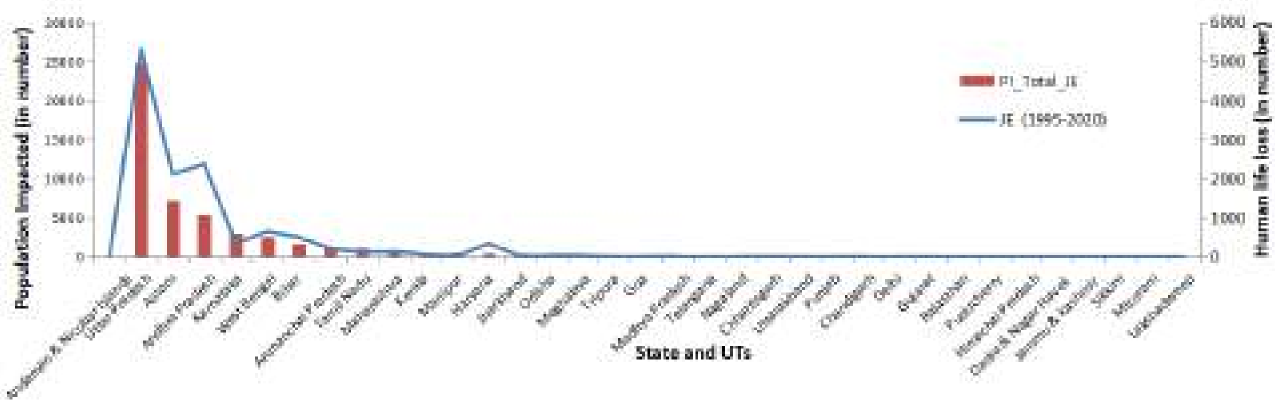


Figure 74: State-wise human lives loss and the population impacted due to JE

There have been a total of 284 people impacted per 100,000 population, with 193 people impacted in the pre-HFA, 44 people impacted during the HFA and 47 people impacted post-HFA periods.

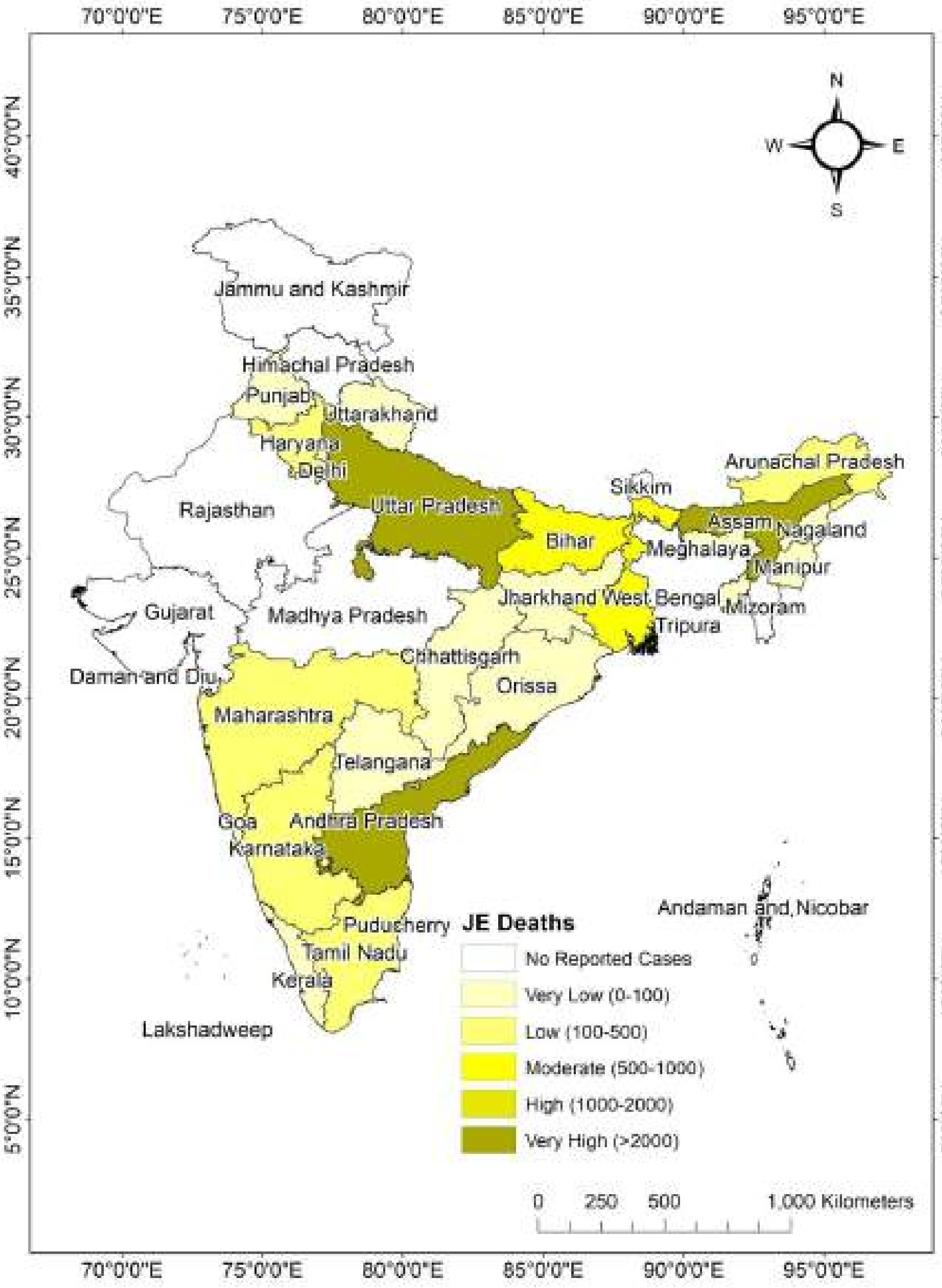


Figure 75: Thematic map depicting the loss of human lives due to JE at the state-level

Data source: Ministry of Health and Family Welfare

3.2.3. COVID-19

The COVID-19 pandemic has led to huge loss of human lives across the world and has affected livelihoods, health systems and businesses. In India, Maharashtra has witnessed the highest number of death cases followed by Tamil Nadu, Karnataka, Delhi, and West Bengal (Figure 76).

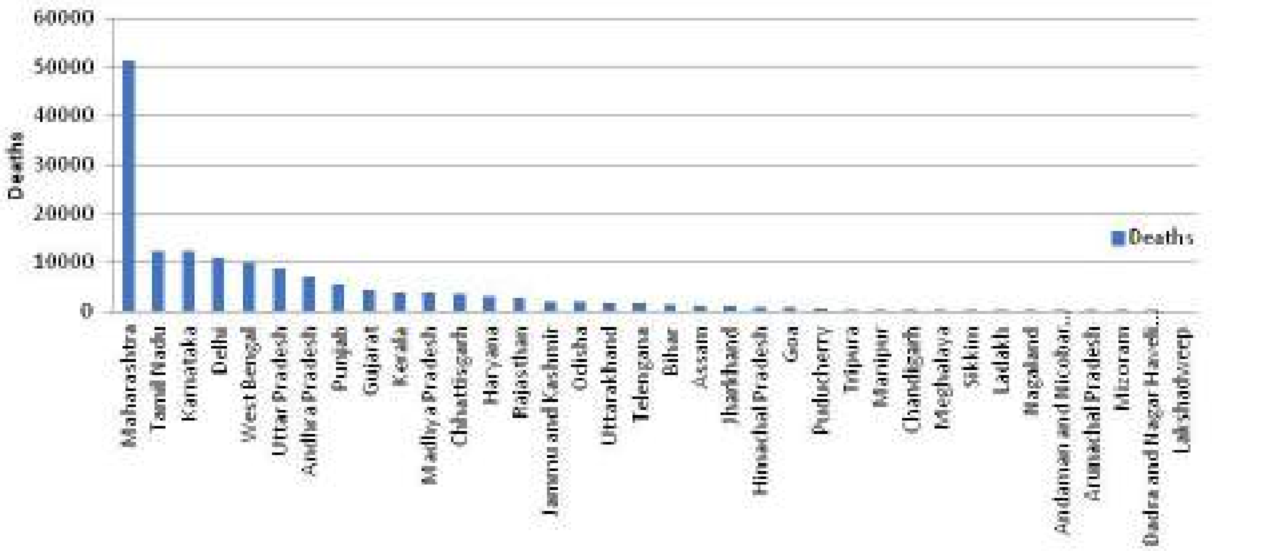


Figure 76: State-wise deaths due to COVID-19 as on 6 February, 2021

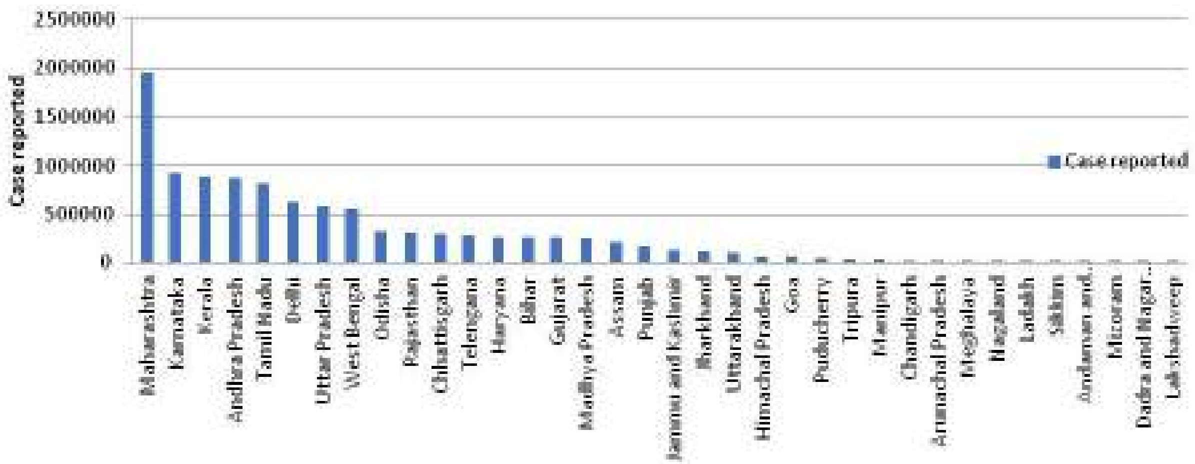


Figure 77: State-wise distribution of reported cases of COVID-19 as on 6 February, 2021

However, the mortality per hundred thousand population depicts that Punjab has the highest reported deaths.

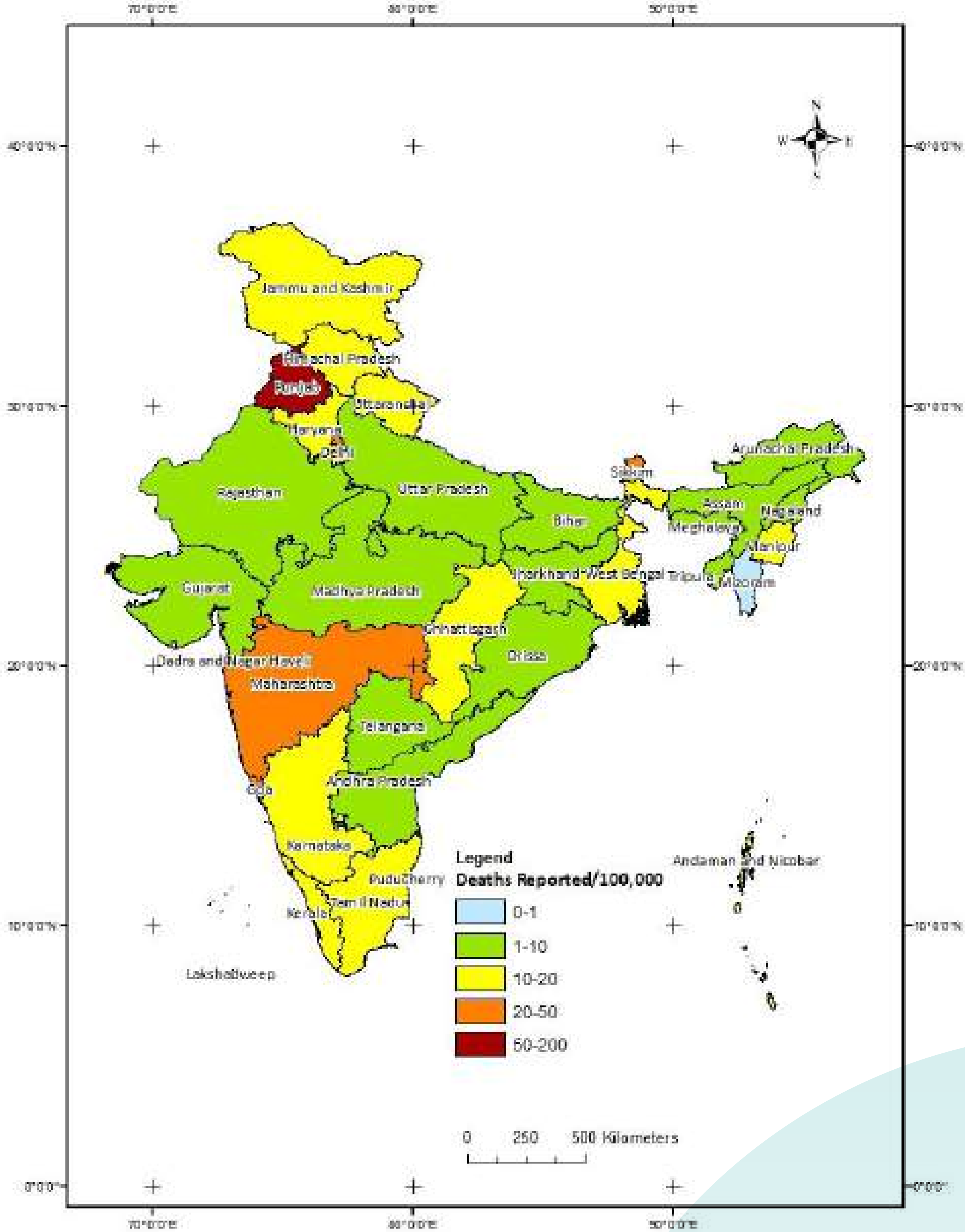


Figure 78: Number of COVID-19 deaths per 100,000 population

Data source: Ministry of Health and Family Welfare

3.3. Composite Analysis

3.3.1. Climatic Disasters

A composite climate change analysis is used here to determine the trend of climate-related disasters and their impacts. During the period from 1995 to 2020, a total of 1,04,311 deaths were reported for select four climate-related disastrous events (floods, cyclones, cold waves and heat waves till the end of October 2020). During the pre-HFA (1995-2005), HFA (2005-2015) and post-HFA (2015-2020) period, a total of 45,348, 38,261, and 20,702 human deaths were reported. Cyclones accounted for 48 per cent of India's overall human life loss due to climate-related disasters, followed by heat waves (26 per cent), 18 per cent due to floods and 8 per cent due to cold waves (figure 79). The analysis highlights that India experienced huge mortality due to climate related events in 26 years period.

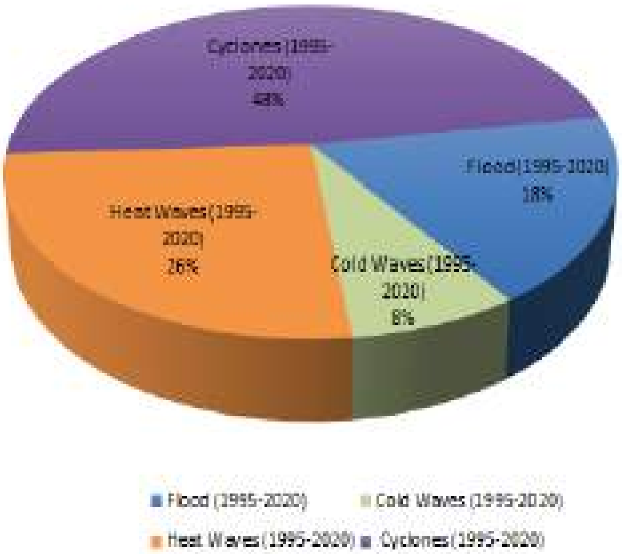


Figure 79: Human life loss by the four types of climatic disasters during the period 1995-2020

State-level composite spatial analysis shows that 11 out of 36 states have reported more than 3,000 human life loss due to climatic disasters during the analysis period. In the current section, farmer suicides have not been considered for the total human life loss due to disasters. The highest number of human deaths associated with climatic events were recorded in Uttar Pradesh (n=15,545), followed by Odisha (n=12,964), Bihar (n=12,148), Andhra Pradesh (n=8,936), West Bengal (n=7,275), Gujarat (n=6,033), Punjab (n=5,153), Maharashtra (n=3,654), Rajasthan (n=3,080), Tamil Nadu (n=3,033), and Madhya Pradesh (n=3,007). However, Andaman & Nicobar Islands and Lakshadweep did not have any reported deaths due to climatic events during that period (Figure 80).

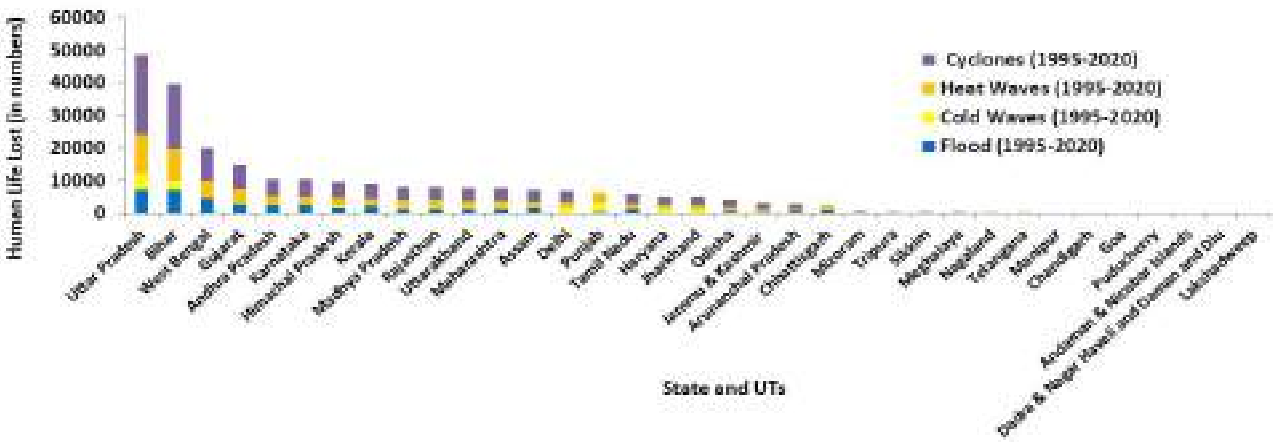


Figure 80: State-wise distribution of total number of deaths associated with climatic disasters

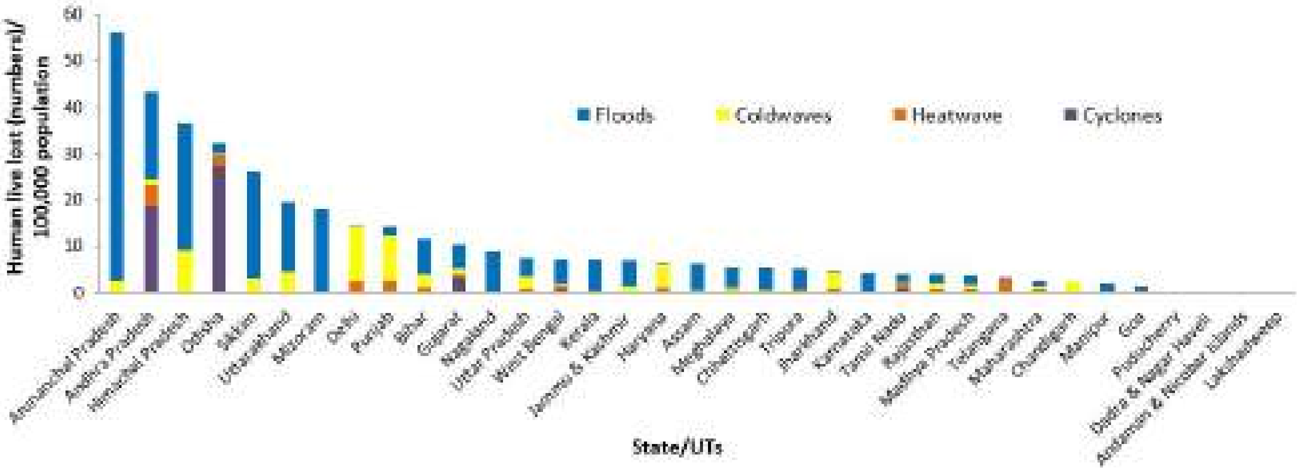
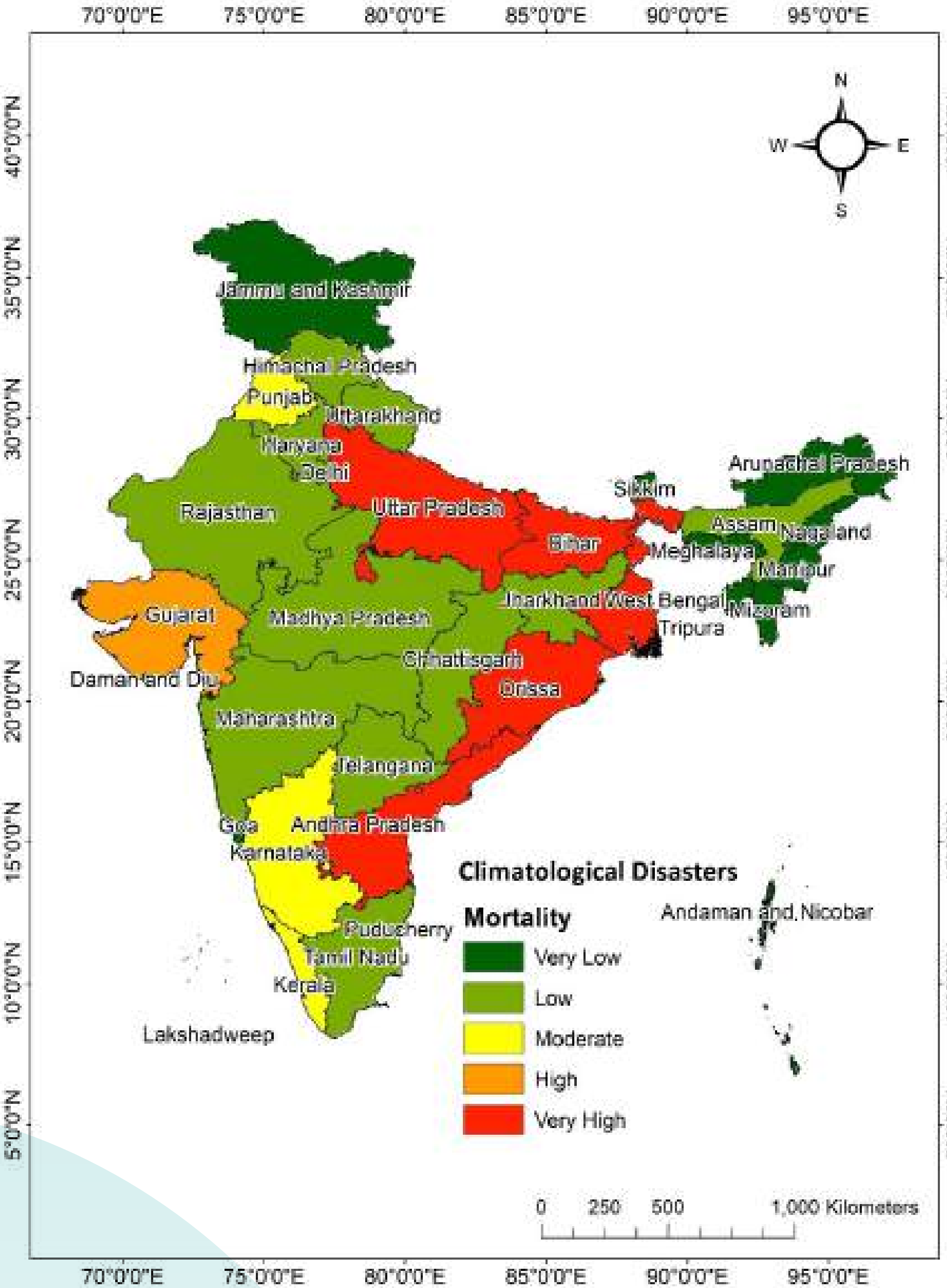


Figure 81: Comparative state-wise analysis for overall numbers of human life lost due to climatic disasters for 100,000 population

Unlike the total number of deaths, the deaths per 100,000 population is highest in Arunachal Pradesh followed by Andhra Pradesh, Himachal Pradesh, Odisha, Sikkim, Uttarakhand and Mizoram (Figure 81). The state of Uttar Pradesh reports the highest number of deaths considering the total figure and 13th position in terms of loss of life per 100,000 population.

The Weighted Overlay Method has been applied for spatial analysis of disaster events by frequency of occurrences. In the study, equal weightages have been assigned to all the events, and ranks from 5 to 1 are assigned to each state for all the five climate related disasters in descending order. Rank 5 means more than 20 events in the reporting period and 1 means less than 5 events. The result of the analysis is presented in Figure 82.



Compiled by: Study Team
Data Source, Disasterous Weather Event Reports, IMD and MHA Reports

Figure 82: Frequency map showing composite human life loss due to climatic disasters for the period 1995-2020

3.3.2. Biological disasters

From our analysis, it has been found that there has been an overall increase in the number of biological outbreaks from 1995 to 2020. Figure 83 shows the state-wise distribution of biological outbreaks, i.e. dengue and JE as per the latest research for the period 1995-2020. COVID-19 has not been taken for comparative analysis here as it was not reported in any of the previous years. It has been used as one event for each state used in the overlay analysis for the composite analysis process. However, the spatial distribution of COVID-19 is much higher than JE and dengue as the infection has spread to every part of India.

As evident from Figure 83, the spatial extent of dengue deaths is more than JE. As per the official data, total incidences of dengue and incidences of JE have been reported in the last 25 years covering all the three timelines. Dengue cases have been reported from all States and Union Territories, most of the cases coming from urban and peri-urban regions of India. Sporadic cases have also been reported from rural India. In the case of JE, maximum cases have been reported from rural India and are strongly linked with states where rice cultivation is the major agricultural practice.

Total incidences of dengue and incidences of JE have been reported in the last 25 years covering all the three timelines. Dengue cases have been reported from all States and Union Territories, most of the cases coming from urban and peri-urban regions of India.

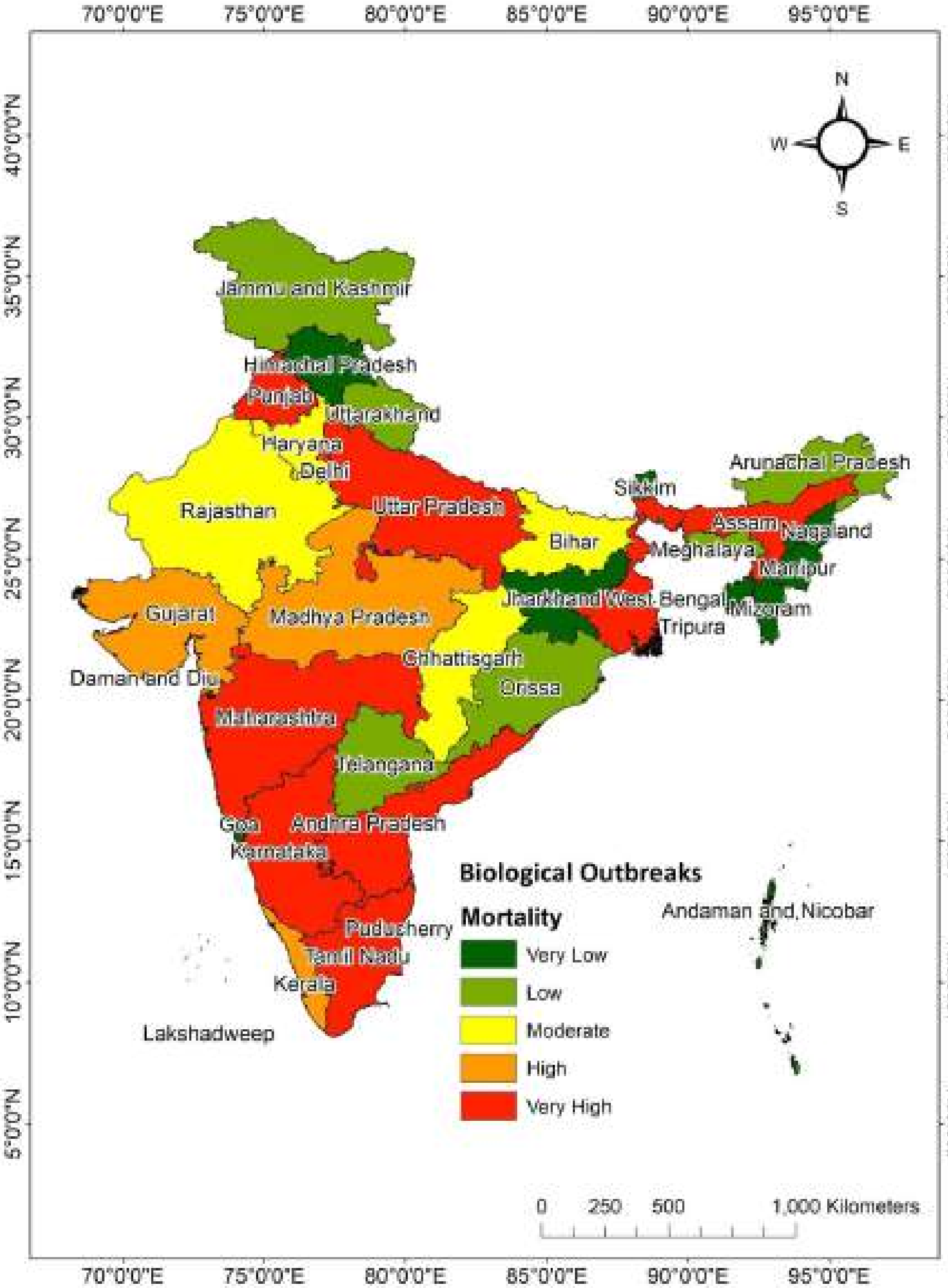


Figure 83: Frequency map showing composite human life loss due to biological outbreaks during 1995-2020.

Data source: Ministry of Health and Family Welfare

3.3.3. Climatic and Biological epidemic disasters

To understand the frequency of selected disaster related death events at state level for all the eight disasters during the analysis period a composite map has been prepared. Similar to the composite map of climatic and biological events, Weighted Overlay method was applied with equal weightage and ranks in descending order of frequency was assigned, Figure 84 below shows the state-wise comparative spatial distribution of both biological and climate related disasters, i.e. JE, Dengue, Drought, Floods, Heat Waves, Cold Waves and Cyclones as per the current study for the period 1995-2020. The figure also indicates that the overall deaths were more due to biological outbreaks rather than climatic disasters. States like Maharashtra, Tamil Naidu, Karnataka, Uttarakhand and Delhi are more impacted due to biological outbreaks in comparison to climatic disasters. Furthermore, the major contributor for human life loss in the states of Odisha, Uttar Pradesh, Andhra Pradesh, Bihar, Gujarat and Himachal Pradesh due to climatic disasters**.**

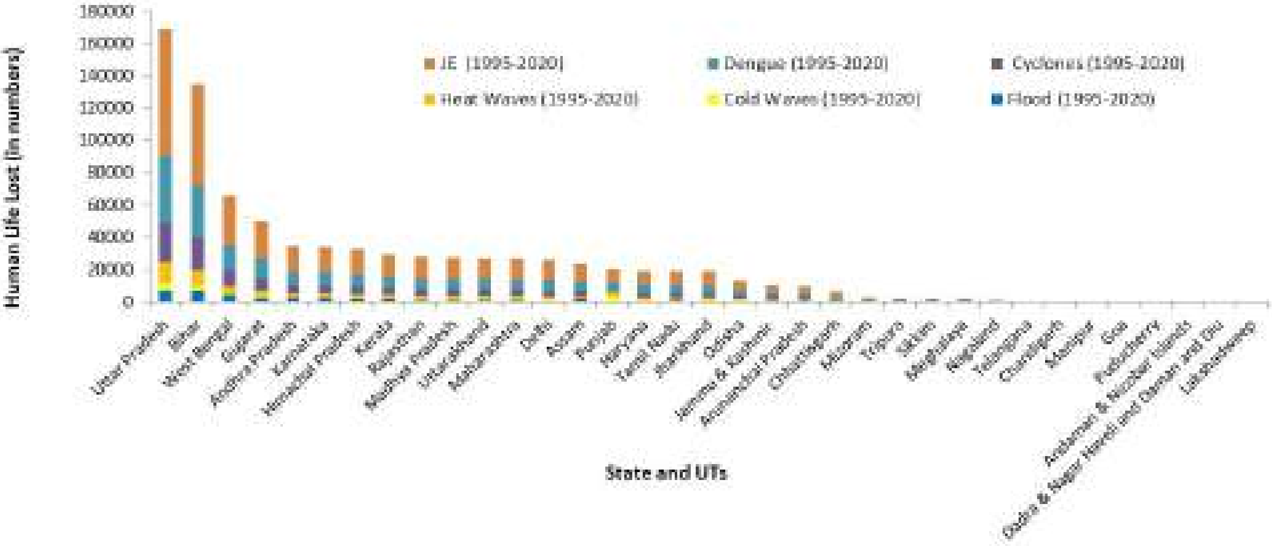


Figure 84: Comparative state-wise analysis for overall numbers of human lives lost due to climatic and biological disease outbreak disasters

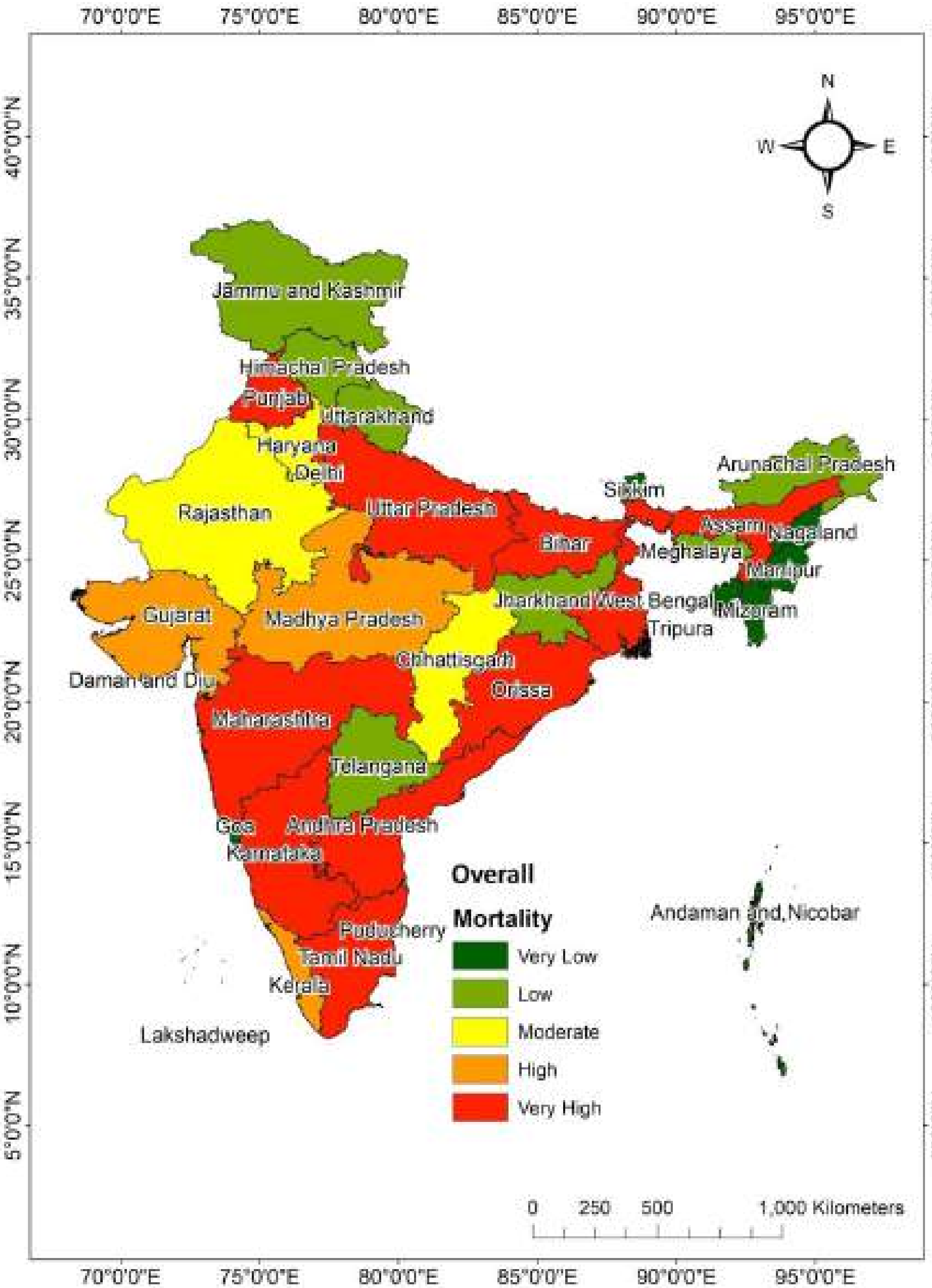


Figure 85: Composite human life loss due to climate and biological disasters during 1995-2020.

Data source: Ministry of Health and Family Welfare

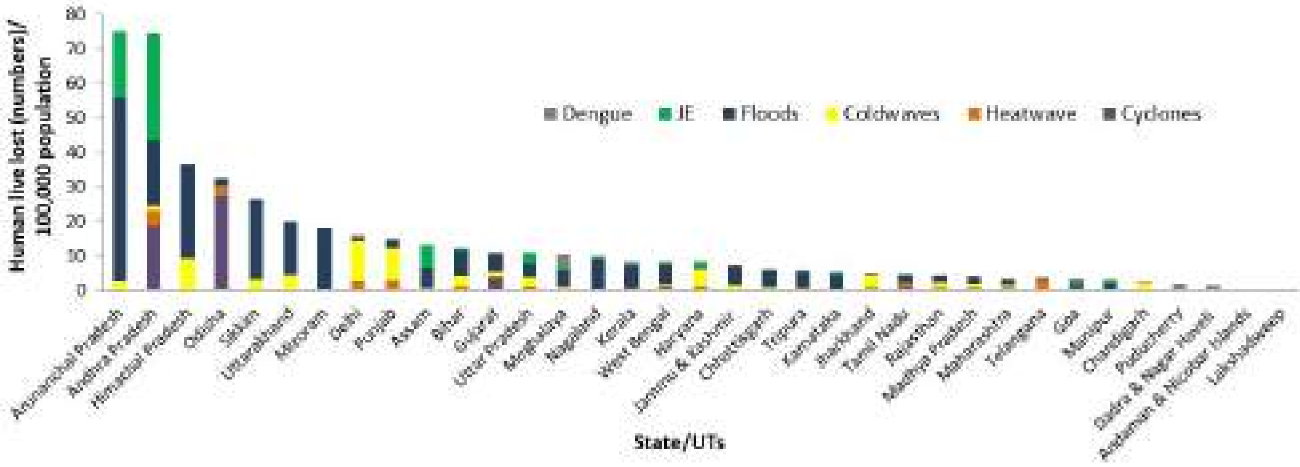


Figure 86: Comparative state-wise analysis for overall numbers of Human life lost due to all disasters for 100,000 population.

Unlike the total number of deaths, as evident from figure 86 the deaths per 100,000 population is highest in Arunachal Pradesh followed by Andhra Pradesh, Himachal Pradesh, Odisha and Sikkim. UP state reports the highest number of deaths considering the total figure and 13th position in terms of loss of life per 100,000 population, considering the four climatic and the two biological disasters. Arunachal Pradesh and Sikkim are less populated and hence loss per 100,000 is high, although actual figures are much lower than the states like UP, Bihar, West Bengal, etc.

3.4. Case studies

3.4.1. Maharashtra Drought 2014 - A Review of Sectoral Impacts

Maharashtra is located in the north centre of peninsular India, north of 14°N and south of 22°N. It is bound by Arabian sea on its western side. It is the third largest state in the area and second largest state in terms of population. It has an area of 307,713 sq. km. with 36 districts, 358 blocks and 43711 villages and a population of 112,372,972. There are four meteorological subdivisions, viz. Konkan, Madhya Maharashtra, Marathwada and Vidarbha in the state. Maharashtra experiences a tropical monsoon type of climate. The annual rainfall of the state can vary from 400-6000 mm and occurs for 3-4 months in a year.

- **Agricultural Impacts**

  Maharashtra has traditionally remained a drought-prone state. Eleven districts of Maharashtra viz., Ahmednagar, Aurangabad, Beed, Nanded, Nashik, Osmanabad, Pune, Parbhani, Sangli, Satara, Solapur are identified as chronically drought prone. Almost 70 percent of the State's geographical area lies in semi-arid regions rendering it vulnerable to water scarcity and drought. Almost all the taluks in Pune, Aurangabad, and Nashik divisions experience drought frequently. The state has 149 Drought Prone Area Programme (DPAP) talukas in 25 districts. These talukas receive 600 to 750 mm rains from the southwest monsoon (June to October).

  Failure of monsoon affects both Kharif and Rabi crops in these areas. The Years 2001, 2002, 2003, 2004, 2008, 2011, 2012, 2013, 2014, 2015 and 2018 were major drought years for the state. The region's worst drought in 40 years was experienced during 2012 affecting 34 districts. The worst-hit areas included Solapur, Beed, Pune, Nashik, Latur, Ahmednagar and Parbhani. Marathwada is one of the meteorological subdivisions of Maharashtra which has seen the worst droughts from 2012 onwards. This drought is worse than the one in 1972, which was termed as a 'famine' (2013, SANDRP) affected 2.5 crore people then.

Maharashtra was one of the states which experienced a severe rainfall deficit during the drought of 2015, ranging from 20 per cent for Vidarbha to as high as 40 per cent for the Marathwada region (Kulkarni et al., 2016). The consecutive three-year drought-like conditions faced by Maharashtra culminated in a severe drought in 2015-16, impacting 28,662 villages in 28 districts of Marathwada, north Maharashtra and Vidarbha. The impact of the drought of 2015 was particularly large for the Marathwada region. The gravity of the situation is reflected, with more than one thousand farmers of that region committing suicides this year. In the year 2014 and 2015, the rainfall decreased drastically in the region.

As a result of the availability of surface water, it is deployed in dams for meeting domestic, agricultural and industrial purposes. The meteorological and subsequent hydrological drought leads to the agricultural drought and then to socio-economic drought. The rainfall deficit in the year 2013 and 2015 affected the overall agricultural yield of Maharashtra state and particularly Marathwada region.

- **Livelihood Impacts**

Two years of successive drought or drought-like conditions had completely eroded the livelihoods, mainly of the farming communities. Every family had borne losses ranging from Rs. 15,000 to 60,000 on an annual basis. Productivity of all the major crops like cotton, soya, pulses, and sugarcane had dropped by more than 60 per cent. Due to increased rates of fodder, there was an additional requirement of Rs.150 per day per animal, which was not part of initial expenditure.

- **Economic impacts**

There was a reported increase in expenditure of Rs. 2,000-2,500 a month for a family of five members, largely for purchasing vegetables, fodder, cooking oil, and sometimes drinking water. Livestock, a mainstay of the families in Latur and Beed had dropped by 50 per cent and the milk production by about 75 per cent. Distress sale of cattle was one of the main causes for this drop. Cross-breeds valued at a unit cost of Rs. 80, 000 had been sold off for less than Rs. 20,000. There were 278 cattle camps set up in Latur and Beed. Almost all farmers visited were heavily in debt to private money lenders. The yield is decreased to a considerable extent in the year 2014-2015, which is 50 per cent deficit in pulses, oilseeds and cotton than the previous year 2013-2014 and the major reason behind it is the deficit rainfall in 2014 and 2015. An agrarian crisis has precipitated a spate of suicides in Maharashtra and resultant farmer's suicide increase from 1,495 (2011) to 2016 (2015) farmers per year except in 2013.

The people from drought affected areas started migration towards urban areas of other parts for employment. Drought disrupts the agricultural production, and the equilibrium between supply and demand of agricultural products will be broken, ultimately increasing inflation. There was a marked increase in the number of families migrating either for seasonal agricultural work in the sugarcane fields or permanently to urban and peri-urban areas like Aurangabad, Pune and even Mumbai, as unskilled labour. The quality of water supplied was very poor, with visible physical impurities. Most villagers managed their drinking water supply from functioning water sources in their villages itself or from nearby private sources. In some cases, villagers even travelled 2-3 km by bicycle to collect potable water. In villages without alternate sources, even purchasing of potable water was a better option than consuming tanker water. In such cases, there was an average incremental

Consecutive three-year drought-like conditions faced by Maharashtra culminated in a severe drought in 2015-16, impacting 28,662 villages in 28 districts of Marathwada, north Maharashtra and Vidarbha.

family expenditure of Rs. 1,000/- to 1,500/- per month per family for water alone. There was a differential impact on food security and nutrition, with the landed farmers having enough stock of their staple food items like bajra (pearl millet) and jowar (sorghum), whereas the landless labourers had to depend on the open market even for jowar and bajra.

3.4.2. Cyclone Fani 2019 – A Review of Sectoral Impacts

The state of Odisha, with a population of 42 million, is the eighth largest state in India comprising 4.7 per cent of the Indian landmass and 3.37 per cent of the total population in the country. There are 30 districts in the state and 83 per cent of the total population lives in rural areas which comprise 6,801 Gram Panchayats and 51,349 villages. Agriculture is the backbone of the state economy and about 62 per cent population of Odisha still depends to varying degrees on the agriculture sector for its livelihood. Although poverty level in Odisha has gone down from 57 per cent in 2004–05 to around 33 per cent in 2011–12, the percentage of poor people remains well above the national average of around 22 per cent. The districts in the south and west of Odisha have a very high level of poverty.

Due to its geographic and socio-economic condition, Odisha is highly prone to disasters. Its location on the east coast of India makes it one of the six most cyclone-prone areas in the world, the coast of Odisha having the highest vulnerability in terms of cyclone landfall. In the last century, out of the 1,019 cyclonic disturbances in the Indian subcontinent, 890 were along the eastern coast, and of these, 260 cyclonic disturbances had their landfall along the Odisha coast. The cyclones which hit the state in the last two decades are the 1999 super cyclone, Phailin 2013 and Titli 2018. The Orissa Super Cyclone 1999 was among the deadliest cyclones since 1990s. The Building Material Technology Promotion Council (BMTPC) of the Ministry of Urban Development, based on Hazard Vulnerability, identified cyclone prone districts of Odisha taking into consideration cyclone hazards of the coastal area. As per Wind and Cyclone Hazard Zones Map of Odisha, out of 30 districts of the state, 14 districts are categorised as high damage risk zones either fully or partially.

Out of the 1,019 cyclonic disturbances in the Indian subcontinent, 890 were along the eastern coast, and of these, 260 cyclonic disturbances had their landfall along the Odisha coast.

Extremely severe cyclonic storm, "FANI", hit the Odisha coast with wind speed of 170-180 kilometres per hour (kmph) on 3 May 2019. FANI was a rare summer cyclone which is one of the three cyclones to hit Odisha in the last 150 years. On 3 May, FANI crossed the Odisha coast close to Puri between 0800 and 1000 hours, with maximum wind speed of around 175-180 kmph. As reported by Indian Meteorological Department (IMD), the maximum sustained surface wind speed of 170-180 km/h gusting to 205 kmph was observed during landfall at Satpada. Although human casualties were relatively low when compared to the super cyclone of 1999, cyclone FANI left 64 dead, affecting about 16.5 million people in over 18,388 villages in 14 of the 30 districts in the state . Puri, Khorda, Cuttack, Jagatsinghpur and Kendrapara remain the five most affected districts.

- **Impacts**

Due to the cyclone, power, telecommunication infrastructure and road services were severely affected. Major roads were blocked due to the uprooted trees, road signages and damaged culverts with complete power outage in several parts of the state for almost two days. High wind speed also resulted in catastrophic damage to the kutcha houses, leaving thousands homeless. It is estimated that 3.6 lakh houses were damaged due to the cyclone. Damage to agriculture, fisheries and livestock has also been considerable. As per the estimate of the Department of Environment and Forestry, a total of 21.9 lakh trees were uprooted or damaged across the state, including urban, rural and sanctuaries. The assessment estimates the total damages to be around INR 16,466 crore (2,352 USD million and total losses to be around INR 7,713 crore. (1102 USD million).

3.4.3. Heat Wave 2015 in Andhra Pradesh

Andhra Pradesh spread over 160,205 sq. km along the east coast of the Indian peninsula (Figure 1) is home to ~50 million people. Nine out of its 13 districts, facing the Bay of Bengal constitute the semiarid coastal region (annual rainfall 943 mm; temperature range 22.6°-31.6°C) and the remaining four districts constitute the interior Rayalaseema region, which is more on the arid side (rainfall 683 mm; temperature range 22.2-30.4°C). May is the hottest month (mean temperature 31°C), while December records the lowest temperatures (22.4°C).

In India, 14,129 heat wave deaths occurred during 1979–2013. The heat waves largely occur in central India, but have intensified in the east coast region, especially in Andhra Pradesh and Odisha during the last two decades. Andhra Pradesh is one of the worst affected states in the recent past. During May, a semi-permanent though usually prevails over Odisha to Tamil Nadu across coastal AP, associated with hot dry winds blowing from north/north westerly along with significant rise in temperature leading to heat-wave conditions. The heat wave that occurred over the east coast during 19 May-10 June 2003 with maximum temperatures soaring over 45-49°C killed 1,421 people in (undivided) Andhra Pradesh alone. The year 2015, the hottest ever on record, proved to be even worse as the heat waves during 22 May–1 June, triggered by a persistent deep throat along the east coast during the period associated with advection of hot and dry winds from northwest India, claimed 2,677 lives.

The heat wave was caused in large part by sparser pre-monsoon season showers, which brought less moisture than normal to the area, leaving large parts of India arid and dry. The sudden end of pre-monsoon rain showers, an uncommon trend in India, has contributed to the heat waves.

Data on the daily maximum temperature recorded at 13 stations, each representing a district in the state, ranged from 42°C to 47°C showing deviations of 3-11°C from the climatic normal during 22 May-1 June 2015. The daily maximum temperatures showed an increasing trend from about 36-45°C on 22 May to 44-47°C by 25 May in the coastal districts. Subsequently, the temperatures showed a progressive decrease to 37-38°C by 28 May in the five northern coastal districts (Srikakulam to West Godavari), but continued to be higher at 44-47°C in the four southern coastal districts (Krishna to Nellore). However, the maximum temperature was more or less consistent at 41-44°C on most days in the four Rayalaseema districts (Chittoor to Anantapur). Generally, heat waves and severe heat waves are classified as conditions when the temperature departures are 5-6°C and 7°C, respectively, for stations where the normal maximum temperature is 40°C, and 4-5°C and 6°C or more, respectively, for stations where the maximum normal temperature is >40°C. The positive anomalies of maximum temperature were 7-9°C on many days and even reached 10-11°C at some stations, indicating heat wave to severe heat wave conditions almost throughout the 11-day period over the coastal AP region (Figures 67 and 68). The four Rayalaseema districts and the adjacent Nellore district in the southern part of the coastal region also experienced heat waves, despite the temperature departures being below the required criteria, since the maximum temperatures in this region were >40°C, which indicates heat wave conditions for the plains. The 2015 heat wave has taken its toll in the state, claiming 1,422 deaths with 1,369 lives by sunstroke only.

In India, 14,129 heat wave deaths occurred during 1979–2013. The heat waves largely occur in central India, but have intensified in the east coast region, especially in Andhra Pradesh and Odisha during the last two decades.

3.4.4. Kerala Floods 2018: A Review of Sectoral Impacts

Kerala, with a population of over 3.3 crore, is globally recognised for its impressive achievements in human development. Within India, Kerala ranks first among Indian states on the Human Development Index (HDI). In 2015–16, Kerala was among the top five Indian states in terms of per capita state domestic product and among the top four in terms of growth in per capita income. Kerala is a land of rains and rivers. The State has mainly two rainy seasons viz. the South-West monsoon that arrives towards the end of May or early June and North-East season which hits the State during mid-October.

Kerala is highly vulnerable to natural disasters and the changing climatic dynamics given its location along the sea coast and with a steep gradient along the slopes of the Western Ghats. Floods are the most common natural hazard in the state. Nearly 14.5 per cent of the state's land area is prone to floods, and the proportion is as high as 50 per cent for certain districts. Landslides are a major hazard along the Western Ghats in Wayanad, Kozhikode, Idukki, and Kottayam districts.

Disaster Event

Between June 1 and August 18, 2018, Kerala experienced the worst ever floods in its history since 1924. During this period, the state received cumulative rainfall that was 42 per cent in excess of the normal average. The heaviest spell of rain was during 1-20 August, when the state received 771mm of rain. The torrential rains triggered several landslides and forced the release of excess water from 37 dams across the state, aggravating the flood impact. Nearly 341 landslides were reported from 10 districts. Idukki, the worst hit district, was ravaged by 143 landslides. As per the PDNA report, 1,259 out of 1,664 villages spread across its 14 districts were affected. The seven worst hit districts were Alappuzha, Ernakulam, Idukki, Kottayam, Pathanamthitha, Thrissur, and Wayanad, where the whole district was notified as flood affected. The devastating floods and landslides affected 5.4 million people, displaced 1.4 million people, and took 433 lives (22 May–29 August 2018).

Between June 1 and August 18, 2018, Kerala experienced the worst ever floods in its history since 1924. During this period, the state received cumulative rainfall that was 42 per cent in excess of the normal average.

Infrastructure and socio- economic Impacts

The devastating floods and landslides caused extensive damage to houses, roads, railways, bridges, power supplies, communications networks, and other infrastructure; washed away crops and livestock and affected the lives and livelihoods of millions of people in the state. Early estimates by the government put recovery needs at about USD 3 billion. The PDNA estimates the total damages to be around INR 10,557 crore and total losses to be around INR 16,163 crore amounting to a total disaster effects of around INR 26,720 crore (USD 3.8 billion). The share of estimated total disaster effects among the main sectors of social and economic activity reveals that the most affected are the infrastructure sectors (38 per cent of the total effects), which includes transportation, water, sanitation and hygiene along with power, irrigation, and other infrastructure sectors. This is followed by the cross-cutting sectors (27 per cent), social sectors (18 per cent), and productivity sector (17 per cent).

Close to 14 lakh people had to be evacuated to relief camps during the floods as their homes were inundated with flood water. Thousands of people also took shelter with relatives and friends. Access to piped water was disrupted for 20 per cent of the state's population (67 lakh people). An estimated 3,17,000 shallow wells were damaged and contaminated in six worst affected districts directly affecting 14 lakh people. Over 95,000 household latrines were substantially damaged affecting nearly 4 lakh people. Over 1.75 lakh buildings have been damaged either fully or partially, potentially affecting 7.5 lakh people. More than 1700 schools in the state were used as relief camps during the floods. Most of the camps closed after 10 days. Floods affected teaching and learning in almost all the districts with institutions being closed from 2 to 23 days. A total of 1613 schools have been affected by the floods. Some schools in Alappuzha were closed for more than a month.

Kerala has suffered huge economic losses on account of the floods. Close to 2.6 per cent of Kerala's gross state domestic product (GSDP) got washed away by the floods instantly. The damage to agriculture and allied activities was immense. It included damage to crops, not only in flood hit areas, but also in other areas due to incessant rains followed by high temperatures, leading to destruction of seasonal crops and reduction in yields of tree crops.

Health Impacts

Although there was no major epidemic outbreak other than a few cases of Leptospirosis following the floods, the health sector impact was substantial as close to 332 health facilities were fully or partially destroyed. Furthermore, infrastructure facilities of the 120 health institutions (61 ayurveda and 59 homeopathic institutions) were damaged as a result of the floods. Among the worst affected were workers in the informal sector who constitute more than 90 per cent of Kerala's workforce. It is estimated that nearly 74.5 lakh workers, 22.8 lakh migrants, 34,800 persons working in micro, small and medium enterprises, and 35,000 plantation workers (majority being women), have been displaced from employment. Thousands of casual workers and daily wage earners such as agriculture labourers, workers in the coir, handloom, and construction sector and in the plantations have experienced wage loss for 45 days or more.

3.4.5. Japanese Encephalitis and response mechanisms in the state of Uttar Pradesh

JE has become a major health problem in India in recent time due to its complex eco-epidemiology as well as challenges in its prevention and control (Pal et al. 2016). It has become endemic in 14 states of India and about 30 crore population are at risk. Every year, JE claims hundreds of lives, particularly in the monsoon season. Almost 80 per cent of JE cases are reported from Assam, Bihar, Haryana, Uttar Pradesh and Tamil Nadu. According to a research study, 47,000 cases reported in the state among which 8,000 deaths were reported during 2005-2018 (Singh et al. 2020). The disease was mainly reported from the eastern part of the state. Gorakhpur, Maharajganj, Deoria, Kushinagar, Basti, Sant Kabir Nagar and Siddharth Nagar districts reported 86 per cent of the total cases in the last decade (Singh et al. 2020). Gorakhpur in Uttar Pradesh is one of the worst affected districts with maximum cases reported (Srivastava et al. 2014). The State Government is running an awareness drive in the form of "Sanchari Rog Niyantran Campaign" and "Dastak" to educate the people about the measures to prevent the spread of the disease.

Lack of cleanliness of water bodies and sanitation has been attributed to the spread of JE in the state. Most of the water sources are polluted and need immediate conservation strategies to prevent the spread of the disease. JE is associated with the pattern of rainfall, flooding and rice production system. Intensive rice cultivation supported by irrigation schemes is considered to be one of the most important reasons for JE spread in new areas. Migratory birds and pigs rearing are also causative agent in the spread of the disease (MoHFW press release, 2019).

Prevalent Resilience Mechanisms and Responses

For the mechanisms and responses to be effective, partnerships/ coordination/ collaboration of and between governments at various levels is needed with communities and other stakeholders.

This section presents prevalent resilience building mechanisms and responses at four different levels–from local to national –community, local authority and district, state and national level. For the mechanisms and responses to be effective, partnerships/ coordination/ collaboration of and between governments at various levels is needed with communities and other stakeholders. In other words, an all-of-society and all-of-government approach is key to effective disaster response and resilience building. While national government has key role in crafting supportive policies/ guidelines/ planning/ regulations/financing mechanisms, state and district governments are involved in planning and implementation. Given that local communities have sound knowledge of local conditions (local vulnerabilities and resources), it is prudent for the governments (at various levels) to work in partnership with community for effectively mitigating the impacts of disasters.

In this section we present specifically:

- Structures and institutions of governments at national, state and district level to respond to each of the select climatic and biological disaster;
- Actions–mostly autonomous–taken by community to deal with each of the select disaster. The community actions rely mostly on (traditional) knowledge, resources and skills within the community; and,
- Case studies to provide real-life examples on responses of governments at various levels and community on recent disasters.

4.1. Community level

4.1.1. Floods

Communities residing near the floodplains, rivers and low-lands are highly exposed to the risk of flooding and are the first responder of any disaster event. These areas are mostly remote as well as underdeveloped (Das et al. 2009) and take significant time for any humanitarian team to approach. Community responses are the result of memory, learning and experience from past events of floods and associated hazards. The recurrent Assam flood is the classic example of community adaptation response mechanisms (as discussed in Table 3) where community have understood the nature of flash floods (Das et al. 2009).

Table 3: Select flood cases of response and coping strategies

Case	Response and coping strategies
Assam, Recurrent (Das et al. 2009)	**Mitigation:** Mishing community lives in traditional stilt houses called chang ghar, a type of house built with bamboo and wood ideally suited to adapt to flood waters. The base of the house (floor) made of bamboo and wood is adjustable and can be raised to cope with rising flood waters. The community has a well-defined traditional practice of storing food and seeds on a three-tiered bamboo platform with the shelves placed at various heights over the oven in the kitchen of the chang ghar. In case of small-scale erosion and breaches, the community tries to control erosion by erecting branches of trees and triangular structures made of bamboo, bamboo screen, and sand bags on their own. **Preparedness:** Mishing community uses two traditional instruments, the 'Le-long' and 'Mabong', which have sounds like cymbals, to warn people of advancing and rising waters of three to four kilometres distance. Villagers have an idea of how soon a flood wave will come and how severe it can become by observing the aspect of the rising waters and the current in the flow, monitoring the weak and erosion-prone parts of the embankment. **Rescue and relief:** The community moves to higher places at the time of flooding along with stocks of food grains and other necessary items.
Bihar, Recurrent (Oxfam India, 2019; Sinha et al.2012)	**Mitigation:** Raised hand pumps for safe drinking water, resilient livelihood techniques such as vermin compost, mushroom cultivation. **Preparedness:** Community forecast the flood by seeing the current in the river. Sometimes they also inform the government officials at block level. **Rescue and relief:** 80 per cent adults in the villages know swimming and they also keep hired boats for evacuation purpose. They also prepare temporary boats by tagging logs of banana trees using bamboos.
Gorakhpur, Recurrent (GEAG, 2018)	**Mitigation:** Raising of embankments, their timely repair, preventing water retention, construction of proper water outlet drainage **Preparedness:** Continuous monitoring of river-water flow and level, and sounding warning accordingly.
Kerala, 2018 (Joseph, et al. 2018; Redr India, 2018)	**Preparedness:** Community participated in the rescue operations as they had previous experience in disaster relief. Coastal community in the state was familiar with the nature and typology of common coastal hazards. **Reconstruction**: Shallow trenches/pits were dug on the sandy parts of the riverbank in Thrissur district, from which a limited quantity of water was collected for drinking and cooking

Many such local communities have developed small-scale adaptation strategies, based on their experiences learned as well as traditional wisdom passed through generations. According to GEAG study, in the maximum adaptive practices, there is strong correlation with people with indigenous knowledge (GEAG, 2018). In case of Kerala flood, 2018, community participated in the rescue operations as they had previous experience in disaster relief. The coastal community in the state was familiar with the nature and typology of common coastal hazards (Joseph, et al. 2018). Identification of such community adaptation strategies and response mechanisms can add value to disaster risk reduction strategies related to flooding event.

4.1.2. Droughts

Drought is an environmental as well as developmental issue and highly related with variability in weather patterns (World Bank, 2010). Drought is no longer mere scarcity or the absence of rainfall, but related to inefficient water resources management. The impact of drought is very severe and leads to large scale migration, loss of human lives due to stress and economic reasons, suicide, starvation, poor health conditions and many social conflicts including forced marriage.

Table 4: Select drought cases of response and coping strategies

Case	Response and coping strategies
Protecting livestock from extreme drought in Bihar (Goswami, et al. 2018)	Feeding of extra crop residues, providing frequent extra clean and fresh feed and water, storage of wheat/rice straw, change in cropping pattern, feeding and milking during cool hours, kept animal in shadow, extra bathing of cattle, feeding of extra concentrate, selling of animals and reducing herd size.
Overcoming drought in Andhra Pradesh (World Bank, 2010)	Farmers have rationalised the use of available water, and shifted from rice, which is water intensive, to less water-intensive crops in times of acute drought condition.
Understanding drought coping strategies in rural eastern India (Sam et al. 2020)	Reduced consumption of rice/cereals, reduced consumption of fish/meat/egg, and reduced milk consumption. Changing cropping pattern and interstate migration
Study of Ahar-pyne in Palamau district (Singh, 2012)	Revival of traditional water management systems
Community Based Institutions (National Drought management manual, 2017)	Water user associations like Pani Panchayat programme are playing important roles in water management.
India's traditional wisdom in coping with extremes (Phansalkar, 2018)	Traditionally farmers had two sets of crops: those that could be sown in June if monsoon came early, or if not then a set of crops to be sown in late July, if monsoon was delayed

Communities, since ages have developed different coping and response strategies to deal with the drought hazard. Several coping mechanisms have been adopted by the livestock dependents in Bihar to mitigate the impact of drought on their livestock rearing and sustain their livelihood security (Goswami, et al. 2018). Sam et al. (2020) have reported five different coping strategies by the rural communities in eastern India to deal with drought situation. These are reduced food consumption, migration, seeking help and change in cropping pattern. Farmers in Andhra Pradesh have also adopted change in cropping pattern by shifting from high water intensive crops to less water intensive crops (World Bank, 2010). Farmers in North Gujarat have two sets of crops based on the monsoon pattern (Phansalkar, 2018). Traditional water management strategies have been adopted by communities across the country and have stood with the test of time. Ahar-pyne is one of the traditional water management systems in Bihar and Jharkhand which has served water to crops at the time of crisis (Singh, 2012).

Sukhomajri village in Haryana and communities in Alwar district of Rajasthan have shown considerable improvement in their socio-economic conditions through community-led water management system. These communities used traditional water harvesting structures, such as village tanks and johads, which had increased the groundwater table in the area, subsequently resulting in increased water availability and crop production. Ralegan Siddhi and Hirve bazar from Maharashtra are the other examples of community-based initiatives in water resource management.

4.1.3. Cyclones

Cyclones and related hazard severely impact day to day life of coastal people. Being the first responder, communities have mitigated the impacts of disaster events to a certain extent (as a response and coping strategies people living along the coastline have changed their housing structures, migrate, change jobs, and take other alternative measures to survive the adversaries of the nature (Garai, 2017). Taking the lessons from Super Cyclone of Odisha in 1999, communities in the states were better prepared to face the cyclone Fani in 2013 (Patel, 2018). In some cases, due to disaster induced crisis, communities cope up during recovery phases through alternate livelihood strategies, forced migration in search of jobs and distress selling of their belongings.

Table 5: Select cyclone cases of response and coping strategies

Case	Response and coping strategies
Cyclone Fani, Odisha 2013 (Patel, 2018)	**Mitigation:** Raised the platforms of tube wells, building toilets higher off the ground, and growing plants to protect houses from strong winds during cyclones. Preserving coastal mangroves to protect villages from the effects of cyclones. **Preparedness:** Locals migrated, borrowed money and food. Community members keep themselves updated and informed about cyclone situation through television and newspapers. People stored dry food like flattened rice, jaggery, biscuits, potatoes and other vegetables, stoves, kerosene and drinking water. **Rescue and Relief:** Community members themselves provided relief and rescue to affected people during cyclone Fani before the government stepped in few villages. Local people carried sticks and torch lights to rescue people on river embankments and other areas.
Cyclone Gaja, 2018 (NDMA, 2019)	**Rescue and relief:** Communities as first responders helped in search and rescue operations and helped people evacuate to safer locations.
Cyclone Thane, 2011 (Rakesh and Narang, 2016)	**Recovery:** Change in livelihood activity, from being a cultivator to engaging in casual or daily wage labour. Reduction in their expenditure on food and education to adjust the other urgent and emergent expenses after Thane cyclone. Avoiding social celebrations during festivals.

4.1.4. Heat Waves

India is urbanising very fast and has considerably high levels of built up area and population density (NDMA, 2019). In terms of heat waves, vulnerability pattern is unequally distributed and affect communities by causing heath related illnesses and increase in mortality rate. As per the NDMA guidelines of 2019, heat wave is defined as “a period of abnormally high temperatures, more than normal maximum temperature that occurs during the summer season (April-June)”. In the year 2018, severe heat wave conditions affected Saurashtra and Kutch in Gujarat, West Rajasthan, Vidarbha , Madhya Pradesh, Andhra Pradesh, Telangana, Northern parts of Karnataka and Tamil Nadu. With temperature continuously rising, communities have adapted few coping mechanisms to deal with the heat.

Table 6: Coping strategies for heatwaves

Coping strategies	References
Drinking lots of water, covering head and ears with cotton cloth, no chill drinks, drinking suspension of chick flour in water with salt and pepper, carrying onion to protect from the heat	Withnall, 2019
Houses are traditionally designed with thick insulating walls of mud and mortar, high indoor ceilings and thatched roofs	Pradyumna et al, 2018
Staying indoors, wear light clothing, using suncoat, change in cooking time, change in work schedule, change in food pattern	Pradyumna et al, 2018

4.1.5. Cold Waves

A cold wave is said to onset when there is rapid fall in temperature within 24 hours to a level that needs substantial and increased protection to agriculture, industry, commerce and social activities. In India, core cold wave zones are Punjab, Himachal Pradesh, Uttarakhand, Delhi, Haryana, Rajasthan, Uttar Pradesh, Gujarat, Madhya Pradesh, Chhattisgarh, Bihar, Jharkhand, West Bengal, Odisha and Telangana. Communities residing in these regions have been coping with severe cold waves by taking certain measures such as wearing multiple layers of clothing, wearing mittens for warmth and insulation, sitting near bonfire, taking hot drinks and staying indoors as much as possible.

4.1.6. Dengue

Community plays an important role in prevention and control of dengue. According to Conyer et al. 2012, community empowerment is the key strategy to eradicate the disease in their environment. Community participation and sensitization programmes have been taken up by government of India through various schemes (MoHFW Report, 2017). The report emphasises that action taken at the household and community level is imperative to control the spread of dengue. Cuttack district in Odisha in India had shown a successful example of controlling the outbreak of dengue disease through effective community participation which also involved school children and self-help groups (MoHFW, 2017). Kerala Government has very effectively utilised the services of Kudumbashree, which is a female oriented poverty reduction program, that has tremendously helped in mosquito control activities. Along with community actions of solid waste management, cleaning water storage areas, elimination of breeding grounds etc., workers also motivate other community members and help increase awareness.

Table 7: Steps for preventing dengue

S.no.	Steps for effective community participation for Dengue
1	Motivating community and invoking participation
2	Initiating dialogue
3	Joint planning and implementation with community
4	Mapping and listing all possible breeding sites by specific places
5	Possible community actions • Covering domestic water/storage containers • Cleaning ACs, refrigerators, water coolers • Managing glass bottles and cans • Disposal and recycling of old used tyres • Cleaning flower vase/pots • Managing plantation areas • Managing construction sites
5	Community actions to ensure personal protection • Protective clothing • Use of mats, coils and repellents • Wire mess on windows and doors • Use of mosquito nets/bed nets
6	Community participation in effective clean-up campaigns
7	Weekly monitoring of breeding sites

4.1.7. Japanese Encephalitis

JE control is mostly dependent on active community participation, which is further dependent on knowledge and practices towards the diseases. A study on assessing the knowledge level of community in West Bengal, Assam and Uttar Pradesh on JE suggests that there is strong knowledge gap regarding JE, its transmission and vector control (Pal et al, 2016, Ahmad, et al. 2017, Yadav & Ahmad, 2017). Information on JE, the causative factor, transmission and prevention of mosquito bites and community action in reducing mosquito breeding places by filling pools, weekly drainage of accumulated water, lowering of water levels in rice fields, etc., can play an important role in controlling the situation (Srivastava et al. 2014, Pal et al. 2016). Health workers working at the grass root level in Darrang district of Assam have been playing a significant role in generating awareness about the disease, vaccination and better hygiene practices (Ahmad et al. 2017). There is a strong need for educational campaigns for increasing the knowledge and awareness among the community. A well-planned mass education and communication strategy is needed for a better informed community (Yadav & Ahmad, 2017).

Table 8: Steps for preventing dengue

S. No	Steps for effective community participation for JE
1	Educational campaigns for increasing the knowledge and awareness among the community about the disease
2	Information on JE the causative factor, transmission and prevention of mosquito bites and disease burden is important
3	Health workers working at the grass root level should be given training
4	A well-planned mass education and communication strategy is needed
5	Good practices related to paddy cultivation needs to be propagated among the agricultural communities as it is one of the important causative agent

4.1.8. COVID-19

The COVID-19 pandemic has emerged as a global and social crisis in the today's time. In such a crisis situation, community involvement plays a leading role in planning local-level actions. COVID-19 is highly contagious and has largely spread due to coming in close proximity with affected cases. Maintaining social distance, wearing masks in public places, washing hands at regular interval and as required, avoiding crowded place, etc., are some of the preventive measures that require active community participation. Identifying vulnerable households, providing support to elderly and vulnerable population, support in quarantine, developing better communication strategies are some of the efforts for sustained and effective community engagement.

4.2. Local Authority and District Level

4.2.1. Floods

At the district level, District Disaster Management Authority (DDMA), chaired by District Magistrate/ District Collector, is the nodal agency for taking all necessary measures for preventing flood disasters in the district. DDMA is responsible for the district disaster management plan including the response plan for the district, coordination and monitoring the implementation of the national policy, the state policy, the national plan, the state plan and the district plans, and ensure that the guidelines for prevention, mitigation, preparedness and response measures laid down by the NDMA and the SDMA are followed by all departments of the government at the district-level and the local authorities in the district

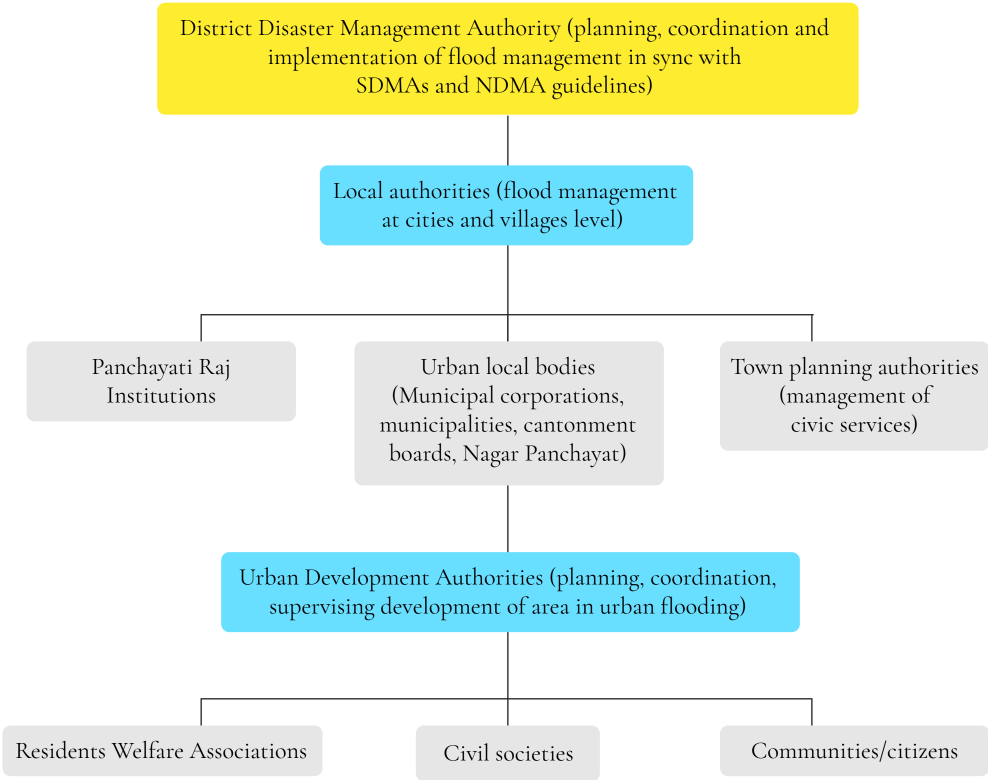


Figure 87: District-level flood response mechanism

4.2.2. Droughts

At the district-level, District Magistrate/ District collector is responsible for implementing all decisions related to drought management on the ground-level. The collector coordinates with a number of line departments and field agencies working on the ground. The efficient management of drought is largely dependent upon effective coordination among different agencies working at the district level.

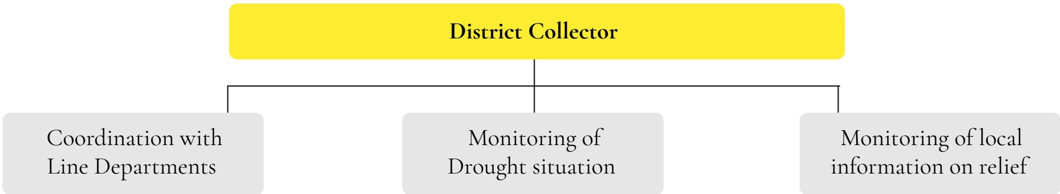


Figure 88: District-level drought response mechanism

The role of DM/DC is to ensure monitoring of all the indicators of drought on the ground as well as monitor local information related to demand for relief employment. The Collector should provide direction to all the line departments and agencies working on drought relief.

4.2.3. Cyclones

The districts/cities/villages lying in the vicinity of coastline become active after receiving the alert and warning from the centre and State Emergency Operating Centre (SEOC). Warning messages are transmitted wireless to all districts and talukas. District Collectors are provided with satellite phones and a HAM radio3 to maintain effective communication. All line departments, police forces and commissioners of municipalities are on alert, based on the communication received. Fishermen and local communities are evacuated to temporary shelter and are provided with food and all emergency support systems.

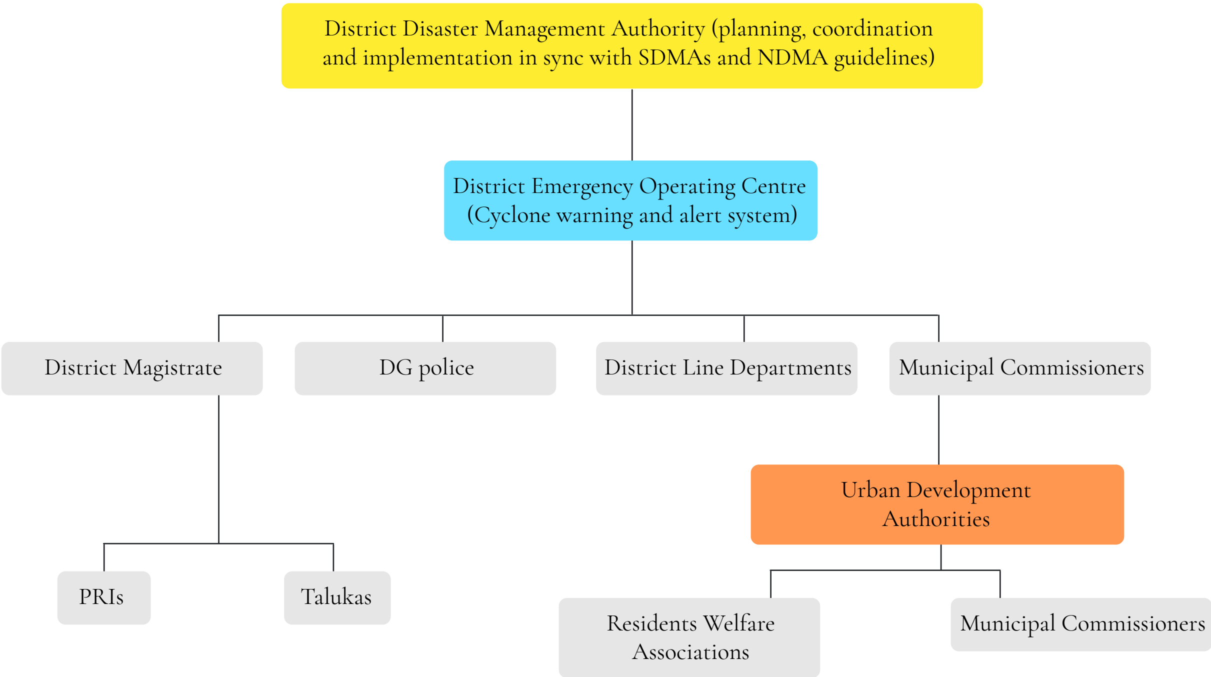


Figure 89: District-level cyclone response mechanism

4.2.4. Heat Waves

District Disaster Management Authority under the chairmanship of District Magistrate is the nodal agency at district-level for heat wave management. Most of the response activities are carried out at the district-level, therefore, District Magistrate plays a vital role in overall management and coordination at the time of disaster.

3. HAM radio also known as Amateur Radio is the use of radio frequency spectrum used for non-commercial exchange of messages as well as emergency communication.

Table 9: Heatwave response strategy at district level

Key strategy	Institutions
Preparation and revision of heat action plan at district level based on guidelines of NDMA	District Disaster Management Authority
Early warning dissemination and risk communications	District Administrations
Medical preparedness and monitoring	Civil Hospitals, U, PRIs
Response	
1. Rescheduling of educational institute timing	District magistrate
2. Direction for rescheduling office working hours	District magistrate
3. Issue heat waves advisory to urban areas	District magistrate
4. Adequate drinking water	ULBs, PRIs
5. Construction of shelters	ULBs, RWAs,

4.2.5. Cold Waves: District and State-level

As Cold Wave/Frost is a localised phenomenon, the relevant State Governments draw up location specific mitigation plans, involving respective DDMAs and local authorities (Panchayats and Urban Local Bodies (ULBs). The State Governments must maintain close coordination with India Meteorological Department (MOES (IMD)) and closely monitor cold wave situation. Warnings should be disseminated to the public through appropriate forums (including local newspapers and radio stations) on a regular basis.

4.2.6. Dengue and Japanese Encephalitis

At the district level, there is District Chief Medical and Health Offices set by the states. The key unit for planning and monitoring of vector borne programme is established under a technical officer called as District Vector Borne Disease Officer (DVBDO). At present 677 District/reporting such Units are functioning. There are sub-centres at village level for delivery of primary health services. They are known as Primary Healthcare Centres and Community Healthcare Centres, which act as the basic units at the rural area for delivery of primary health care in an integrated manner. Active surveillance at the grass root level is carried out by health workers known as Accredited Social Health Activist (ASHA).

1.1.2. COVID-19: District and State level

The overall health care delivery services at the district-level are categorised as primary, secondary and tertiary care services and at the state-level being managed by different Directorates of the State Health Department. While the primary health care services by Sub-Centre (SC), and Primary Health Centre (PHC) are largely preventive and mitigative, the Community Health Centre (CHC) works as the first referral unit for curative services. The District hospitals, sub-divisional hospitals form the core of the secondary services, which the Medical college hospitals and super specialty hospitals forms part of the tertiary health services.

4.3. State level

4.3.1. Floods

Flood being a state subject, flood management schemes are planned and executed by the state governments. The role of the central government is advisory, catalytic and promotional in nature. The states have to investigate, plan, construct, maintain and operate all flood works. At the state-level, the State Disaster Management Authority (SDMA), headed by the Chief Minister, lay down policies and plans for DM in the state. It works in accordance with the guidelines laid down by the NDMA, coordinate the implementation of the state plans, recommend provision of funds for mitigation and preparedness measures and review the developmental plans of the different departments of the state to ensure the integration of prevention, preparedness and mitigation measures. Every state government had a State Executive Committee (SEC) to assist the SDMA in the performance of its functions. The SEC is headed by the chief secretary to the state government and coordinates and monitors the implementation of the national policy, the national plan and the state plan. At the local-level, the initiatives by state government departments like Municipal Administration and Urban Development (MA&UD), Public Works Department (PWD)/ Irrigation/ Roads and Buildings, Education, Health, State Pollution Control Board (SPCBs), State Remote Sensing Application Centres (SRSACs), etc., have a definite role in the management of urban flooding. However, at the cutting-edge level, it is the ULBs that are responsible for the management of urban flooding.

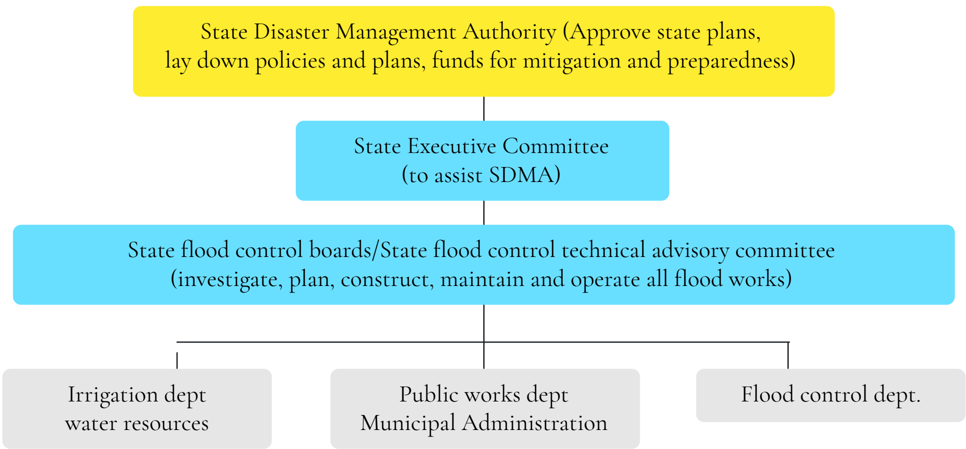


Figure 90: State-level flood response mechanism

4.3.2. Droughts

Relief and revenue department of the state is responsible for directing drought response directions at state-level. Relief Commissioner, with a team of officers, monitors the drought situation through the drought management centres, district collectors, concerned departments and agencies. Relief Commissioner declares drought based on the ground assessment and reports of the team. Relief Commissioner also administers State Disaster Mitigation and Response Fund (SDMRF) and issues orders for its release to districts and concerned departments. State Executive Committee under the Chairmanship of the Chief Secretary is also responsible for taking policy decisions on drought. Drought management requires efficient coordination with departments of agriculture, horticulture, animal husbandry, water resources, irrigation, social welfare, public distribution, rural development, school education, power, drinking water, public health, and finance.

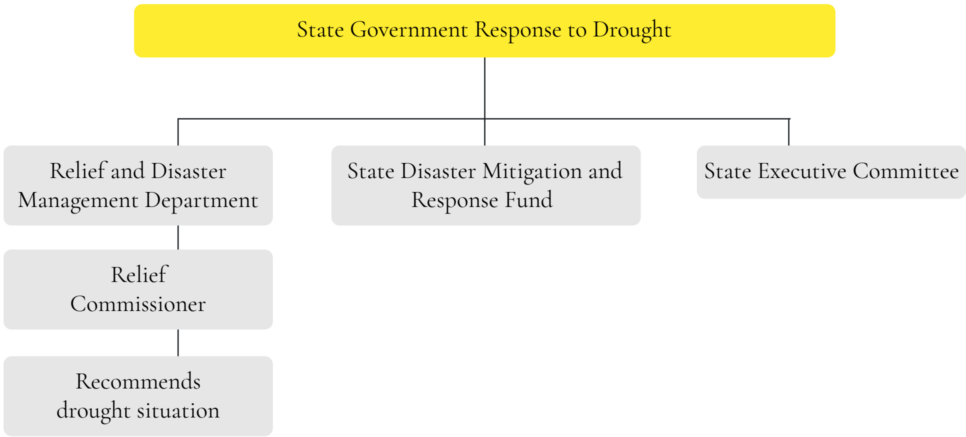


Figure 91: State level drought response mechanism

4.3.3. Cyclones

The primary responsibility of cyclone disaster management rests with the states. The Revenue Department of state is the nodal department for controlling, monitoring and giving directions for organising rescue and relief operations. SDMA along with all relevant line departments maintain proper records of all essential services needed for rescue, response and relief phases.

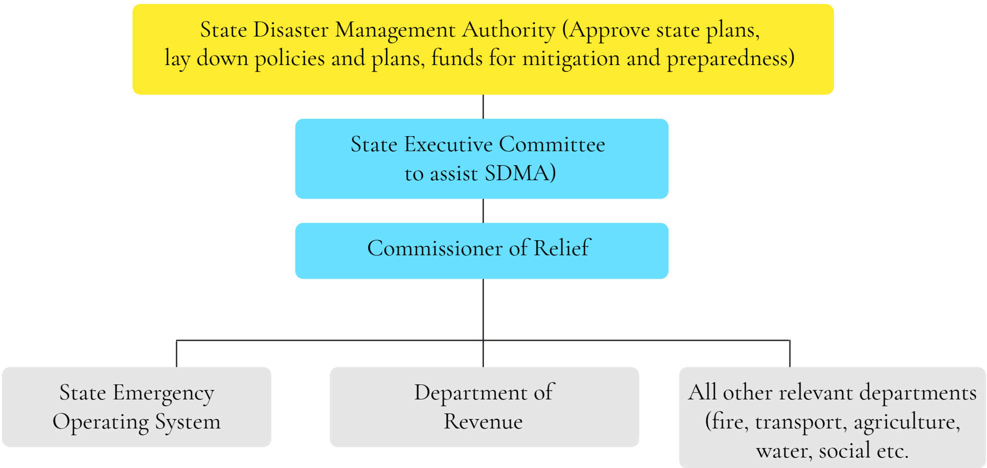


Figure 92: State-level cyclone response mechanism

After receiving early warnings from IMD, State Emergency Operating System becomes functional in disseminating warnings and alerts to all stakeholders under the leadership of the Commissioner of Relief.

4.3.4. Heat Waves/ Cold Waves

At the state-level, State Disaster Management Authority, along with respective state agencies prepare heat action plan based on NDMA guidelines and local experiences. Commissioner of Relief, in coordination with state agencies, disseminate information on heat health warning to the public, as received from IMD. State health department develops monitoring mechanisms for heat action plans, along with deployment of rapid medical response teams. Other state agencies act as and when required based on the warning received from the SDMAs.

Table 10: Heatwave response strategy at the state-level

Key strategy	Institutions
Preparation and revision of heat action plan at state level based on guidelines of NDMA	State Disaster Management Authority, respective State Departments, Commissioner of Relief
Early warning dissemination	State Departments, Commissioner of Relief
Risk communication and dissemination of heat-health warning	State Departments, Commissioner of Relief
Medical preparedness and monitoring Hospital preparedness plans	State Health Departments, PHC, UHC
Response measures	
1. Drinking water facilities	State drinking water department
2. Rescheduling of educational institute timing	State Education Department
3. Direction for rescheduling office working hours	State Labour Department
4. Heat wave advisory for agriculture crops	State Agriculture Dept
5. Issue heat waves advisory to urban areas	Urban Dept
6. Rescheduling of load shedding	Department of Power/DISCOMs

4.3.5. Dengue, Japanese Encephalitis and COVID-19

At the state-level, there is a state Vector Borne Disease Control Unit under the State Directorate of Health Services. There are State Programme Officers and system of coordination between the state and centre for effective implementation and monitoring of Programme.

4.4. National level

4.4.1. Floods

The Disaster Management Act, 2005 (DM Act, 2005) lays down institutional, legal, financial and coordination mechanisms at the national-, state-, district- and local-levels. The NDMA, as the main body under the GOI, has the responsibility of laying down policies, plans and guidelines for flood management in the country. It approves the national DM plan prepared by the National Executive Committee (NEC) and plans of the central ministries and departments.

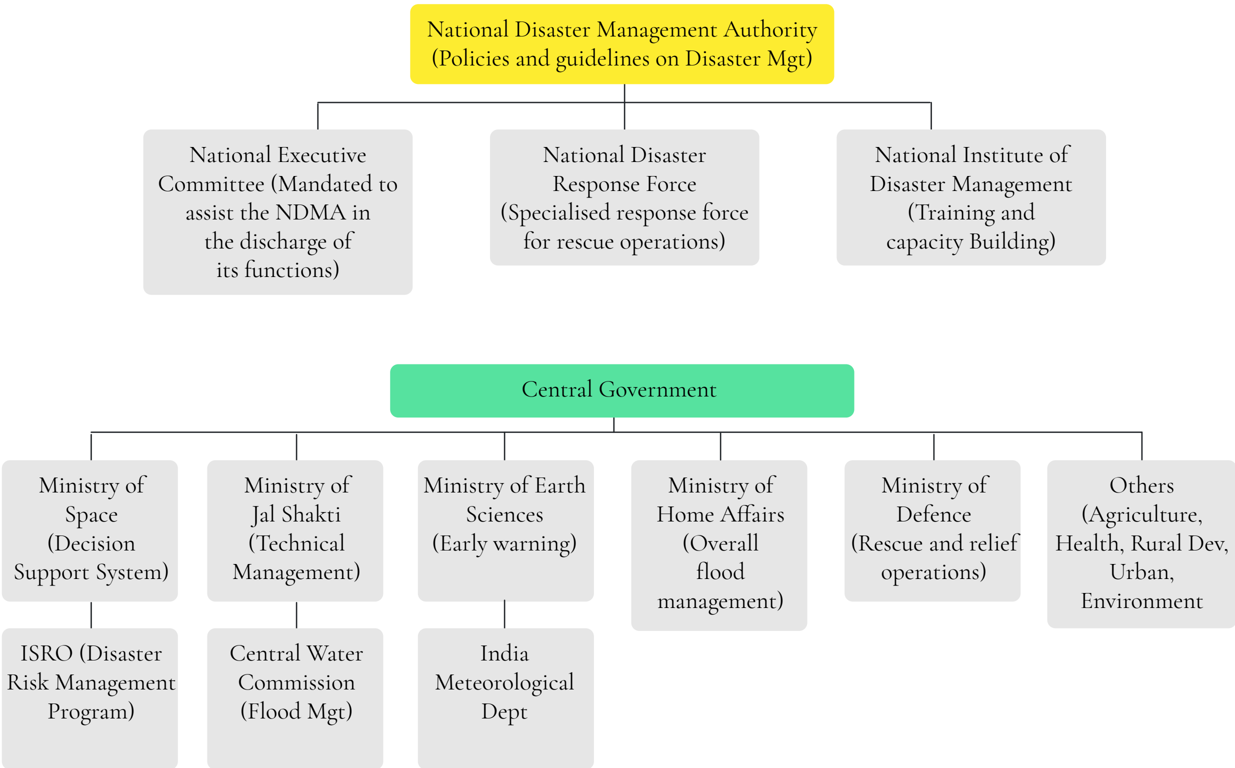


Figure 93: Flood response mechanism at national level

The NDMA may take such other measures, as it may consider necessary, for the prevention of disasters, or mitigation, or preparedness and capacity building, for dealing with a threatening disaster situation or disaster. In accordance with the provisions of the DM Act 2005, the central government will take all such measures, as it deems necessary or expedient, for the purpose of DM and will coordinate actions of all agencies. It will ensure that central ministries and departments integrate measures for the prevention and mitigation of disasters into their developmental plans and projects, make appropriate allocation of funds for pre-disaster requirements and take necessary measures for preparedness to effectively respond to any disaster situation or disaster.

4.4.2. Droughts

At the central-level, Ministry of Agriculture and Farmer's Welfare is the nodal Ministry responsible for monitoring and coordinating the response to drought. Drought Management Division is mandated for coordination of relief efforts. Additional Secretary under Department of Agriculture and Farmer's Welfare is designated as Central Drought Relief Commissioner (CDRC) for the purpose of drought management. Crisis Management Group (CMG) and Crop Weather Watch Group (CWWG) functions under the CDRC, having representatives of concerned ministries and government officials.

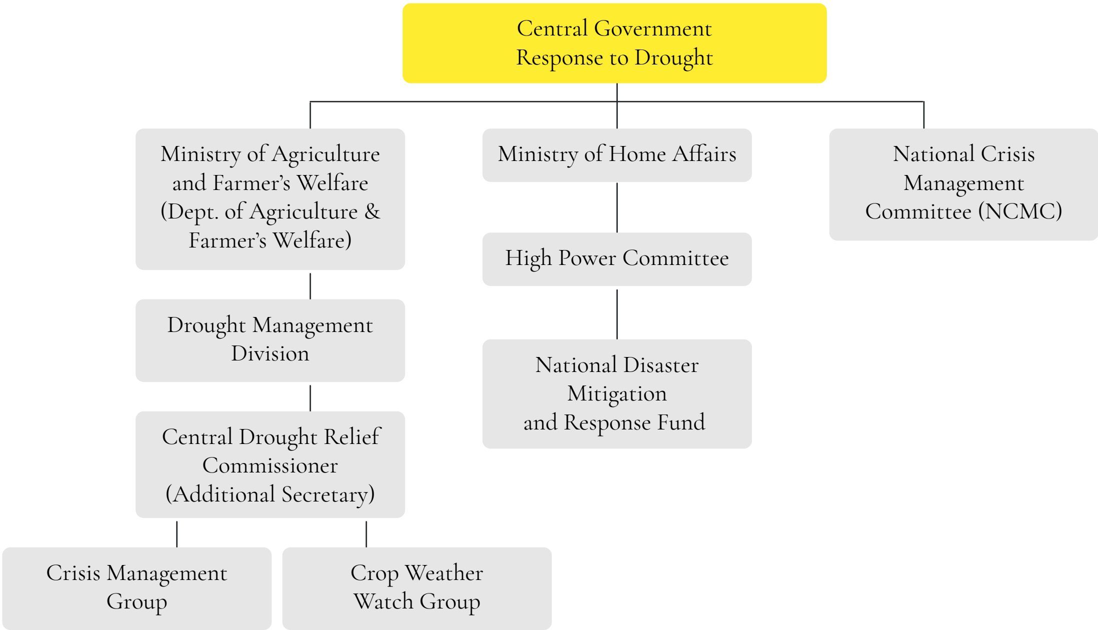


Figure 94: Drought response mechanism at national level

Inter-Ministerial Central Team under the Dept of Agriculture and Farmer's Welfare visits the affected areas, assesses the damage and recommends for assistance to the states. Ministry of Home Affairs, through their National Disaster Mitigation and Response Fund (NDMRF), gives assistance to affected farmers with the recommendation of High Level Committee (HLC). National Crisis Management Committee (NCMC) under the chairmanship of Cabinet Secretary is updated with the relief and other developments regularly.

4.4.3. Cyclones

National Disaster Management Authority is the apex body for the overall management of cyclones in the country. It lays down plans, policies, guidelines and function through its National Executive Committee for the discharge of its functions. The Disaster Management Act, 2005 has also mandated the constitution of National Disaster Response Force as a specialised response force for the search and rescue operations. National Crisis Management Committee (NCMC) under Ministry of Home Affairs, is headed by Cabinet Secretary and is mandated for effective coordination for relief and operations.

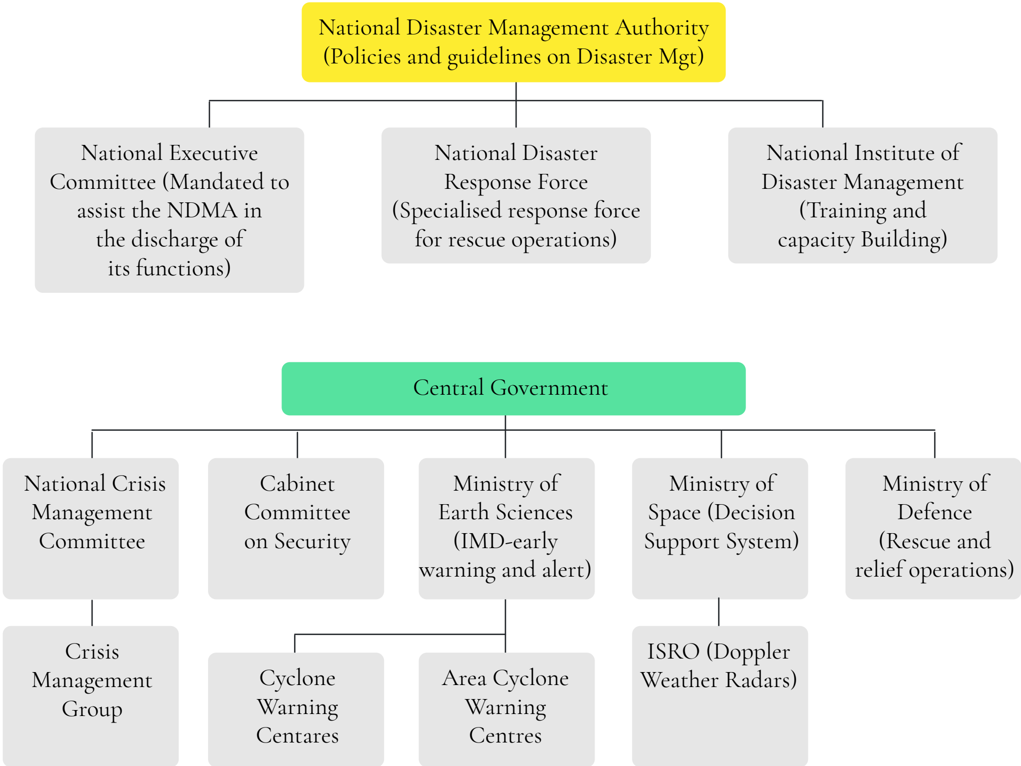


Figure 95: Cyclone response mechanism at the national-level

NCMC gives command to Crisis Management Group (CMG) as deemed necessary for the matters related to relief in the wake of major events. The CMG consist of Relief Commissioner and various nodal officers from concerned ministries. IMD is the nodal agency for early warning and generating alert system. Cyclones are monitored with the help of land-based, ocean-based and space-based observational system.

4.4.4. Heat Waves

National Disaster Management Authority is the nodal agency for formulation of policies, plans and guidelines related to heat wave disaster. India Meteorological Department, under Ministry of Earth Sciences is the nodal agency for providing weather information along with issuing warnings and alert. IMD provides real time data and weather prediction of maximum temperature, heat wave warning, extreme temperatures, and heat alerts for vulnerable cities and rural areas. It issues alert system based on colour codes as green (no action), yellow (heat alert), orange (severe heat alert for all day) and red (extreme heat alert). Ministry of Health and Family Welfare is responsible for hospital preparedness measures for managing heat related illness. Based on the need, related ministries take immediate actions such as Ministry of Jal Shakti, Human Resources, Labour and employment, Housing and Urban Affairs and Ministry of Power.

Table 11: Heatwave response strategy at national level

Key strategy	Institutions
Formulation of policies, plans, guidelines and overall coordination	National Disaster Management Authority
Early warning and coordination with state agencies: Issuing warning on the basis of colour code, green (no action), yellow (alert), orange (be prepared), red (take action)	Ministry of Earth Sciences (India Meteorological Department)
Medical preparedness and monitoring Formulation of schemes and programs of heat health safety	Ministry of Health and Family Welfare
Response measures	
1. Ensuring availability of drinking water facilities	Ministry of Jal Shakti-Dept of drinking water
2. Rescheduling of educational institute timing	Ministry of Human Resources
3. Direction for rescheduling office working hours	Ministry of Labour and Employment
4. Heat wave advisory for agriculture crops	Ministry of Agriculture and Farmers Welfare
5. Heat waves advisory to urban areas, directions for constructions of shelters and sheds	Ministry of Housing and Urban Affairs
6. Rescheduling of load shedding	Ministry of Power

4.4.5. Cold Waves

India Meteorological Department is the nodal agency for early warning dissemination for frost and cold waves. Ministry of Agriculture and Farmer�s Welfare is the nodal agency for relief and financial assistance to crops damaged by cold waves. Severe cold wave conditions would be said to prevail in an area: (i) If minimum temperature is lower than 7°C in an area where normal minimum temperature is 10° C or above; and (ii) If minimum temperature is lower than 5°C in an area where normal minimum temperature is less than 10°C. Frost conditions would be said to prevail when temperature falls below 0oC in an area where it is an abnormal phenomenon during the kharif/rabi season (GoI, 2010).

For declaring a district affected by frost/ cold wave conditions by the State Government concerned, the meteorological data on departure of normal minimum temperature in the affected area, as released by the India Meteorological Department (IMD) shall be taken into consideration, for prevalence of frost/ cold wave conditions. Areas that suffer crop loss of 50 per cent or more by cold wave/frost conditions will be eligible for assistance. Similarly, animal husbandry, including poultry sector, would get assistance from SDRF/ NDRF in the wake of cold wave/frost. The Central Team would make a field visit for assessment of damage to agriculture and horticulture production due to cold wave/ frost and shall take into consideration all concomitant factors such as crops cutting experiment, fall in normal production, Normalized Differential Vegetation Index (NDVI) status of crops in the affected area, crops sown in the area affected, the vulnerability of the cold wave/frost on standing agriculture/horticulture crops, etc. in the guidelines (GoI, 2010).

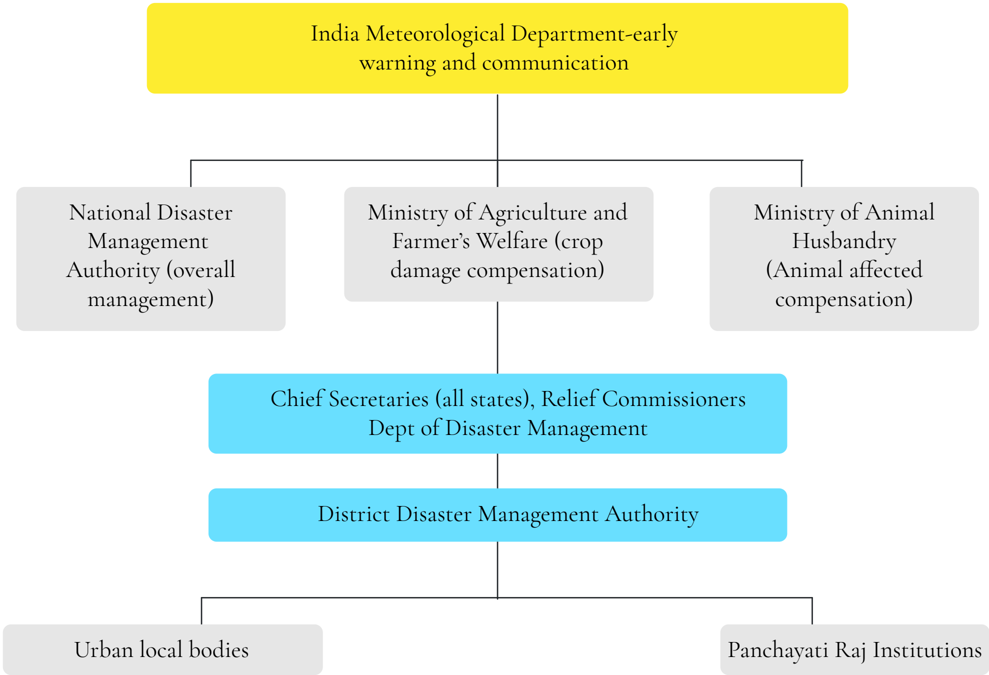


Figure 96: Cold wave response mechanism at the national-level

4.4.6. Dengue & Japanese Encephalitis

Directorate of National Vector Borne Disease Control Program (NVBDCP) is the central nodal agency for prevention and control of dengue and JE along with four other vector borne diseases namely, malaria, lymphatic filariasis, kala-azar and chikungunya. NVBDCP is the technical arm of Directorate General of Health Services under Ministry of Health and Family Welfare. Directorate is well equipped with technical experts in the field of public health, entomology, toxicology and parasitological aspects of vector borne diseases. It is responsible for framing technical guidelines and policies to guide the states on the control of dengue and JE along with other four vector borne diseases. The directorate is also responsible for evaluating programme implementation. There are 17 Regional Offices for Health and Family Welfare (ROH&FW) responsible for coordination and monitoring of national health and family welfare programs. ROH&FW are associated with NVBDC for conducting entomological studies of vectors in coordination with zonal entomological setup of the state.

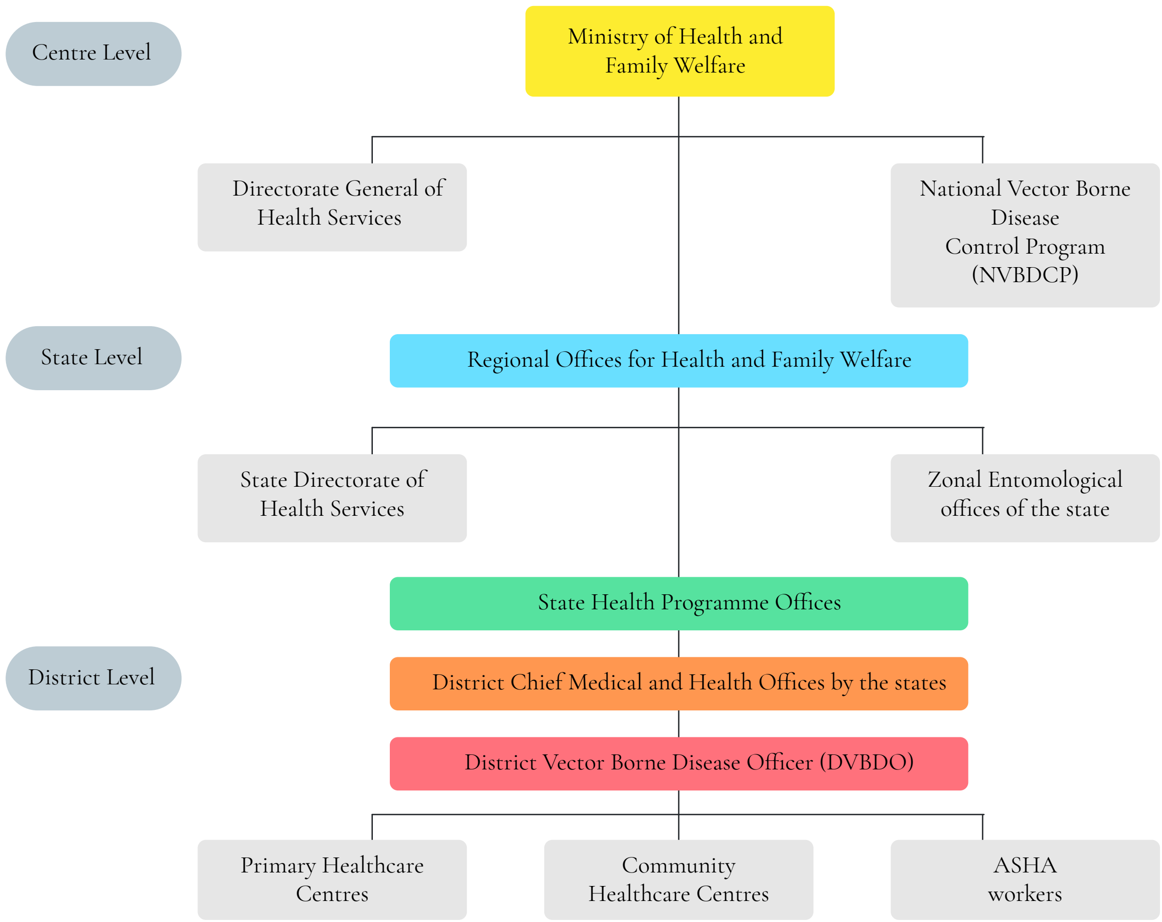


Figure 97: Dengue and JE response mechanism at the national-level

4.4.7. COVID-19

The National Centre for Disease Control (NCDC), which function under Ministry of Health and Family Welfare has a centre for arboviral and zoonotic diseases responsible for the Inter-Sectoral Coordination for Prevention and Control of Zoonotic Diseases. Government has made the testing and treatment for COVID-19 available under Ayushman Bharat Pradhan Mantri Jan Arogya Yojana (AB-PM JAY) free. India has been proactively taking measure for containing the spread of disease, which are in line with the guidance of international agencies like WHO and CDC. The institutional responses are still evolving based on the COVID-19 situation. Ministry of Health and Family Welfare is the nodal Ministry under the guidance of which state and district health departments are working for containing the spread of the disease. Some of the response measures taken have been shown in the table below.

Table 12: COVID-19 response strategy at the national-level

S.no	Response strategy	Nodal agency	Date
1	Advisory on Social Distancing, mass gathering, home quarantine	Ministry of Health and Family Welfare	March, 2020
2	Guidelines for handling, treatment and disposal of waste generated during treatment, diagnostics and quarantine of COVID19 patients	Central Pollution Control Board	March 2020 and April 2020
3	Strategy of COVID19 Testing in India	Indian Council of Medical Research	March 17, 2020
4	Standard Operating Procedures for Passenger Movement Post Disembarkation	Ministry of Health and Family Welfare	March 2020
5	Essential commodities order w.r.t to mask and hand sanitizer	Official Gazette	
6	COVID19 Guidelines on Dead Body Management	Director General of Health Services	March 15, 2020
7	Norms of assistance from State Disaster Response Fund (SDRF) in wake of COVID-19 outbreak	National Disaster Management Authority and State Management Authority	

4.5. Case Studies on Institutional Response Mechanisms for Climatic Disasters

4.5.1. Kerala Flood, 2018: Institutional response mechanisms

The devastating Kerala flood of 2018 affected 5.4 million people, displaced 1.4 million and took 433 lives (UNDP, 2018). The state government was very swift in responding to this calamity along with the support from Central Government and the community. The fishing community of the state gave voluntary assistance to save the lives of affected people. Government of India, with the help of different wings of Ministry of Defence, saved many lives by mobilising national force to rescue and search operations. The state of Kerala and affected district machineries were also involved in various relief and rescue operations.

Table 13: Response strategy at different levels for Kerala flood

Level	Institutional response mechanisms	
	Rescue	Relief and recovery
Community	Fishing community (669 boats with 4537 fishermen saved 65 thousand lives	
District	As per the State and Centre directions	As per the State and Centre directions
State	Kerala Fire and Rescue Services (4,100 individual along with rescue equipment were deployed)	Chief Minister Disaster Relief Fund and Lottery: INR 1,740 crore mobilised Build Back Better approach: Reconstruction of 17,316 new houses, repairing 46,000 houses Nava Kerala: Building green and resilient Kerala under four pillars (IWRM, land use planning, inclusive development, knowledge management)
Central	NDRF: 58 teams, 207 boats Army: 23 columns, 104 boats Navy: 94 rescue team, 1 medical team, 9 helicopters, 2 fixed wings aircrafts, 94 boats Coast Guard: 36 teams, 49 boats, 2 helicopters, 2 fixed wings aircraft, 27 boats Air Force: 23 helicopters, 23 fixed wing aircrafts Central Reserve Police Force: 10 teams Border Security force: 2 companies, 1 water vehicle team	Ministry of Home affairs: Assistance of INR 600 crore to affected families, Ministry of Rural Development: INR 1,800 crore under MGNREGS Centrally Sponsored Schemes-Pradhan Mantri Awas Yojna

Coping mechanisms and responses across India are led by institutions and agencies at various scales of space, time and governance. Generally, emergency preparedness framework is prepared at the Central level highlighting guidelines and standard operating procedures for multitude of disasters affecting different geographies across India. Founded on the culture and principal values of prevention, preparation, response and recovery, mechanisms for coping to multitude of disasters across India are led and implemented by various agencies, agents, and actions at the national, state or regional, local or city, and community levels.

4.5.2. Ahmedabad Heat Action Plan

Ahmadabad Heat Action Plan was the first heat wave management plan in India which was prepared in 2013. One of the studies found that the city of Ahmadabad was able to avoid approximately 1,190 deaths in 2015 after implementing the Heat Action Plan (NRDC, 2020). The plan included an early warning system for "red alert" days when maximum temperatures rise above 450C . The municipality keeps parks open for public during day time, hospitals keep ambulances ready with ice packs and programmes were launched for homeowners with tin roofs to paint their roofs with white to reflect sun rays.

The plan focused on four key strategies:

- Building public awareness on risk of heat waves through mass outreach programme in local language
- Implementing response system to prevent heat-related death and illness at the onset
- Initiating an EWS and inter-agency collaboration framework to alert citizens on predicted extreme temperature and
- Capacity building among city officials and healthcare professionals to recognize and respond to heat-related illnesses.

The work also led to identification of adaptive measures such as mapping high risk areas and cooling spaces during extreme heat days and coordinating utility services such as water and electricity to support life.

The success from Gujarat has now spread to other states of country. The regions of Nagpur in Maharashtra and Bhubaneswar in Odisha launched Heat Action Plans in March 2016. The leadership of Maharashtra State Public Health Department and Nagpur Municipal Corporation put into place, the Nagpur Regional Heat Action Plan. The plan led to coordination among Nagpur and four neighbouring cities, creating the first regional approach to heat wave planning in India. Similarly, in Odisha, the Odisha State Disaster Management Authority (OSDMA), along with the local branch of IMD, has taken the action forward. The other states to prepare the plans are Karnataka, Telangana, Andhra Pradesh and Rajasthan (Draft).

4.5.3. Cyclone Gaja, 2018: Institutional response mechanism

Severe cyclonic storm Gaja made a landfall in coastal districts of Tamil Nadu, Puducherry and Andhra Pradesh in 2018. The cyclone affected districts of Nagapattinam, Thanjavur, Pudukottai, Cuddalore, Trichy and Ramanathapuram. The centre, state and district governments were well prepared with all the rescue and relief materials in place. Though it was a severe cyclone but the impact on lives were reduced due to advance preparedness and strong institutional response mechanism of the centre and state government, in coordination with the local communities.

Table 14: Response strategy at different level for Cyclone Gaja

Level	Institutional response mechanisms	
	Early warning and preparedness	Rescue, Relief and recovery
Community		3,124 first responders helped in search and rescue operations and helped people evacuate to safer locations.
District	People were advised to stay indoors and holidays were announced in coastal districts that were affected. At Cuddalore, the district administration had set up 19 inter-departmental zones and made arrangements to evacuate people living in coastal areas to relief centres.	82,000 people took shelter in Government buildings and Multipurpose Evacuation Shelters in the affected districts mainly in Nagapattinam, Tiruvarur, Thanjavur and Padukottai.
State	Advisories were issued and communicated through print, electronic and social media. Seven units of the State Disaster Response Force were stationed in the coastal districts. 6,812 Relief centers were identified, Additionally 507 relief centers with all basic amenities were opened and kept ready in 10 districts which were likely to be affected during the land fall. 1,151 JCBs and 1,650 Power saws were prepositioned and utilized for clearing operations.	828 relief centres for 1,22,754 families and provided them with temporary shelters, food, milk and essentials. Sanitary napkins and other materials as required to women were also provided.
Centre	IMD issued specific warning for the system on 12th November related to wind warning, sea condition, storm surge warning as well as damage expected. Indian Coast Guard Remote Operating Centres broadcasted weather warning alerts in local languages along the coast. The Indian Navy had positioned a Dornier Detachment at Arrakkonam to facilitate damage assessment and any other assistance.	Nine teams of National Disaster Response Force consisting of 237 rescuers with 19 boats were deployed in Tamil Nadu. 74 ship days and 10 air sorties were pressed into action; special community interaction programmes were conducted at 11 places for fishermen and coastal population for taking safety measures. ICG assisting in shifting of 1,500 fishing boats south of Pamban. One helicopter sortie was made from INS Parundu to assess the effect of Cyclone Gaja damages in and around Ramanathapuram.

1.1.2. Assam Case Study: COVID-19 Institutional Response

Assam witnessed a delayed outbreak of COVID-19 as compared to other states in India, reporting the first case on March 31, 2020. The delayed infection helped the state government to prepare well in advance, activating all response and preparedness mechanism on time. In the early phase of the infection, government identified physical infrastructures as quarantine centres and subsequently increased the bed numbers in public and private hospitals, strengthened the manpower with more doctors, nurses and paramedics. With the continuous support of Ministry of Health and Family Welfare at the centre, Assam government led a mass campaign involving all means of communication for generating awareness and educating public at large.

The Assam Government passed The Assam COVID-19 Regulations, 2020 and Assam COVID-19 Containment Regulations, 2020. These two regulations strategised testing of all suspected cases, isolating, treating, tracing their contacts and quarantining them during the peak time of COVID-19 pandemic. This was further facilitated by enhanced active surveillance through house-to-house survey. State Level Task Force was notified to supervise the implementation of above two regulations. As the country was preparing for complete lockdown from March 24, Assam Government proactively announced state-wide lockdown from March 16. Except for essential services, the state was under complete lockdown along with the rest of the country. District Disaster Management Authority, headed by DM, was authorised for planning and management of containment measures in their respective districts. The strict lockdown helped in containing the spread of disease and thus Government was responding swiftly and on time to every case of COVID-19.

During this period, Assam was also affected by flood two times. In order to contain the spread of COVID-19 in the relief camps, the State Government took special measures like segregating people above 60 years and masks, soaps, sanitizers were distributed in the relief camp. The government also established "Assam Aarogya Nidhi Trust" to provide financial assistance and medical services to the needy. Under the "Dhanwantari Scheme" locally unavailable medicines were delivered to patients at their homes with the help of ASHA workers. The role of local community is also very important as they stand by the government in each and every decision made. Though the challenges are huge due to multi-hazard profile of the State, the Government is putting its best effort to manage them.

Understanding Climate Change Impacts on Disasters Observed

Climate change is likely to exacerbate the intensity and frequency of weather-related disasters. In India, the climate variability and extremes majorly manifest in floods, droughts, heat and cold waves, and cyclones, apart from biological disasters.

India is highly vulnerable to climate-related disasters given the socio-economic, environmental and climatic contexts. A large share of population is majorly dependent on climate-sensitive agriculture sector and natural resources such as forests and fisheries for livelihoods. In 2018, India ranked 5th topmost country affected by weather-related disasters as per the Germanwatch Global Climate Risk Index report (Eckstein et al 2020). As per the same report, India ranks 17th on impacts of weather-related disasters over the 20-year period (1999-2018).

As per the report on Assessment of Climate Change over Indian Region (Krishnan et. Al 2020), the average temperature in India has risen by 0.7°C during 1901-2018 and is largely due to GHG emissions. The devastating impacts of climatic-disasters in India are likely to significantly increase as the temperature is likely to increase by 4.4°C relative to 1976 to 2005 by end-century under RCP8.5 scenario.

Climate change is likely to exacerbate the intensity and frequency of weather-related disasters. In India, the climate variability and extremes majorly manifest in floods, droughts, heat and cold waves, and cyclones, apart from biological disasters.

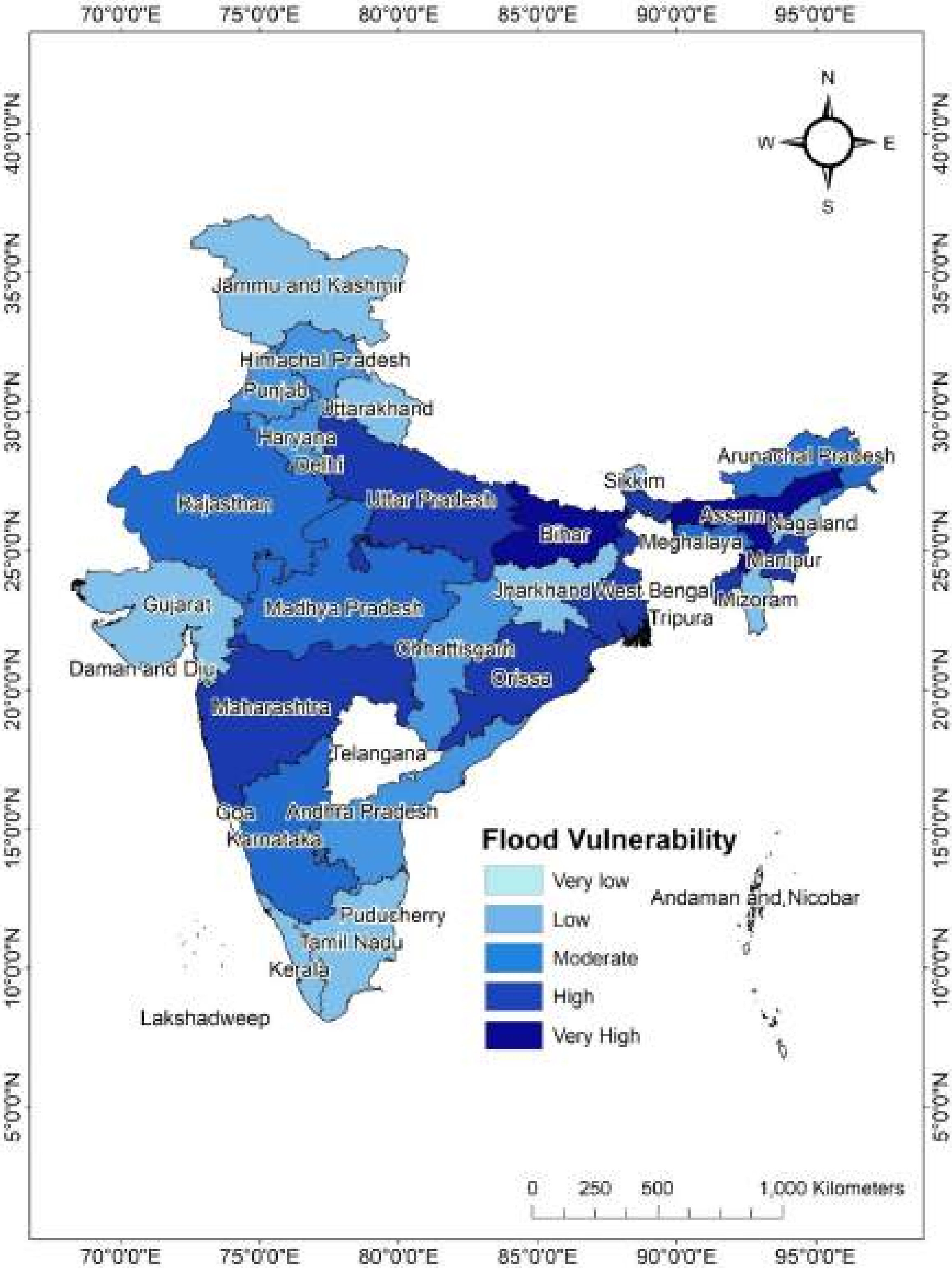
Chapter 2 covers spatio-temporal distribution of climatic disasters. Specifically, the chapter presented variations in the number of the disaster events across the three time periods - pre-Hyogo, Hyogo and post-Hyogo/ Sendai period. In this chapter we explore how climate change is likely to exacerbate vulnerability of various states of India.

Vulnerability is multi-dimensional and comprises an array of inter-related factors. And, poverty is both cause and consequence of disasters. Given the limitations of data availability, we assess vulnerability by multiplying two parameters—level of exposure in terms of number of disaster events, and poverty. For poverty, we consider values of Multidimensional Poverty Index (MPI)[4] developed by Oxford that uses data of NFHS-3 and NFHS-4 (Alkire, 2020). Weighted Overlay Method is used for ranking states on a scale of 1 to 5 on exposure and poverty, with 5 being highest exposure/poverty.

4. Multidimensional Poverty Index (MPI): MPI is an international measure of acute multidimensional poverty covering over 100 developing countries. It has three-dimensional approach to assess the level of poverty namely, health, education and living standards. A total of 10 indicators are used to measure the poverty level. For more details refer http://hdr.undp.org/en/2020-MPI.

5.1. Floods

High ranking states on floods	Historical pattern and climate change impacts on floods/ heavy precipitation as per Krishnan et. al (2020)
On Vulnerability (in descending order): Assam, Bihar, Uttar Pradesh, Odisha and Maharashtra (Figure 98) **From Climate change perspective on flood risk (future): UP, Bihar, Assam**	Historical • Six per cent decline in summer monsoon precipitation during 1951-2015; higher decrease over Indo-Gangetic Plains and the Western Ghats. • More intense wet spells during summer monsoon • Higher variability during winter monsoon season • Increase in daily precipitation extremes (>150mm) over central India by 75 percent during 1950-2015 • Substantial increase in daily precipitation extremes Climate change impacts • Overall and consistent increase in precipitation throughout the 21st century; • Increase in mean and variability of precipitation by end of 21st century • More than 20 per cent increase in annual mean precipitation specifically over west coast and southern areas (mostly western part) by end of 21st century • Significant increase in inter-annual variability of precipitation • Frequency of 1– 5-day precipitation increase by 10-30 per cent under RCP8.5 scenario; significant increase in southern and central India. • Increase in floods in Indus, Ganga and Brahmaputra basins • Increase in frequency of 100-year return floods in the southern peninsular India, Ganges, and Brahmaputra basins to <15 year in 21st century under RCP8.5 scenario • Increase in short duration rainfall extremes and consequent flood risk over urban areas of India under 1.5 and 2°C global warming levels

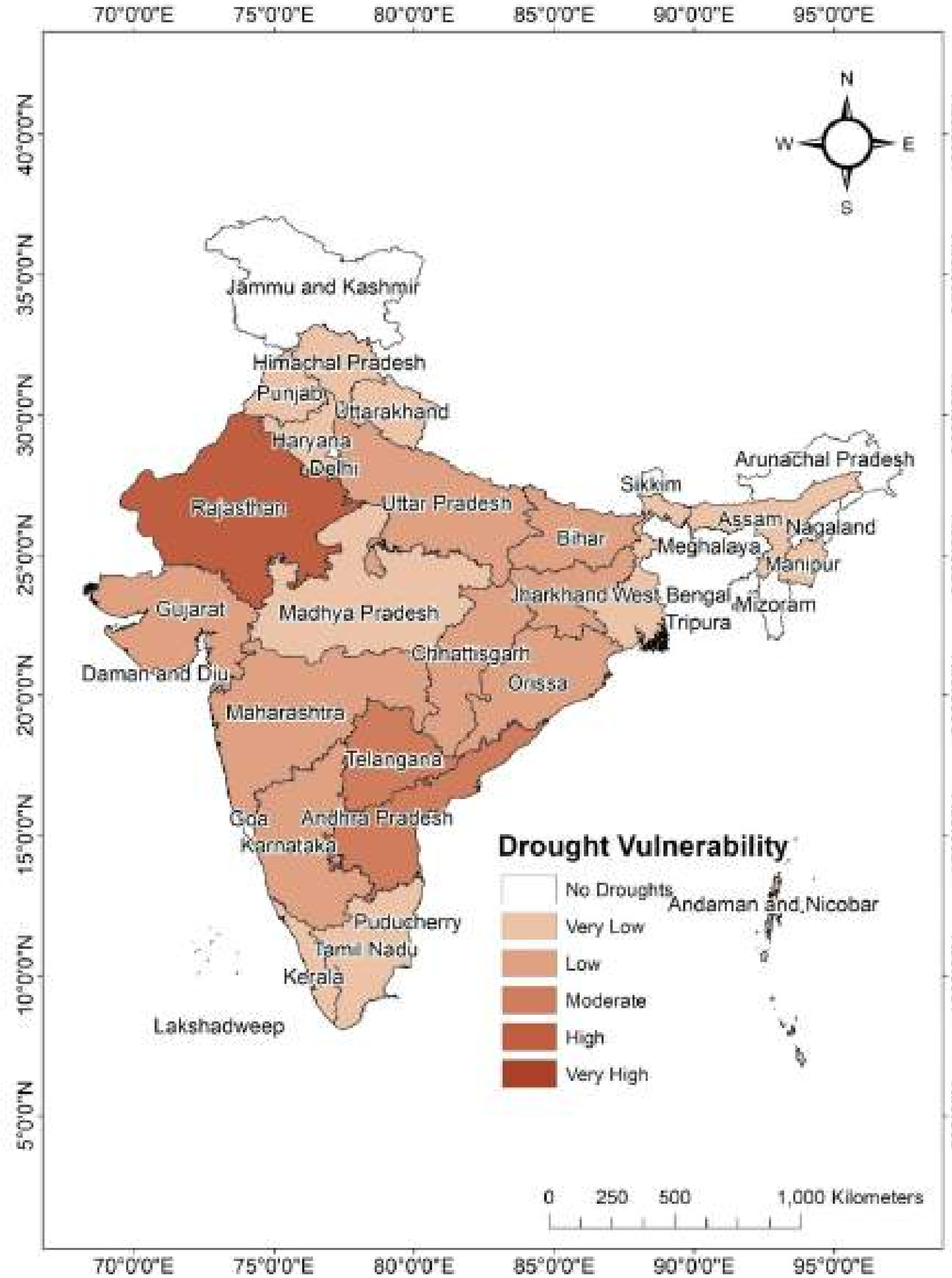


Compiled by: Study Team
Data Source, Disasterous Weather Event Reports, IMD and MHA Reports

Figure 98: Flood vulnerability map based on exposure and poverty

5.2. Droughts

High ranking states on droughts	Historical pattern and climate change impacts on drought/ dry/ deficit precipitation as per Krishnan et. al (2020)
On Vulnerability: Rajasthan, Telangana and Andhra Pradesh (Figure 99) From Climate change perspective on drought risk (future): Rajasthan	Historical • Relative to 1951-1980, 27 per cent more frequent dry spells during 1981-2011 • Increase in the frequency of droughts by more than 2 events per decade (relative to 1951-2016) by end-century under RCP8.5 scenario Climate change impacts • Under RCP8.5 scenario, increase in frequency of droughts in (> 2 events per decade) relative to 1976-2005 in Gangetic plains, north-west and central parts of India; reduction in drought frequency in south peninsular India • Increase in frequency, intensity and spatial extent of droughts over India during the 21st century

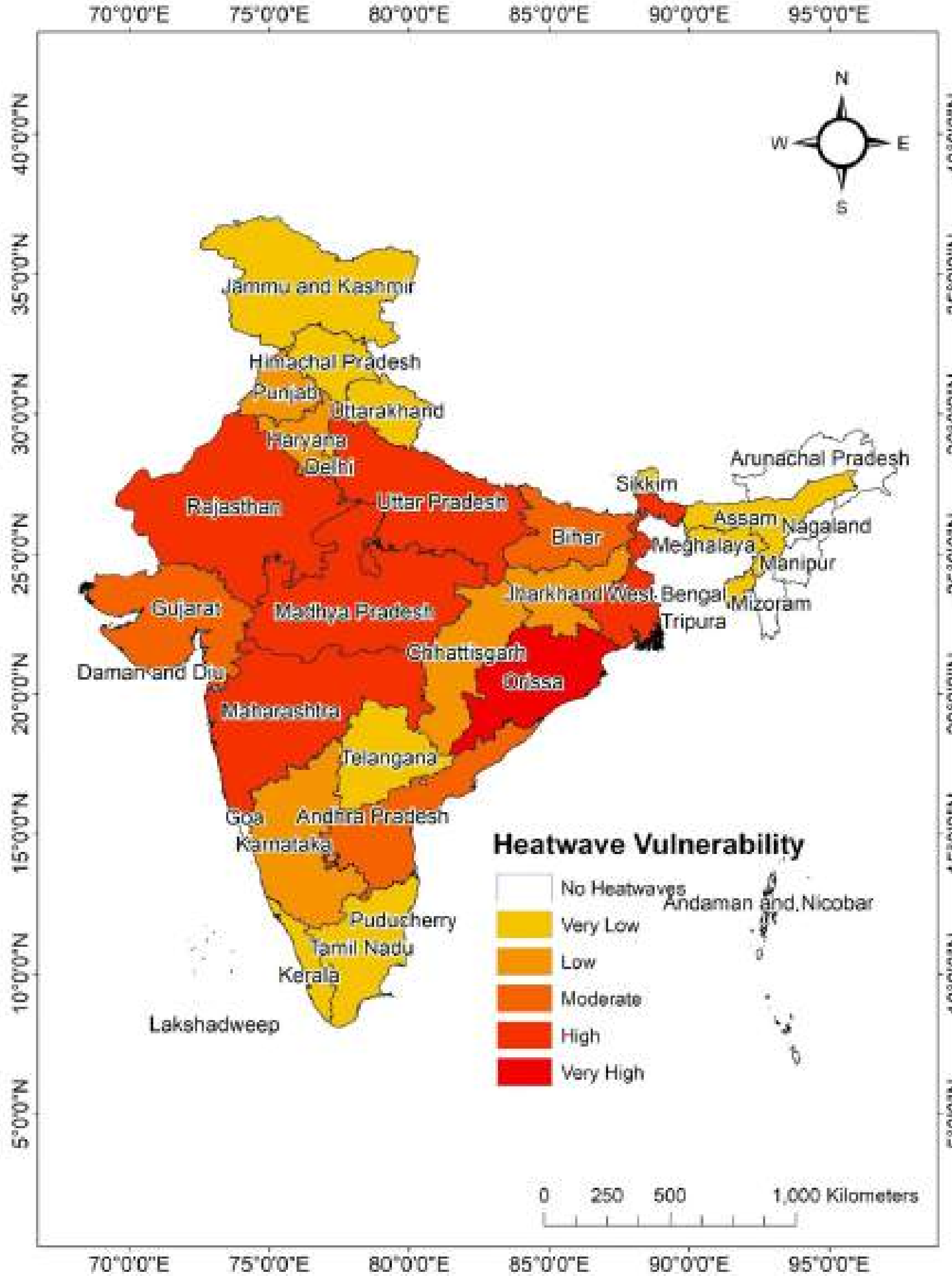


Complied by: Study Team
Data Source, Disasterous Weather Event Reports, IMD and MHA Reports

Figure 99: Drought vulnerability map based on exposure and poverty

5.3. Heat Waves

High ranking states on heatwaves	Historical pattern and climate change impacts on warm days/ nights and heatwaves as per Krishnan et. al (2020)
On Vulnerability: Rajasthan, Maharashtra, Madhya Pradesh, Odisha and West Bengal (Figure 100) **From Climate change perspective on drought risk (future): Rajasthan, Maharashtra, Madhya Pradesh**	Historical • Temperatures of warmest day and night increased by 0.63°C and 0.4°C, respectively, during 1986-2015; end-century projections under RCP 8.5 scenario (relative to 1976-2005) indicate corresponding increase by 4.7°C and 5.5°C Climate change impacts • Increase in frequencies of warm days and warm nights relative to 1976-2005 by 55 and 70 per cent, respectively, by end-century under RCP 8.5 scenario • Frequency of heatwaves during April-June projected to increase by 3-4 times relative to 1976-2005 by end-century under RCP 8.5 scenario; increase in southern and central India, eastern parts of Gujarat and significant increase in north-western areas of India; similar pattern of increase in heatwave duration.



Compiled by: Study Team
Data Source, Disasterous Weather Event Reports, IMD and MHA Reports

Figure 100: Heat wave vulnerability map based on exposure and poverty

5.4. Cold Waves

High ranking states on cold waves	Historical pattern and climate change impacts on cold days/ nights as per Krishnan et. al (2020)
On Vulnerability: Rajasthan, Uttar Pradesh (Figure 101) **From Climate change perspective on Cold Wave risk (future): though reduction of cold wave is indicated (Rajasthan and Uttar Pradesh)**	Historical Climate change impacts • Reduction in frequencies of cold days and cold nights with more prominent reduction as compared to increase in warm days and warm nights.

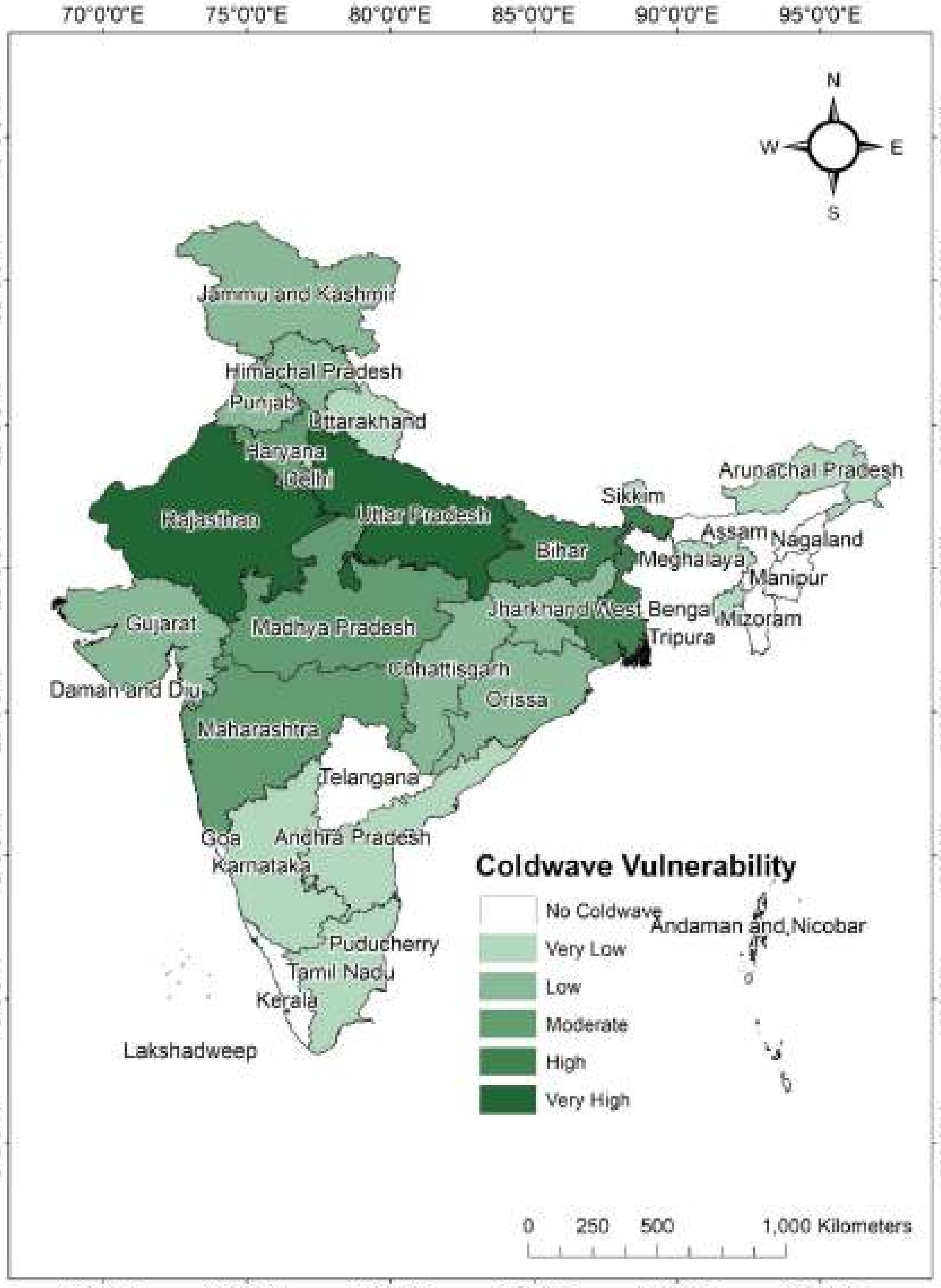
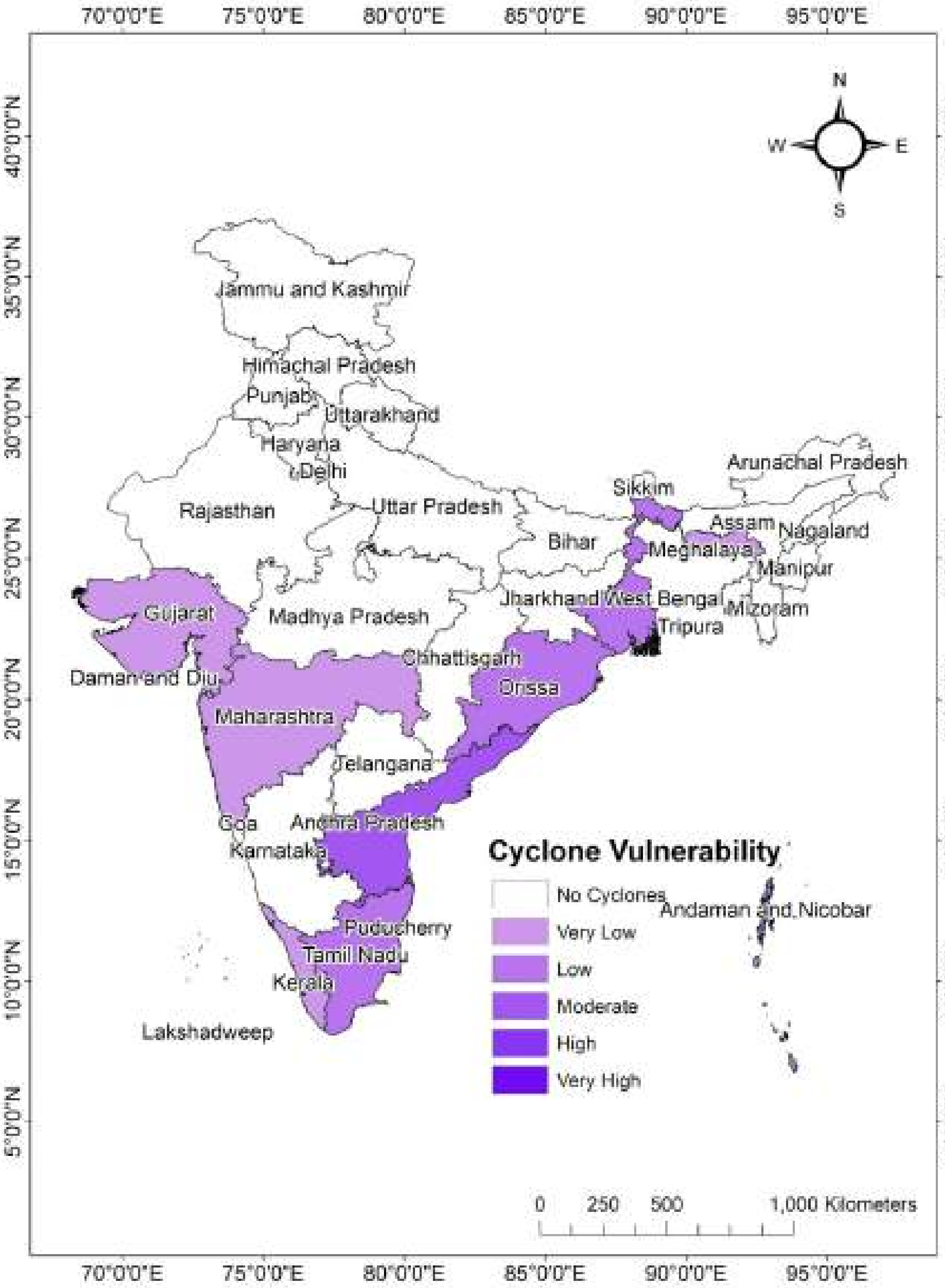


Figure 101: Cold wave vulnerability map based on exposure and poverty

5.5. Tropical Cyclones

High ranking states on Cyclones	Historical pattern and climate change impacts on frequency and intensity of cyclones as per Krishnan et. al (2020)
On Vulnerability: Andhra Pradesh (Figure 102) **From Climate change perspective on cyclone risk: West coast (Maharashtra, Gujarat, Kerala)**	Historical • Annual frequency of cyclones significantly reduced from 1951-2018; however, frequency of Very Severe Cyclonic Storms during post-monsoon season increased significantly Climate change impacts • Continued increase in Sea Surface Temperature (SST) and ocean heat content • Higher intensities of Tropical Cyclones likely in future due to climate change • Climate simulations show increase in frequency of cyclones in Arabian Sea (46 per cent) in contrast to reduction (31 per cent) in the Bay of Bengal Region; frequency of cyclones in Arabian Sea and Bay of Bengal likely to reduce in pre-monsoon season



Compiled by: Study Team

Data Source, Disasterous Weather Event Reports, IMD and MHA Reports

Figure 102: Cyclone vulnerability map based on exposure and poverty

Programmes and Schemes related to Disaster Risk Reduction and Climate Change Adaptation

As per the mandates of Disaster Management Act 2005, the Government of India has to ensure that the funds are provided by the Ministries and Departments within their budgetary allocations for the purpose of disaster management under Centrally Sponsored Schemes (CSS). The law endorses the need for mainstreaming of the DRR by making budgetary arrangements for the purpose by the respective Ministries and Departments within their overall agenda. As per the Department of Expenditure, Ministry of Finance, all Central Ministries shall keep at least 25 per cent of their Plan budget for each CSS as flexi-fund, which can be utilised for mitigation, prevention, recovery and restoration of activities in the event of natural calamities. For the first time, the 13th Finance Commission recognised the importance of mitigation funds for averting disasters. The 15th Finance Commission recommended the National and State Disaster Risk Mitigation Fund for promoting mitigation activities at the local-level. There are also sector specific schemes for different ministries that relate to natural resources management and can be tapped for mitigation purpose. Risk financing is also one of the important mechanisms that reduce disaster risks by sharing or transferring the cost of compensation for post disaster recovery and restoration.

The absence of disaster insurance means that the government has to bear a huge cost for compensation and rehabilitation work in post-disaster situations. Programmes and schemes have been divided into three categories:

1) Centrally Sponsored Schemes,
2) Sector Specific Schemes and
3) Risk transfer Schemes.

Table 15: Scope of building resilience through various programmes and schemes of Government of India

S. No.	Schemes/ programmes/ missions	Aspects of disaster risk management	Scope for building resilience identified disasters	Institutions/ Agencies
Overall Disaster Management				
1	National Disaster Risk Management Fund under 15th Finance Commission	Mitigation fund to address the different phases of disaster management cycle. Out of the total budget allocated, 20 per cent will be used for mitigation activities, while 80 per cent will be used for post disaster activities (Response-40 per cent, Recovery-30 per cent and Capacity building 10 per cent)	• Supports development of long-term district level drought mitigation plans for 12 drought affected states (AP, Bihar, Gujarat, Jharkhand, Karnataka, MP, Maharashtra, Odisha, Rajasthan, TN, Telangana and UP). • Reducing risk of urban flooding in seven most populous cities (Mumbai, Chennai, Kolkata, Bengaluru, Hyderabad, Ahmadabad, Pune). • Preventing risk of coastal and river erosion.	MHA, NDMA
Agriculture, NRM and Livelihood				
2	Mahatma Gandhi NREGS	The mandate of the Scheme is to provide at least 100 days of wage employment in a financial year to every rural household whose adult member volunteers to do unskilled manual work. It addresses integrated natural resource management aspects along with livelihood generation perspective and have been addressing mitigation, preparedness and recovery aspects of DRM	• Supports construction of buildings including cyclone shelters. • Constructions related to drains and culverts helping in flood mitigation. • Hand pump elevation, building toilets on raised platform as mitigation efforts. • Construction of food grains storage for disaster preparedness • Other NRM related works like water harvesting structures, plantations etc.	Ministry of Rural Development
3	Green revolution-Krishi Unnati Schemes	An umbrella scheme addressing 11 schemes and missions in the agriculture sector to increase the farmers income, improve crop production, soil management and provide high returns and markets for produce. It covers Food Security Mission, Horticulture development, Sustainable Agriculture Mission, agriculture extension, mechanisation, seeds development, plant protection, marketing, agriculture census, cooperation and information services	• Improving awareness and knowledge efficiency of farmers to deal with disaster management, in particular heat waves, cold waves, frost management, drought and pest attack	Ministry of Agriculture and Farmer's Welfare
4	Rashtriya Krishi Vikas Yojana- Remunerative Approaches for Agriculture and Allied Sector Rejuvenation (RKVY-RAFTAAR)	Making farming a remunerative economic activity by strengthening the farmer's efforts along with risk mitigation activities and promoting entrepreneurship in the field of agri-business	• Promote on action-based research and field-based studies for the identification, validation and location specific adaptation of agricultural practices, enhancing resilience to droughts, floods, hail storms, extreme weather events, and pests & diseases.	Ministry of Agriculture and Farmer's Welfare

S. No.	Schemes/ programmes/ missions	Aspects of disaster risk management	Scope for building resilience identified disasters	Institutions/ Agencies
5	Pradhanmantri Krishi Sinchayi Yojana	The scheme covers water to every field (har khet ko pani), per drop more crop, integrated watershed development program and Accelerated Irrigation Benefit and Flood Management Programme	• Promote revival of traditional water management systems as drought mitigation strategies • Develop capacity building programme for water efficiency and water productivity. • Use of water saving technology in cropping system • Includes flood management programmes	Ministry of Agriculture and Farmer's Welfare
6.	Deendayal Antyodaya Yojna (NRLM)	Aims at creating efficient and effective platforms for the rural poor and enabling them to increase household income through sustainable livelihood enhancement	• Risk mitigation through sustainable livelihood enhancement • Access to financial services	Ministry of Rural Development
Housing and infrastructure				
6	Pradhan mantri Gram Sadak Yojana	Provide all weather-access to unconnected habitations	• Reconstruction of damaged roads due to disasters along with building new connectivity	Ministry of Rural Development
7	Pradhan mantri Awas Yojana-urban and rural	Facilitate housing for all through adoption of modern, innovative and green technologies	• Low cost and disaster resilient infrastructures • Includes disaster restoration and recovery	Ministry of Rural Development, Ministry of Housing and Urban Development
Health, sanitation and vulnerable groups				
8	National Rural Drinking Water Program (Jal Jeevan Mission)	Adequate and safe drinking water through household tap connections to households in rural India.	• Scope to address unforeseen challenges and issues emerging due to natural disasters and calamities • Creation of water supply infrastructure • Augmentation of water supply sources	Ministry of Jal Shakti-Dept of Drinking Water and Sanitation
9	Swatchh Bharat Mission (Urban and Rural)	Addresses sanitation and health related aspects by eliminating open defecation and solid wastes management	• Toilet construction on raised platform as mitigation efforts in climate related disasters • Preventing biological disasters as clean drive initiatives under solid waste management	Ministry of Housing and Urban Development (Urban), Ministry of Jal Shakti-Dept of Drinking Water and Sanitation (Rural)
10	National Health Mission (Urban and Rural)	The mission aims to address the health concerns of the rural and urban poor through facilitating equitable access to available health facilities and strengthening the existing capacity of health delivery. It focuses on vulnerable populations like rag pickers, rickshaw puller, street children, construction workers and other temporary migrants. The mission also lay emphasis on sanitation, clean drinking water and vector control programmes	• Access to public services for food and nutrition, sanitation, hygiene, health care services with emphasis on women and children health and universal immunization. • Prevention and control of non-communicable and communicable diseases. • Access to integrated and comprehensive primary healthcare and promotion of healthy life styles	Ministry of Health and Family Welfare

S. No.	Schemes/ programmes/ missions	Aspects of disaster risk management	Scope for building resilience identified disasters	Institutions/ Agencies
11	National Nutrition Mission	Addressing various nutritional security of vulnerable groups including women and children	• Providing adequate nutrition at the time of rainy months when there is scarcity of food, outbreak of water-borne and vector borne diseases, low agriculture productivity and natural calamities that include both climate related and biological disasters.	Ministry of Women and Child Development
Environment protection and conservation				
12	Green India Mission	Increase forest cover, enhance ecosystem services and support forest-based livelihood as a strategy towards climate adaptation and mitigation efforts.	• Green wall construction • Restoration of wetlands for flood control • Restoration of new mangroves plantation for mitigating storm surges and cyclones in coastal areas	Ministry of Environment, Forest and Climate Change
13	National River Conservation Programme	Provides financial assistance towards infrastructure development for abatement of pollution of major rivers	• River front development work, interception and diversion works as structural mitigation measures for flood management • Construction of low cost sanitation toilets	Ministry of Jal Shakti-National River Conservation Directorate
14	National Plan for conservation of aquatic eco-systems	Includes National Lake Conservation Plan (NLCP) and National Wetland Conservation Plan (NWCP) for protection of water bodies including lakes and wetlands	• Lake cleaning and lake front development for mitigating urban flooding • Catchment area treatment	Ministry of Environment, Forest and Climate Change
Insurance and Risk Transfer				
15	Pradhan Mantri Fasal Bima Yojana	Aims at covering the losses suffered by farmers due to reduction in crop yield as estimated by the local appropriate government authorities.	• The scheme provides comprehensive risks insurance against yield losses viz. drought, hailstorm, floods and pests disease etc. • The scheme also covers pre sowing losses, post-harvest losses due to cyclonic rains and losses due to unseasonal rainfall in India. • There is a provision to cover losses due to localised calamities such as inundation, in addition to the previously covered hailstorm and landslide risks.	Ministry of Agriculture and Farmer's Welfare
16	Restructured weather based crop insurance scheme	Provide insurance protection to the farmers against adverse weather incidence	• Floods, drought, heat waves, cold waves, humidity, etc., which are deemed to impact adversely the crop production are covered under the scheme	

Strategic Lessons and Recommendations

Spatio-temporal mapping of climatic and biological disasters in India is undertaken using historical data and scientific tools to explore options to support for relief, recovery, resilience and adaptation through integration with existing development programmes. Climatic disasters (Floods, Droughts, Cyclones, Heat Waves and Cold Waves), and biological disasters (Dengue, JE and COVID-19) have been considered, given their widespread occurrences and impacts in India. In addition, assessments are carried out for combined climatic, combined biological, and combined climatic and biological disasters. Three international policy regimes on disaster reduction (time-periods) have been selected for assessing spatio-temporal changes in disasters and their impacts in India: pre-Hyogo (1995-2005), Hyogo (2005-2015) and post Hyogo/ Sendai period (2015-2030). The data till 2020 is considered. The study provides insights into impacts in terms of mortality (the only parameter) on which data was consistently available for long-term due to the select climatic disasters (except drought) and biological disasters, while delving on holistic impacts of recent major disasters through case studies.

Further, influence of climate change on the select climatic disasters has been assessed to identify hotspot states where risks are likely to increase.

Large tracts of India are prone to Floods, Droughts, Cyclones, Cold Waves, and Heat Waves. The prominent biological disasters include Dengue, JE and COVID-19. Both climatic and biological disasters have impacted large population and caused high mortality.

The study analysed the disasters only at the national- and state-level and not at finer resolution, given the limitations of data availability and challenges of aggregating data in the context of changing administrative boundaries at lower level.

We present below key findings and lessons from the study that have a bearing on overall implementation of disaster management system in India vis-à-vis changing risk patterns due to progress/changes in development, urbanisation and environmental health over the last 25 years (1995-2020):

A. Spatial distribution aspects across India

- The average annual number of flood events decreased during Hyogo period relative to Yokohoma period (/pre-Hyogo) while it increased during the post Hyogo/ Sendai period. Similar pattern of temporal variation is observed for droughts, cyclones and cold waves. However, heat waves have steadily increased over the three periods.
- Biological disasters (JE and Dengue, specifically) have shown increasing trend in the average number of incidences annually across the three periods (pre-Hyogo, Hyogo and post-Hyogo). Further, India currently has the largest number of confirmed cases of COVID-19 in Asia.
- Floods are very common in almost entire India with highest number of incidents in Bihar, followed by West Bengal, Assam, Manipur and Tripura during 1995-2020.
- Almost all states/ UTs (33 of the 36 States/ UTs) experienced droughts during 1995-2020. Prominent states of higher frequency include Andhra Pradesh, Telangana and Rajasthan, followed by Karnataka, Bihar, Chhattisgarh and Odisha.
- During 1995-2020, around a third of total states/ UTs were impacted by cyclones. Highest number of cyclones occurred in the Bay of Bengal area; Andhra Pradesh experienced maximum number, followed by Tamil Nadu, Odisha and West Bengal. Maharashtra had the largest number of cyclones, followed by Gujarat, on the western coast of the Arabian Sea. In Andhra Pradesh, the number of cyclone incidents decreased whereas it increased

in Odisha and Tamil Nadu during the post-Hyogo period. The increase is observed in the case of western coastal state of Maharashtra too.

- Three-fourth of total number of states/ UTs experienced heat waves during 1995-2020 with highest number in Odisha, followed by Maharashtra, West Bengal and Rajasthan.
- In two-third of total number of states/ UTs, cold waves occurred during 1995-2020. Uttar Pradesh recorded the highest number, followed by Rajasthan and Bihar. The number of incidents increased during the post-Hyogo period in Madhya Pradesh, Jharkhand Gujarat, Chhattisgarh and Uttarakhand and Himachal Pradesh. Further cold wave incidences started in four states (Tripura, Arunachal Pradesh, Sikkim and Meghalaya) in post-HFA.
- Twelve states experienced more than 20 outbreaks of JE and Dengue during 1995-2020.

B. Temporal changes in mortality across various regimes of international policies on disaster reduction

- The flood mortality in terms of annual average number of human life loss has remained almost the same across pre Hyogo, Hyogo and post Hyogo periods. The mortality due to floods has been very high in the states of West Bengal, Uttar Pradesh and Bihar, followed by Gujarat, Andhra Pradesh, Karnataka and Kerala
- Cyclone mortality has reduced overall. However, it is showing increasing trend in post-Hyogo (Sendai) period in Tamil Nadu and Maharashtra. Specifically, the states along the western coast of Arabian sea are likely to become greater area of concern due to climate change.
- Heat Wave related deaths show an increasing trend in most of the states including Andhra Pradesh, Uttar Pradesh, Bihar, Maharashtra, Telangana and Jharkhand in the post-HFA period. While it has significantly reduced in Delhi and Tamil Nadu, other states such as Punjab, Odisha, Madhya Pradesh and West Bengal also show a decreasing trend in post-HFA. Also, Heat Wave deaths per 100,000 population are highest in Maharashtra followed by Kerala, Tamil Nadu and Delhi.
- Highest number of Cold Wave related deaths were reported in Uttar Pradesh (accounting for 26 per cent of the total deaths in India), followed by Bihar and Punjab. Increasing trend is seen in several states including, UP, Jharkhand, Uttarakhand, Jammu & Kashmir, Assam, Meghalaya, Chandigarh and Tripura in the post-HFA period.
- The highest number of human deaths associated with combined select four climatic disasters (Floods, Cyclones, Heat Waves and Cold Waves; Drought was not considered as deaths could not be directly linked to it) was recorded in Uttar Pradesh, followed by Odisha, Bihar, Andhra Pradesh, West Bengal, Gujarat, Punjab, Maharashtra, Rajasthan, Tamil Nadu, and Madhya Pradesh.
- Unlike the total number of deaths, the deaths due to the combined select climatic disasters per 100,000 population is highest in Arunachal Pradesh, followed by Andhra Pradesh, Himachal Pradesh, Odisha, Sikkim, Uttarakhand and Mizoram. The state of Uttar Pradesh reported 13th highest total number of deaths stands per 100,000 population.
- Mortality on the select biological disasters: In case of Dengue, the annual average number of human life loss has steadily increased across pre-Hyogo, Hyogo and post-Hyogo periods. Likewise, it is showing an increasing trend in most of the states. Himachal Pradesh showed highest deaths per 100,000 population followed by Kerala. In contrast, the mortality due to JE has reduced; the annual average number of human

Top-ranking states requiring enhanced action for addressing increasing impacts of climate change (enhanced frequency and intensity) combined with their vulnerabilities (Multi-dimensional Poverty Index) are: Floods (UP, Bihar, Assam); Droughts (Rajasthan); Heat Waves (Rajasthan, Maharashtra and Madhya Pradesh); Cold Waves (Rajasthan, Uttar Pradesh); Cyclones (Maharashtra, Gujarat and Kerala)

life loss has decreased across pre-Hyogo, Hyogo and post-Hyogo periods. UP ranks highest on total deaths, while Andhra Pradesh in terms of per 100,000 population. With regard to COVID-19, Maharashtra ranks highest in terms of deaths, followed by Karnataka, Andhra Pradesh and Tamil Nadu (as of end of first wave/early 2021).

In addition, the recent major disasters (for example, the floods of Kerala) have caused significant socio-economic impact.

The study observes that there are good examples of responses at various levels for each of the select climatic and biological disasters—community, and governments at the district-, state- and national-levels. However, more needs to be done/supported/ catalysed.

The top-ranking states requiring enhanced action for addressing increasing impacts of climate change due to likelihood of enhanced frequency and intensity of climatic disasters combined with their vulnerabilities (measured through Multi-dimensional Poverty Index as a proxy variable) are: Floods (UP, Bihar, Assam); Droughts (Rajasthan); Heat Waves (Rajasthan, Maharashtra and Madhya Pradesh); Cold Waves (Rajasthan, Uttar Pradesh); Cyclones (Maharashtra, Gujarat and Kerala).

C. Strategic lessons and recommendations:

- The post-Hyogo period (2015 onwards) has witnessed higher annual average number of both, climatic and biological, disasters as compared to the pre-Hyogo period. We note similar pattern on mortality too, except in case of cyclones. Thanks to "Zero Causality Policy" adopted by Government of India that is supported through strengthened early warning system, preparedness and response. Given that mortalities have remained similar across the three policy regimes with regard to floods, there is an urgent need to look at ways to tackle it. A "Zero Causality Policy" may also be promoted in case of floods and other disasters. An in-depth study may be taken up to design key elements of it. Specifically, we believe enhancing investments in doppler radars on both the capital, and (more importantly) operation and maintenance costs, in the concerned states might catalyse effective implementation of the zero causality policy, especially for floods.
- The findings also present that some states have been relatively more exposed to various select disasters as also showing increasing trends (on incidences) across various international policy regimes on disaster reduction. More emphasis on mitigation needs to be given to those states through enhanced support through designing projects/ schemes and/ or enhanced allocation of Finance Commission funds.
- Sovereign risk assessment to various climatic disasters needs to be conducted considering effects of climate change to design and promote suitable financing instruments for sharing and transfer of risks within and across different geographical areas of India.
- Climate change will basically alter the hydrological regime that is best assessed at river basin / watershed scale; while policy decisions are taken at administrative level. There is need to create databases on frequency and intensity of various climatic disasters at basin/ watershed scale to suitably design basin/ watershed scale risk prevention and mitigation actions that can be implemented by districts/ states jointly through a programmatic approach.
- Apart from frequency, intensity of climatic disasters plays crucial role in determining impacts and risks. This study needs to be complemented by incorporating the aspect of intensity observed of various disasters.
- With climate change, new states are likely to become more vulnerable (at risk) to various disasters. There is a rich experience of dealing

with specific disasters in states that have been traditionally impacted. Programmes/schemes can be designed for sharing cross-learning/support across states (for example, Odisha has rich experience in dealing with cyclones and has effectively reduced mortality which can be used to enhance capacity of the state of Maharashtra which is more likely to be exposed to cyclones in the future due to climate change).

- Effective disaster risk reduction happens only when it is backed by appropriate institutional arrangements (and adequate budget). On institutional arrangements, innovative institutional arrangements may be promoted that enhance disaster reduction outcomes. For example, WASCA (the project of MoRD and MoJSGR with GIZ) in select states aims to promote water security in climate change context in rural areas by promoting tools for appropriate planning and implementation of Mahatma Gandhi NREGA activities (which is under the ambit of MoRD) for water security (aim of MoJSGR). It has been made possible by making changes in guidelines of Mahatma Gandhi NREGA that incorporated NRM and water conservation activities. Hence, such cross-ministerial "collaborations" may be promoted by identifying suitable schemes through research, development of tools, implementation and monitoring (see box below on WASCA for more details).
- Finally, as proposed in the NDMP (2019) frameworks, templates and systems need to be put in place for systematic collection of data on disaster impact (especially on and including economic impacts) by Central Statistical Organisation (CSO), so that there is better understanding of scale and types of impacts especially in the context of changing climate.

Water Security and Climate Adaptation (WASCA) project

German Federal Ministry for Economic Cooperation and Development (BMZ) in partnership with the Ministry of Rural Development (MoRD) and Ministry of Jal Shakti (MoJS) of Government of India has commissioned the WASCA project, and is implemented by GIZ. WASCA adopts an integrated approach to water security and climate adaptation at national, state and local levels. It is being implemented in two districts in each of the four states – Uttar Pradesh, Madhya Pradesh, Rajasthan and Tamil Nadu. In addition, WASCA supports two districts of Karnataka under Jalamrutha scheme. The outputs of the project are: a) Improved convergence of existing planning and financing approaches to strengthen water security; b) Demonstration of convergent planning, financing and implementation at local level; and, c) Strengthening cooperation with the private sector. Through a multi-stakeholder approach that brings together public and private institutions at various levels, it fosters planning and implementation of integrated water resources management in rural areas.

The key partners of WASCA are Mahatma Gandhi National Rural Employment Guarantee Act (Mahatma Gandhi NREGA) in MoRD and NWM (National Water Mission) in Ministry of Jal Shakti.

Table 15: Number of various climatic disaster events during 1995-2020

State	Number of Cylone events	Number of Cold wave events	Number of Heat wave events	Number of Flood events	Number of Drought events	Total Climatic Disaster events
Karnataka	1	7	23	17	11	59
Madhya Pradesh	2	26	25	12	4	69
Rajasthan	0	26	26	13	16	81
Tamil Nadu	0	8	19	10	5	42
Uttar Pradesh	0	26	26	18	7	77

Relevant findings and implications for WASCA

- All the WASCA states were impacted by at least four of the select five climatic events, with Rajasthan ranking the highest in total number of events. While being multi-hazard prone, each WASCA state ranked high (in number of events) on a particular climatic event. The highest frequency of floods was in Uttar Pradesh, followed by Karnataka; Rajasthan with most droughts, followed by Karnataka, higher and almost same frequencies in heat waves and cold waves in Uttar Pradesh, Madhya Pradesh and Rajasthan. In addition, Madhya Pradesh, though not a coastal state, was affected by a greater number of cyclones, as compared to Karnataka.
- Strikingly, Rajasthan experienced similar frequencies of flood and drought events during 1995-2020.
- On overlaying the observed frequencies of various types of climatic events with poverty levels, captured through MPI (Multidimensional Poverty Index) that used a proxy for vulnerability and adaptive capacity, the vulnerability of various WASCA states rank differently: on floods, it is highest for Uttar Pradesh; Rajasthan on droughts; Uttar Pradesh, Madhya Pradesh and Rajasthan at higher and similar levels on heat waves; Uttar Pradesh and Rajasthan on cold waves; and, Tamil Nadu on cyclones.
- When we account for climate change in form of increase in exposure in terms of frequency/magnitude of climatic events, the WASCA states that need a higher priority on adaptation include: Uttar Pradesh (floods); Rajasthan (droughts); Rajasthan and Madhya Pradesh (Heat Waves); Rajasthan and Uttar Pradesh (Cold Waves); and, Karnataka followed by Tamil Nadu (Cyclones).

Implications for WASCA

- The findings point to the following issues of relevance to WASCA, considering its thematic focus on rural water resource management:
- Given that floods and droughts are intricately related to Water Resources Management, there is a need for WASCA to link up with additional wings of Ministry of Jal Shakti, specifically the River Boards and Central Groundwater Board. This way it can work on constituting/strengthening River Basin Authorities which is critical to decide and enforce year-on-year allocation of surface water resources at macro/ river basin scale, across states/districts and sectors (domestic, irrigation and industrial). For this, a dynamic decision-making tool can be developed for different scenarios of rainfall (deviation from normal) within the range of variation anticipated due to climate change. Similarly, different scenarios of Composite Water Resources Management Plan (CWRMP) approach developed by WASCA will need to be developed at the district scale. Once the allocation at state/ district level is finalised, the district-scale corresponding to CWRMP can be executed for that year. Required Mahatma Gandhi NREGA-NRM works can be appropriately supported in a phased manner.
- The "Sahi Fasal" campaign, as part of National Water Mission, will need to

include flood-/drought-/ cold wave-/ cyclone-tolerant crop varieties and cropping system, as appropriate. This is in addition to promoting crops and cropping system based on agro-climatic perspective. Specifically, in the context of Mahatma Gandhi NREGA, interventions such as watershed development, rainwater harvesting, drainage and plantations, as appropriate, can be promoted.

- The findings emphasise the need to address vulnerabilities to specific Climatic Disaster(s) for various WASCA states. Climate indices (such as Wet Days and Consecutive Dry Days) relevant to state-specific disaster(s) can be given higher weightage from the comprehensive list of climate indices included in the Composite Water Resources Management Planning Framework.
- In the case of JE, maximum cases have been reported from rural India and are strongly linked with states where rice cultivation is the major agricultural practice. In such areas, water stagnation/water logging can be mitigated by Mahatma Gandhi NREGA activities (grey water management).

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Glossary of Terms

- Adaptation - The adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

- Adaptive capacity - Adaptive capacity is "The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

- Biological Disasters - Process or phenomenon of organic origin or conveyed by biological vectors, including exposure to pathogenic micro-organisms, toxins and bioactive substances that may cause loss of life, injury, illness or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

- Climate Change - The Inter-governmental Panel on Climate Change (IPCC) defines climate change as: "a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural 07 internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use".

- Climatic disasters - Climatic disasters are defined as events caused by long-lived/meso to macro scale processes in the spectrum from intra-seasonal to multi-decadal climate variability. Such events are further classified as: Extreme Temperature; Drought; Wildfire. Extreme Temperature events are heat waves, cold waves and extreme winter conditions.

- Cold waves - A rapid fall in temperature within 24 hours to a level requiring substantially increased protection to agriculture, industry, commerce, and social activities.

- Cyclones - A tropical cyclone is a rotational low pressure system in tropics when the central pressure falls by 5 to 6 hPa from the surrounding and maximum sustained wind speed reaches 34 knots (about 62 kmph). It is a vast violent whirl of 150 to 800 km, spiraling around a centre and progressing along the surface of the sea at a rate of 300 to 500 km a day.

- Dengue - Dengue is a mosquito-borne flavivirus found in tropical and sub-tropical regions of the world, mostly in urban and semi-urban settings. Day-biting Aedes mosquitos spread disease.

- Disaster - A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources.

- Disaster Management - The systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster.

- Disaster Risk Reduction - The concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events.

- Drought - According to India Meteorological Department, drought over an area is defined as a situation when the seasonal rainfall received over the area is less than 75% of its long term average value. It is further classified as "moderate drought" if the rainfall deficit is between 26-50% and "severe drought" when the deficit exceeds 50% of the normal.

- Exposure - People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses.

- Flood - A great flow of water, especially, a body of water rise in, swelling and overflowing land usually thus covered. Generally flood occurs due to heavy rainfall in the catchment area but some time it occurs due to upstream discharge/ dam failure.

- Hazard - A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

- Heat waves - A continuous spell of abnormally hot weather. Heat wave need not be considered till the maximum temperature of a station reaches at least 40° C for Plains and at least 30° C for Hilly regions.

- Hydrometeorological hazard - Process or phenomenon of atmospheric, hydrological or oceanographic nature that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

- Hyogo framework - The Hyogo Framework for Action provides the foundation for the implementation of disaster risk reduction. Agreed at the World Conference on Disaster Reduction in January 2005, in Kobe, Japan, with the support of 168 Governments, its intended outcome for the decade is "the substantial reduction of losses, in lives and in the social, economic and environmental assets of communities and countries".

- Japanese Encephalitis - Japanese encephalitis (JE) is the main cause of viral encephalitis in many countries of Asia. The JE virus is a flavivirus related to dengue, yellow fever and West Nile viruses.

- Mitigation - The lessening or limitation of the adverse impacts of hazards and related disasters.

- Post-Hyogo Framework (Sendai Framework) - The Sendai Framework for Disaster Risk Reduction 2015-2030 was adopted at the Third UN World Conference in Sendai, Japan, on March 18, 2015. It is the outcome of stakeholder consultations initiated in March 2012 and intergovernmental negotiations from July 2014 to March 2015, supported by the United Nations Office for Disaster Risk Reduction at the request of the UN General Assembly.

- Pre-Hyogo Framework (Yokohama strategy) - The Yokohama Strategy for a Safer World: Guidelines for Natural Disaster Prevention, Preparedness and Mitigation and its Plan of Action ("Yokohama Strategy"), adopted in 1994, provides landmark guidance on reducing disaster risk and the impacts of disasters.

- Resilience - The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.

- Response - The provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected.

- Risk - The combination of the probability of an event and its negative consequences.

- Sensitivity - The degree to which a system is affected, either adversely or beneficially, by climate-related stimuli.

- Vulnerability - The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.

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